AMISR SSPA
AUTOMATED TEST SUITE

Project Report

A Major Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
And performed at SRI INTERNATIONAL
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Degree of Bachelor of Science

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Abstract

SRI International has been developing an Advanced Modular Incoherent Scatter Radar (AMISR) for the purpose of observing upper-atmospheric phenomena with an easily deployable modular radar system. This project was mostly concerned with the power amplifier in the AMISR, specifically a Solid State Power Amplifier (SSPA). Our project was to design and build an automated test station for use during production testing and design verification testing as well as design circuitry that will be used during a twenty-four hour burn-in test.

Executive Summary

The National Science Foundation is funding the construction of a radar system to be built in Alaska called AMISR, Advanced Modular Incoherent Scatter Radar. SRI International, a non-profit research organization based in Menlo Park, California, is responsible for the design and construction of the AMISR. The radar is unusual because it is made up of a planar array of emitting elements. By controlling the phase relationships between the elements, the radar beam can be instantaneously repositioned without the use of mechanical systems. The AMISR project is slated to use 4,096 Solid State Power Amplifiers (SSPAs). SRI is currently redesigning the amplifier and production will be starting in the spring of 2007.

During production, each SSPA needs to be calibrated and tested to ensure that each meets the specifications. Transporting equipment to the radar's location is difficult and costly because the deployment location for the AMISR is Poker Flats, Alaska. In June of 2007, a barge will be departing for Alaska and all equipment for the AMISR must be on board or else it will delay the project for another year. Since this does not leave much time for the production and testing of the SSPAs, SRI needs an automated test station that is capable of calibrating and performing a specification test on an amplifier in five minutes without unnecessary human interaction. The test station must be simple to use, self-calibrating, portable, and able to store test data in an easily accessible database.

After the initial calibration, each unit will be tested to ensure it meets the specifications set forth by SRI. These tests include power measurements at multiple frequencies, amplifier efficiency measurements, and an input power variation test. In order to conduct all required tests, an integrated system needed to be built. The system became known as the Automated Test Suite (ATS). It required the implementation of a power supply, signal generator, power meter, I/Q detector, and a computer to control the test equipment as well as provide the user interface.

A control box had to be designed to provide a signal control center for interfacing multiple devices. The control box distributes the timing signals generated by the computer's data acquisition card (DAQ) to various components. It also interfaces the I/Q detector with the analog inputs of the DAQ, contains the directional couplers and attenuators that are needed to make power measurements, as well as the switch that changes the load that is connected to the SSPA.

The I/Q detector consists of Analog Device's AD8347 demodulator chip implemented using its evaluation board. The I/Q detector demodulates the in-phase and quadrature phase components of a signal by mixing a reference signal with the output RF signal. When the two signals are mixed, the output's frequency domain has peaks at DC and 880MHz. Since the DC signal is the one that represents the phase of the SSPA, we designed an RF filter to eliminate the 880MHz signal. The I/Q Detector was also modified to disable the automatic voltage offset compensation feature.

A significant amount of time was spent developing code to intelligently calibrate and test the amplifiers without any human intervention because the station needed to be automated. Several software-related obstacles needed to be overcome during the project. The drivers for the DAQ card and the GPIB card had to be installed on Linux without manufacturer support. In addition, interfacing Python with the GPIB card and DAQ card was difficult because Python was an unfamiliar language. A Python package called PyVISA, which is a wrapper for National Instrument's GPIB control libraries, was used to inteface the GPIB card. For the DAQ card, a custom wrapper was written in C to interface the Python code with the hardware because there were no preexisting wrappers. After overcoming these difficulties, all that remained was the task of writing the software to drive the system and store measurements and results into a database.

We undertook the additional responsibility of designing and developing the burn-in system because the original project was ahead of schedule. The burn-in system is required to run ninety-six amplifiers for a twenty-four hour period. During this time, the SSPAs need to be monitored to make sure they are on for the full length of the test. The burn-in process tests the units for component failures prior to installing the amplifiers in the field. A single signal generator is used to supply the necessary RF input signal for operating all ninety-six amplifiers concurrently. The burn-in system is designed in two stages. The first stage splits the input RF and timing signals six ways while the second stage splits each output from stage-one sixteen ways. To make operation of the burn-in system easier for the user, stage-two had to be designed with latching circuitry to indicate if an SSPA's alarm signals tripped during the test. As an added feature, there is also an indicator to show when an amplifier has been tested for twenty-four hours. A circuit board was designed to meet the requirements of the second stage of the burn-in system. Revision one was fabricated, populated, and troubleshot with modifications made to demonstrate the required changes for revision two. The modifications were replicated in the schematics and the revised design has been submitted for layout changes.

The Automated Test Suite project has been successfully completed. The station is physically complete and the software has been fully implemented. Since production of the SSPAs has not started, new production tests are being developed and the DVT test suite may be altered in the future. The burn-in system, which was assigned as a secondary project, is not yet complete. Stage-one has been tested and is complete, however, the stage-two circuit board has entering its second revision and will be completed by the staffs at SRI International..

1. Introduction

SRI International, a non-profit research and development organization, is in the process of developing an Advanced Modular Incoherent Scatter Radar (AMISR) for the purpose of observing upper-atmospheric phenomena with an easily deployable modular radar system. The AMISR uses phased scanning principles allowing quick redirection of the scanning lobe without any physical movements of the antenna elements. The AMISR consists of antennas, power amplifiers, low noise amplifiers, delay shifting circuitry, control circuitry, a power supply system, and a chassis to hold the equipment together. The power amplifier in the antenna element unit (AEU), specifically a Solid State Power Amplifier (SSPA), is what this project was mostly concerned with because the SSPA is being redesigned and the units will need to be tested to ensure their proper functionality. Our project was to design and build an automated test station for this purpose as well as design circuitry that will be used during a twenty-four hour burn-in test.

2. Background

Founded in 1946 by a group of west coast industrialists and Stanford University, SRI remains a research institution committed to the discovery and application of new technology in fields ranging from communications to the biomedical industry. In 1970 SRI separated from Stanford University and in 1977 formally changed its name from Stanford Research Institute to SRI International. The company holds more than 1,000 patents worldwide. There are currently over 1,400 people employed by SRI International alone. In addition, over 600 people are employed at its subsidiary Sarnoff Corporation. Their main offices are located in Menlo Park, CA however they have additional offices located in Washington, DC and Tokyo, Japan as well as several other US locations.

In an effort to move technology developed at SRI to the marketplace, SRI international has worked in conjunction with their subsidiary Sarnoff Corporation and top-tier investment and venture capital firms to form approximately two dozen new ventures. These ventures include companies such as Artificial Muscle Inc, Bridge Pharmaceuticals, Spanlink Communications, and Intuitive Surgical Inc. Sarnoff Corporation has won 10 Emmy awards and developed the HDTV standard used in the US. SRI has also won an Academy award and is recognized for developing the current automated check processing system that utilizes magnetic ink coding, the world's first computer network which was known as ARPANET, and the first prototype of a computer mouse.

SRI International is expanding rapidly. They were recently awarded $56.9 million from the National Institute of Allergy and Infectious Diseases for research and development of drugs and antibodies for anti-infective therapeutics. SRI International is also opening a new research facility in St. Petersburg, FL for marine technology research. The facility will research and develop technologies related to ocean science, the maritime industry, and port security.

2.1. National Science Foundation

In 1950, congress created the National Science Foundation, an independent federal agency, to encourage the advancement of science, national health and prosperity, and to improve national security. The government's reliance on innovation and scientific progress intensified during the World War II. Following the war, government involvement in universities and science was at an all-time high. At this time, several congressmen and scientists pushed for legislature to create an agency to fund scientific research through government grants, this agency became known as the National Science Foundation (NSF).

Today, the NSF is the funding source for approximately twenty percent of all federally sponsored university research. The agency also funds high-risk, high-payoff ideas that are on the bleeding edge of innovation. An example from the National Science Foundation's website is nanotechnology. They were funding scientists who were researching ways to manipulate movement on an atomic level, years before the public had even heard of nanotechnology.

In addition to funding research, the NSF also helps finance high-cost equipment and facilities that are too expensive for one research group or researcher. This includes "giant optical and radar telescopes, Antarctic research sites, high-end computer facilities and ultra-high-speed connections, ships for ocean research, sensitive detectors of very subtle physical phenomena and gravitational wave observatories." One of the projects that the NSF has funded for the past 10 years is the AMISR project.

2.2. Advanced Modular Incoherent Scatter Radar

The Advanced Modular Incoherent Scatter Radar, AMISR, is a mobile radar facility that will eventually be utilized by scientists to study the atmosphere and observe space weather events. The project is funded by the National Science Foundation and is being developed in a collaborative effort led by SRI International. SRI is responsible for the lead design and construction of the radar as well as overseeing operations and the initial design verification tests. Sanmina-SCI and VECO Alaska are manufacturing the antenna element units and overseeing the structural engineering of the radar respectively. This radar will be built using a phased-array antenna system that will allow the radar to function in different configurations. The system will be controlled remotely and the radar beam will be electronically controlled allowing scientists to instantaneously position the beam to accurately measure changing weather events. The AMISR utilizes three separate radar faces, each consisting of 128 panels, which can be deployed in up to three separate locations. In Figure 1, the AMISR radar is pictured with two full faces. The first radar face is being constructed in Poker Flat, Alaska and subsequent faces will be constructed in Resolute Bay, Canada, and Nunavut, Canada. Each face of the radar is made up of 8 groups of panels. Each group has 16 panels and therefore each face has 128 panels. There can be up to 32 solid state power amplifiers (SSPA) per panel. Therefore, each face can have up to 4,096 individual transmit and receive elements.

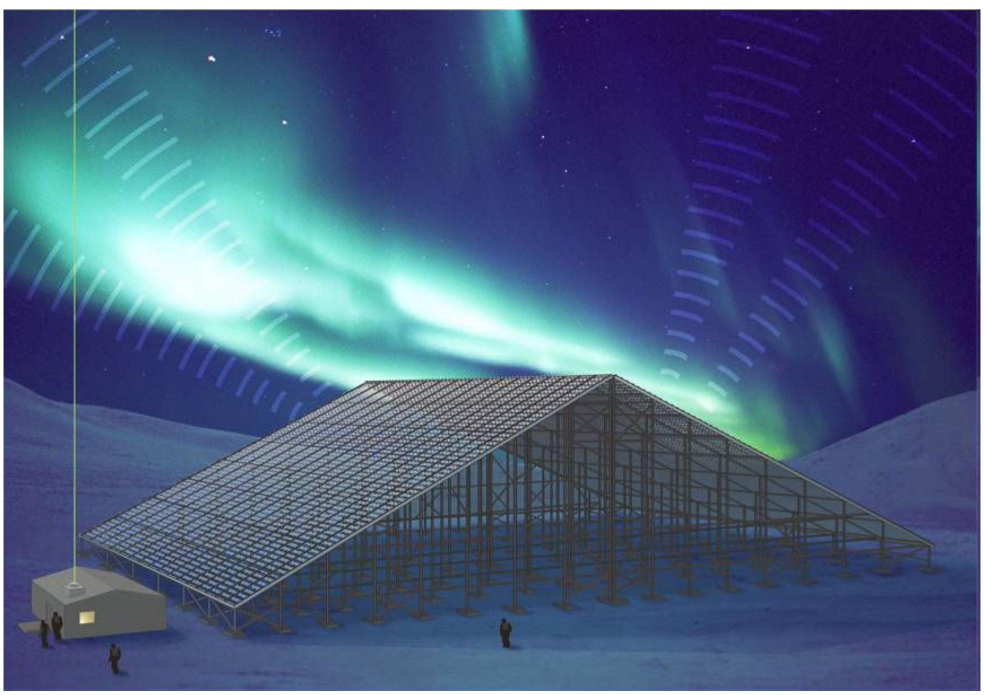

Figure 1: Artists concept of an AMISR radar with two faces.

3. Project Goals

The goal of this project was to design and build an automated test station for the SSPA. The test station should be able to calibrate the amplifier, and then test the RF characteristics of the unit such as power gain, current draw, amplitude, phase, and VSWR at the upper and lower signal frequency limits as well as the middle operating frequency. Following the RF characteristic tests, the test station will check the fault conditions of the amplifier, such as an open output, and a mismatched load. The automated test station must also be capable of powering an SSPA during environmental testing, including periodic measurements of power, current, ambient temperature, and device temperature.

The automated test system must be capable of testing the RF characteristics of about 1000 SSPAs per month at the rate of about forty per day. Testing will be conducted twenty-three days per month and testing will take place during an eight hour shift on these days. The expected yield rate is approximately 90% based on information provided by SRI and therefore we will be designing our test system to test each SSPA in less than five minutes. For the twenty-four hour burn-in process, which will not utilize the ATS, our goal was to design a system to test multiple SSPAs during a single twenty-four hour period.

4. SSPA Design Specifications

The SSPAs are designed to meet a number of important specifications. The Automated Test Suite is designed to test these specifications to ensure that each SSPA meets the designated requirements. The requirements include:

Full Operating Temperature:

- -40 Degrees C to 35 Degrees C

RF Power:

- Input: 10dBm ± 1.5dB
- Output: 57dBm (-0/+.5dB)

RF Pulse Characteristics:

- Minimum Pulse Width: 1μs
- Maximum Pulse Width: 2ms
- Amplitude Droop: <10% at maximum pulse width

Phase Response:

- Unit-to-Unit match: ± 5 degrees

Stability/Impedance:

- Input VSWR : < 1.3:1
- Output VSWR: < 1.5:1

Protection:

- Over-drive protection if input exceeds specified range
- VSWR mismatch protection when VSWR is greater that 6:1
- Over-temperature protection

Each SSPA will also be subjected to a twenty-four hour burn-in test that will not utilize the ATS. After the burn-in procedure, each SSPA will be retested on the ATS to ensure that it is still functioning properly.

5. Technical Background

When a company produces a device in large quantities, it is important to ensure that each product meets the company's standards. Production testing allows companies to determine if a device meets its requirements before the device is sold or delivered. SRI needs to conduct production testing on the SSPA's to ensure that they meet their specifications. Test data from production testing provides many useful statistics to companies like SRI. Test data allows companies to determine if there are reoccurring problems or manufacturing trends that could potentially affect future products. There are five phases of testing for the AMISR SSPAs.

- Phase 1: Calibration
- Phase 2: Pre Burn-in Test
- Phase 3: 24-hr Burn-in Test
- Phase 4: Post Burn-in Test
- Phase 5: Design Verification Test

Four phases involve the ATS; they include calibration, pre burn-in testing, post burn-in testing, and the design verification testing. The third phase, the twenty-four hour burn-in process, does not utilize the ATS, however, it utilizes the burn-in distribution system which will be discussed later in this report. It is important to note that only the first four phases are included in production testing. The design verification testing (DVT) will not be performed on every SSPA; only select number of amplifiers will be subjected to DVT.

5.1. Phase 1: Calibration

Phase 1 of production testing is used to calibrate each SSPA prior to design specification testing. During calibration, the VSWR, output power, and phase of each SSPA is calibrated and set to ensure proper matching between SSPAs. A list of steps for the automated calibration phase can be found below.

- Initialize Devices

- Initialize Digital Potentiometers
- Set Driver Bias
- Set Output Bias
- Set Gain
- Set Phase
- Set VSWR

5.2. Phase 2: Pre Burn-in Test

After the calibration procedure, pre burn-in testing is conducted to further verify the device meets the design requirements. There are five tests performed during pre burn-in testing. The output power and current are verified at three frequencies at the beginning of the test. An over pulse width test is conducted to verify that each SSPA automatically limits the pulse width to less than 2.5ms when the pulse width is outside its specifications. The fifth test verifies that the amplifier gain is consistent when the input is decreased to 8.5dBm and increased to 11.5dBm. The various tests for pre burn-in are listed below.

- Output Power & Current Verification: 440MHz
- Output Power & Current Verification: 430MHz
- Output Power & Current Verification: 450MHz
- Over Pulse Width Test
- Input Power Variation Test
- Efficiency Test
- Open Circuit Test
- VSWR 3:1 Trip Test

5.3. Phase 3: 24-hr Burn-in Test

The next phase is the twenty-four hour burn-in test which consists of running ninety-six SSPAs at once while monitoring the two status bits—over-temperature and VSWR fault. Each amplifier that passes the twenty-four hour burn-in process is retested during post burn-in testing. The twenty-four hour burn-in test utilizes the distribution board that was designed to simplify the wiring of the system, monitor the two status bits, and to alert a user when each SSPA has run for the full twenty-four hours.

5.4. Phase 4: Post Burn-in Test

During phase 4 of production testing, the same tests that were completed during phase 2 will be completed again. This will allow engineers to determine if the twenty four hour burn-in test affected the performance characteristics of each SSPA. The various tests for post burn-in are listed below.

- Output Power & Current Verification: 440MHz
- Output Power & Current Verification: 430MHz
- Output Power & Current Verification: 450MHz
- Over Pulse Width Test
- Input Power Variation Test
- Efficiency Test
- Open Circuit Test
- VSWR 3:1 Trip Test

5.5. Phase 5: Design Verification Test

One out of every sixty-four SSPAs will be subjected to design verification testing. The design verification test package in the ATS system includes a qualification test, pre-environmental test benchmark, post-environmental test benchmark, and an operating test. The design verification test plan entails an initial qualification test and then a series of environmental tests. DVT includes many environmental tests, some environmental tests will be conducted when the amplifier is operation and others will be conducted when the amplifier is in non-operational mode. The operating test will be used to collect data during environmental tests that include an operating amplifier. The pre-environmental test will be conducted before an amplifier is subjected to a non-operational environmental test and a post-environmental test will be conducted after a non-operational environmental test. The design verification test plan is shown below.

Qualification Test: (Performed at 430, 440, and 450MHz for each SSPA)

- Power Consumption (Input Current and Input Voltage)
- RF Power Output
- Amplifier Gain
- RF Pulse Droop (2ms Pulse Width)
- Amplifier Insertion Phase

Environmental Tests:

- Low & high temperature stress testing (SSPA Operational).
- Random vibration stress testing (SSPA Operational).
- Temperature Cycling with & without vibration step (SSPA Operational)
- Temperature Cycling with Condensation (SSPA non-operational)
- Random Vibration (SSPA non-operational)
- Half sine shock test (SSPA non-operational)
- Low Temperature Soak Test – 22hr duration (SSPA operational)
- High Temperature Soak Test – 22hr duration (SSPA operational)
- Temperature Cycling without Condensation – 48hr duration (SSPA operational)
- Humidity Cycling without Condensation – 96hr duration (SSPA operational)

6. Automated Test Suite

The automated test suite (ATS) was designed to simplify the testing of the SSPAs. The ATS in used in the following phases of production testing:

- Calibration
- Pre Burn-in Testing
- Post Burn-in Testing
- Design Verification Testing

The ATS has been designed to meet several specifications. These specifications are listed below.

- Conduct Calibration and Pre Burn-in Test in less than 5 minutes.
- Must be capable of measuring phase, power, and current.
- ATS must be capable of being relocated easily.
- Easy to modify calibration tolerances.
- System must be self-calibrating.
- System must be network accessible.
- Data must be stored in a database.
- Data must be easily accessible.
- Simple to use.

The block diagram shown in Figure 2 summarizes the test system setup.

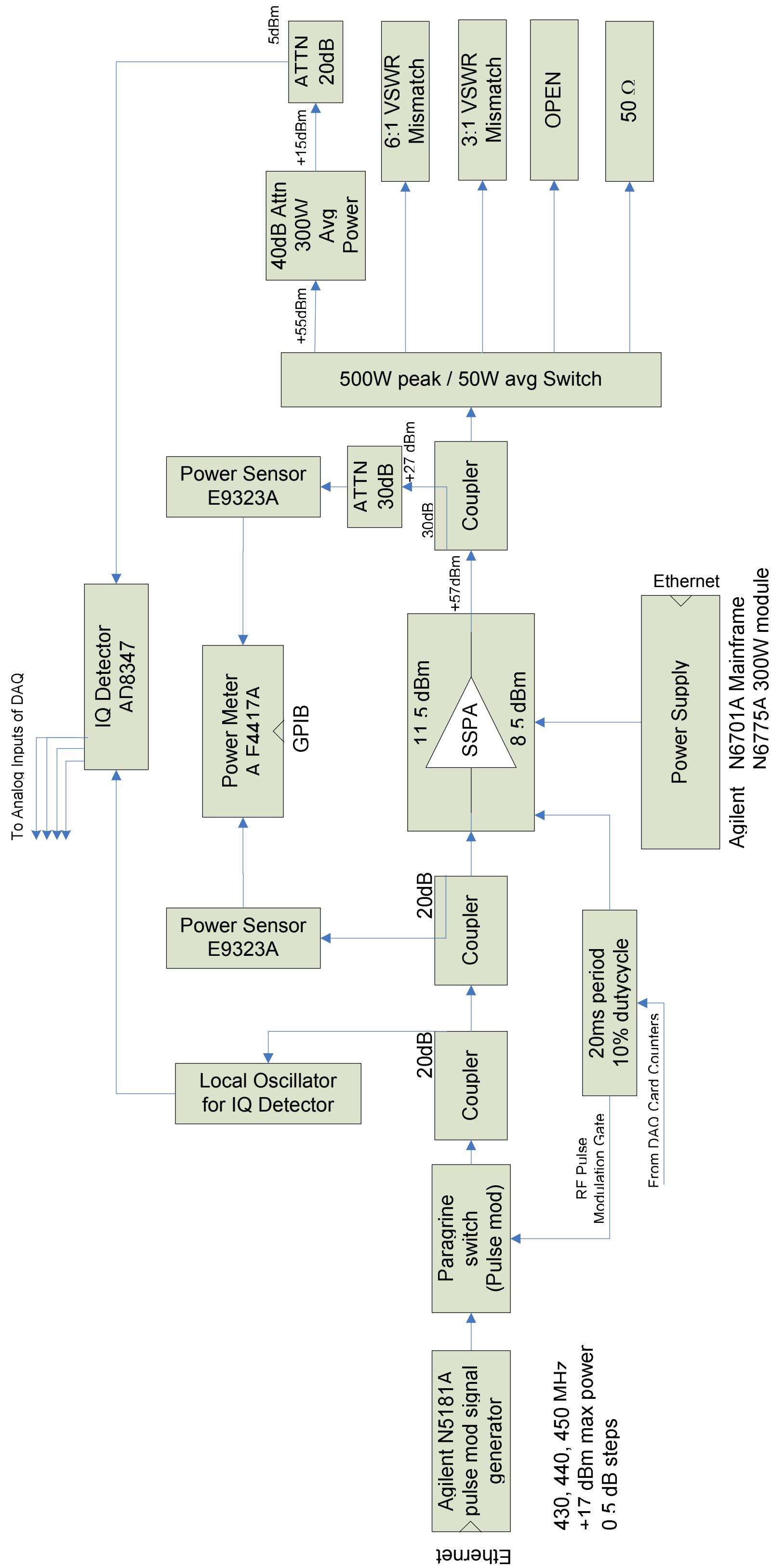

Figure 2: Block Diagram of Test System

6.1. System Design & Integration

The ATS includes a number of major components, all of which are integrated within our stand alone system. These include:

- Industrial PC
- RF power meter and power heads
- Power supply
- GPIB card
- Digital I/O card
- Signal generator
- Control Box
- Switch Box

The system diagram in Figure 3 shows how these different resources are connected and implemented. As you can see in the diagram, the industrial PC controls the test station. It communicates with various components through GPIB, Ethernet, and through the digital I/Os of the DAQ. The components that are controlled by the PC include the power supply, power meter, signal generators, and DAQ card. Each of these components connect to the SSPA, with the exception of the power meter which connects to the SSPA via the power heads. A switch box is also connected to the output of the SSPA and is used to switch between various loads.

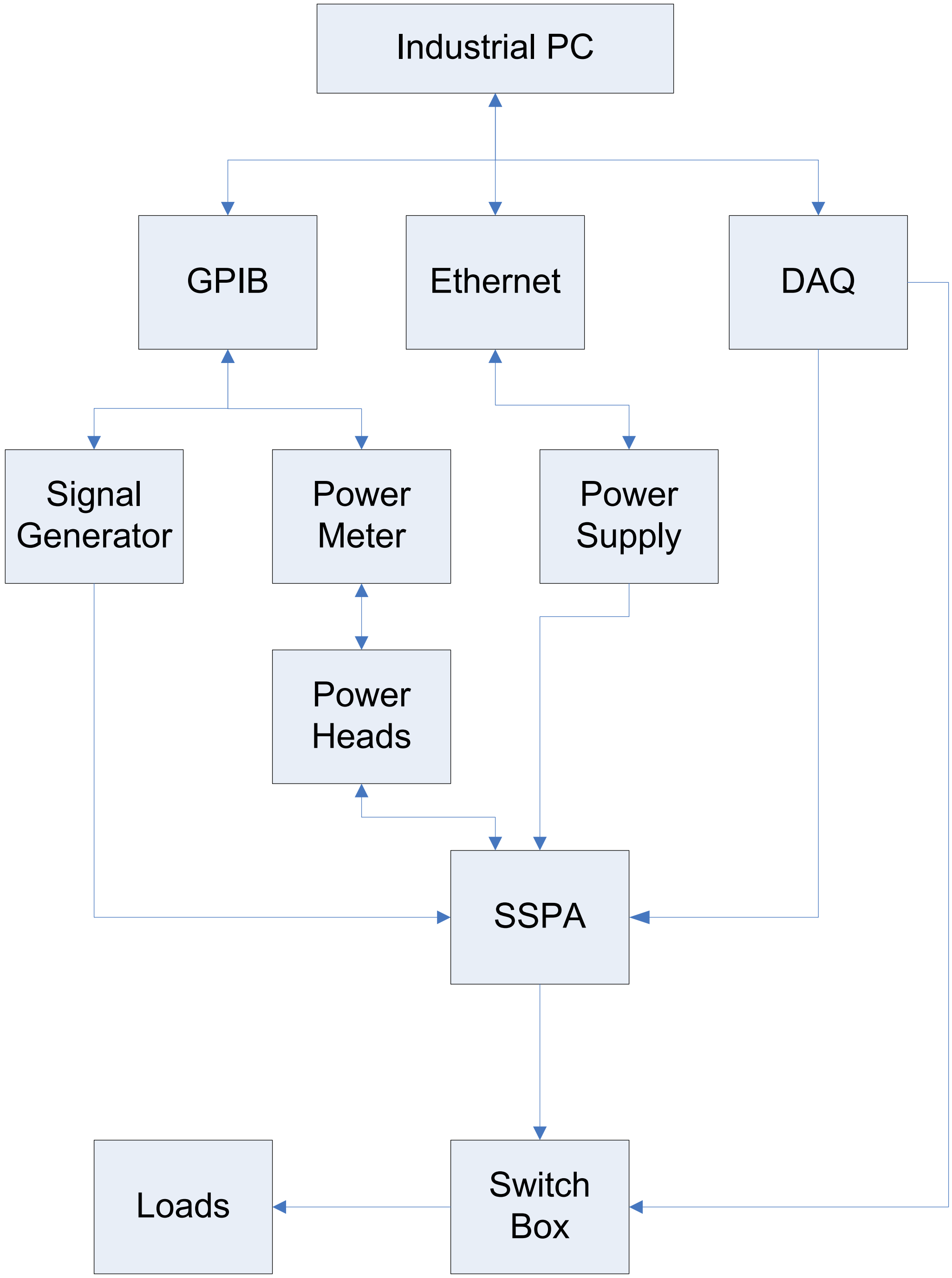

Figure 3: Test Station System Block Diagram

6.1.1. Signal Generator

The signal generator is used to produce our test signal. The frequency that the RF amplifiers will operate, between 430 MHz and 450 MHz, is within the limits of many of the signal generators we found which are shown in Table 1. It is important that the signal generator is programmable because we need to control it using our industrial PC. The Agilent N9310A signal generator was chosen because of its short lead-time, low-cost, and it is programmable via ethernet.

Company	Model #	Price	Lead Time	Programmable	Pulse Modulation Built-in
Agilent	E4400B ESG-A	$8,162	8 weeks	N/A	N/A
Agilent	N9310A	$6,810	4 weeks	Yes	Yes
Agilent	N5181A	$6,349	4 Weeks	Yes	Yes

Table 1: Comparison of Signal Generators

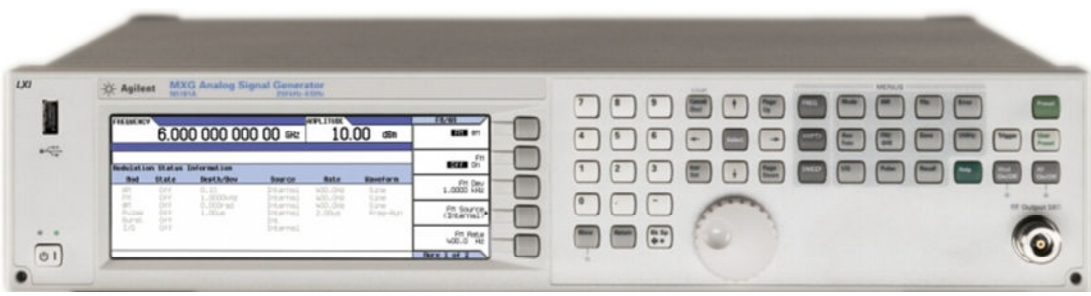

Figure 4: Agilent 5181A Signal Generator

6.1.2. Power Supply

The DC power supply is an important component of the test station. The power supply must be capable of covering the operating voltage and current ranges and must be able to be programmed remotely to allow automation of the testing procedure. This means that there must be a USB, Ethernet, or GPIB interface for programming. During the calibration and normal operation of the SSPA, the supply voltage needs to be 32V. Another important feature for the power supply is the current sensing resolution. The power supply must be able to supply 5A maximum current and should have a high current sensing resolution because the current draw of the SSPA will be measured by the supply. Below is a comparison of the features of different units and their prices.

Mfgr	Model #	Voltage	Current	Power	Programming Interfaces	Current Measure Res.	Price
Agilent	N5746A	40V	19A	760W	GPIB, LAN, USB 2.0	57mA	$2,442.11
Agilent	6653A	35V	15A	500W	GPIB	15mA	$3,434.69
Amrel	PD 40-25A	40V	25A	1kW	RS-232, GPIB	.2%	$3,833.00
Amrel	PD 40-25E	40V	25A	1kW	RS-232, GPIB, LAN	.2%	$4,528.00
Agilent	N6700A+ Filler Panel Kit	60V	5A	300W	GPIB, LAN, USB 2.0	.15%	$3,699.30
Agilent	N6700B+ Filler Panel Kit	35V	9A	300W	GPIB, LAN, USB 2.0	.15%	$3,699.30

Table 2: Comparison of Power Supplies

The Agilent N6700A power supply was chosen because it is capable of supplying the voltage and current necessary and it is also programmable via ethernet. In addition to these features the power supply has a current measurement resolution suitable for our application.

Figure 5: Agilent N6700A Power Supply

6.1.3. RF Power Meter & Power Head

We require RF Power-meters to be able to measure the input power into and the output power out of the power amplifier. The output power of the amplifier is expected to be approximately 500W of peak power or +57dBm. It is not easy to measure very high power directly; hence we will have to go through the process of attenuation before power measurements. Some of the specifications that we are looking in terms of power-meters and power-heads are:

- High sampling rate
- Peak power measurement capability
- High video bandwidth
- Wide power measurement range

We needed a high sampling rate because we need to perform a droop test. This involves capturing a trace of the output power and measuring the droop associated with the pulse. The peak power measurement capability is required because the RF pulse is only of 10% duty cycle which can output a maximum of 500W power or 50W average power. The high video bandwidth is required to measure sharp rising edge triggers. The wide power measurement range is an optional specification for flexibility. The tables below (Table 3 and Table 4) summarize the various power meter products and power-head products that are able to fulfill our technical requirements.

Manufacturer	Model	Measurement	Sampling rate /Measurement rate	Bandwidth	Price US$
Agilent	E4417A	Peak, Average, Peak-to-average ratio	20 Msample/s		7,077
Agilent	N1912A	Peak, average, Peak-to-average ratio, rise time, fall time and pulse width	100 Msample/s	50 MHz to 40 GHz	10,214
Gigatronics	8540C	Peak, average and CW	500-4000 reading/s	100 kHz to 40 GHz	N/A
Gigatronics	8502A	peak power, time, fall time and pulse width plus	70 measurements of a point/second	.03 or 0.75 to 18.5, 26.5 or 40 GHz	N/A

Table 3: Power-meter specifications comparison

Manufacturer	Series	Product	Frequency Range	Power Range	Video BW	Price from (US$)
Agilent	E9320	E9321A	50 MHz to 6 GHz	-65 dBm (320 pW) to +20 dBm (100 mW)	300 kHz	1,567
Agilent	E9322A	E9322A	50 MHz to 6 GHz	-60 dBm (1nW) to +20 dBm (100 mW)	1.5 MHz	2,089
Agilent	E9323A	E9323A	50 MHz to 6 GHz	-60 dBm (1 nW) to +20 dBm (100 mW)	5 MHz	2,867
Agilent	E9325A	E9325A	50 MHz to 18 GHz	-60 dBm (320 pW) to +20 dBm (100 mW)	300 kHz	1,880
Agilent	E9326A	E9326A	50 MHz to 18 GHz	-60 dBm (1 nW) to +20 dBm (100 mW)	1.5 MHz	2,507
Agilent	E9327A	E9327A	50 MHz to 18 GHz	-60 dBm (1 nW) to +20 dBm (100 mW)	5 MHz	3,336
Agilent	N192XA	N1921A	50 MHz to 18 GHz	-35 dBm to +20 dBm	N/A	3,763
Gigatronics	200mW PPS	80350A	45 MHz to 18 GHz	-20 to +20 dBm / +23dBm	N/A	N/A
Gigatronics	5 W PPS	80351A	45 MHz to 18 GHz	0 to +40 dBm / +43 dBm	N/A	N/A
Gigatronics	25 W PPS	80352A	45 MHz to 18 GHz	+10 dBm to +50 dBm / +53 dBm	N/A	N/A
Gigatronics	50 W PPS	80355A	45 MHz to 18 GHz	+10 to +50 dBm / +53 dBm	N/A	N/A

Table 4: Power-head specifications comparison

For the power-meter, Agilent E4417A was chosen because it met all of our specifications along with our budget. For the power-head, the Agilent E9323A was chosen over other Agilent E-series primarily because if it's high video bandwidth specification.

Figure 6: Agilent E4417A Power Meter and E9323A Power Heads

6.1.4. Switch Box

The switch box must be a single pole five throw switch cable of handling 50W average input power and 500W peak input power. A VSWR as close to 1 as possible is desirable so that the loads following the switch are properly matched to the amplifier under test. The switch must also be programmable so that the computer can control the load configuration and automate the test plan.

Manufacturer and Part Number	Frequency range	Insertion Loss	Isolation	SWR	Connectors	Control Logic
Agilent 87106A	DC to 4GHz	0.3dB + .015 x Freq.(GHz)	100dB Min	1.2 Max	SMA	Internal Control Logic
Agilent 87106B	DC to 20GHz	0.3dB + .015 x Freq.(GHz)	70dB Min	1.7 Max	SMA	Internal Control Logic
Agilent 87206B	DC to 4GHz	0.3dB + .015 x Freq.(GHz)	100dB Min	1.2 Max	SMA	Requeires External Control Logic

Table 5: Load switch specification comparison

The Agilent 87106A switch was chosen because it meets the necessary requirements. The switch also provides flexibility for future adjustments to the ATS because it is a six-pole switch.

Figure 7: Agilent 87106A Load Switch

6.1.5. Industrial PC

The industrial PC will function as the control unit for our project. It will control all of the instruments and run the test program that we develop. A few companies that offer industrial PCs are shown in Table 6 with their respective systems. We determined that we are looking for an industrial PC with at least 512MB of RAM, an 80GB hard drive, and 6 PCI slots. We determined these specifications to be suitable for our application because our program will not be extremely large and will not require extensive resources to operate. We would prefer the PC to be a rack mountable unit to save shelf space for the other test equipment that is not available in a rack mountable package.

Company	Model	PCI express	ISA	PCI Slots	Processor	Mount Type	Ram	Price US$
Nortech Eng.	IRC Series	14 or 20 Slot Combination Backplane			P4	Standard	512MB	TBD
Allen Bradley	6177RR4SXP	1	0	6	P4 2.66 GHz	4U rack mount	512MB	TBD
Allen Bradley	6177RR4PXP	1	0	6	P4 3.0 GHz	4U rack mount	1GB	TBD
Industrial Comp.	4UBASICIP	0	3	3	P4 2.8 GHz	4U rack mount	256MB	1,289

Table 6: Various industrial PC's and their respective specifications

After careful consideration, a PC that was already in possession of SRI International was chosen for use in the ATS. The PC is not rack mountable, however the space saved by using a rack mountable PC was not deemed important or necessary. The rack that was chosen contains enough space for all the components used in the ATS including a traditional PC.

General Purpose Interface Bus Card

General Purpose Interface Bus (GPIB) cards are specifically designed to connect computers, peripherals and laboratory instruments for data and control transfer between them. Another name for the GPIB is IEEE-488 or HPIB, and is electrically equivalent to

IEC-625 bus. GPIB uses 16 line parallel connections which are divided into eight data lines, three handshake lines for synchronous transfer and five management lines to control the bus. To use the GPIB, we need a GPIB adaptor card in the computer and a GPIB cable. The GPIB cards generally go into the PCI slot of the computer which will be used to control the automated test unit. The GPIB will be used to communicate with the power meter and feed the measurement readings back into our program. There are a variety of GPIB cards with different specifications which are summarized in Table 7.

Manufacturer	Part Number	Specifications / Comments	Price US$
National Instruments	778032-01	NI PCI-GPIB NI-488.2 for Windows 2000/XP (Includes Type X2 Cable, 2M)	529.00
National Instruments	778032-51	PCI-GPIB NI-488.2 for Windows 2000/XP (Includes Type X2 Cable, 2M)	599.00
National Instruments	778686-01	PCI-GPIB NI-488.2 for LINUX (Includes Type X2 Cable, 2M)	529.00
National Instruments	778686-51	PCI-GPIB NI-488.2 for LINUX (Includes Type X2 Cable, 2M)	599.00

Table 7: Comparison of different GPIB cards

The GPIB card from National Instrument, NI PCI-GPIB NI-488.2 for Linux w/ 2 meter cable, part number 778686-51, was chosen because it fits into our budget easily and National Instruments provides extensive technical support. The fact that the GPIB card specifically says for Linux systems ensures us that there are some drivers and support for Linux.

Figure 8: National Instruments 488.2 GPIB Card

Data Acquisition Card (DAQ)

A data acquisition card is required to connect to the programmable digital potentiometer which will be used to set various currents and voltages for different measurements. They are also required to feed in the data regarding temperature faults and VSWR faults. The market for the DAQ cards like the GPIB cards is owned by National Instruments. However, there are a variety of DAQ cards available with different specifications and for different purposes. Table 8 below summarizes some DAQ cards that were found searching by the low cost requirement.

Manufacturer	Part Number	Specifications / Comments	Price
National Instruments NI PCI-6220	779065-01	16-Bit, 250 kS/s 16 Analog Inputs 24 digital I/O 32-bit counters Digital triggering Correlated DIO (8 clocked lines, 1 MHz), Includes NI-DAQmx, VI Logger Lite data-logging software, and other measurement services.	$ 399.00
National Instruments NI PCI-6023	777742-01	200 kS/s 12-Bit 16 Analog Input Multifunction DAQ 8 digital I/O lines Two 24-bit counters	$ 499.00
National Instruments NI PCI-6024E	777743-01	200 kS/s, 12-Bit 16-Analog-Input Two 12-bit analog outputs 8 digital I/O lines Two 24-bit counters	$ 699.00
National Instruments NI PCI-6036E	778465-01	200 kS/s, 16-Bit 16-Analog-Input Multifunction DAQ Two 16-bit analog outputs Eight digital I/O lines Two 24-bit counters	$ 999.00

Table 8: Comparison of different Digital I/O cards

Each NI PCI-6XXX series requires: 1 Cable, 1 Connector Block. The part numbers are different depending on which IO card is chosen, however the prices are the same as shown in Table 9.

Manufacturer	Part	Specifications / Comments	Price
National Instruments	Cable	SH68-68-EP Cable (2m)	$ 119
National Instruments	Connector Block	SCC-68 -Unshielded	$ 299

Table 9: Additional parts for the Digital IO cards

Digital IO card from National Instruments, NI PCI-6220, part number 779065-01, was chosen because of its low cost, and sampling rate of 250kS/s. The number of analog inputs and digital outputs (16 and 24 respectively) is suitable for our application.

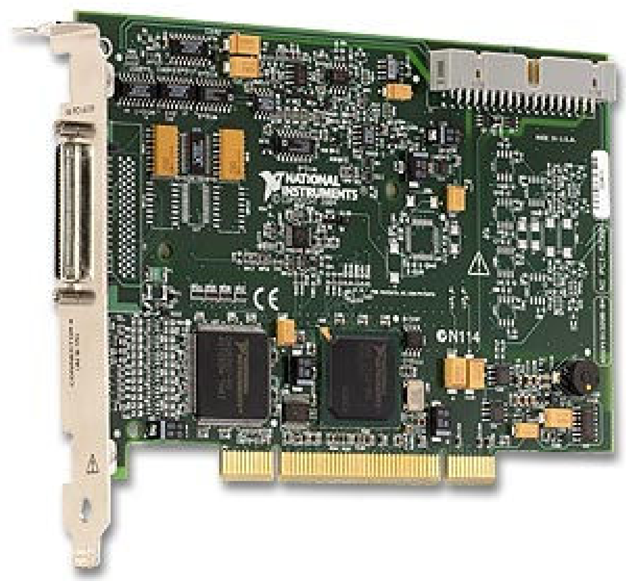

Figure 9: National Instruments PCI-6220 DAQ Card

6.1.6. Control Box

The control box was built in an effort to simplify the wiring and installation of the devices in the Automated Test Suite. The ATS requires a large number of connections to be made between devices and the control box was designed to make this easier for both the original designers as well as test and service technicians. The following devices are contained within or interfaced using the control box:

- Signal Generator
- Power Supply
- Power Heads
- Data Acquisition Card
- Load Switch
- Five Loads
- I/Q Detector
- Pulse Modulation Switch
- Three Couplers
- One Attenuator

The control box design allows the SSPA input, output, controller, and power to plug into the front of the control box, while the remaining connections are made in the rear of the box. The couplers and attenuator are incorporated into the control box to ensure they are never accidentally removed because that could permanently damage the power heads. The RF input amplitude is 10dBm and the signal passes through two 20dB couplers that are implemented in series as shown below. The first input coupler attenuates the signal to approximately -10dB and provides the LO signal for the I/Q detector. The second input coupler also attenuates the signal to -10dBm prior to being measured by the power meter using channel A.

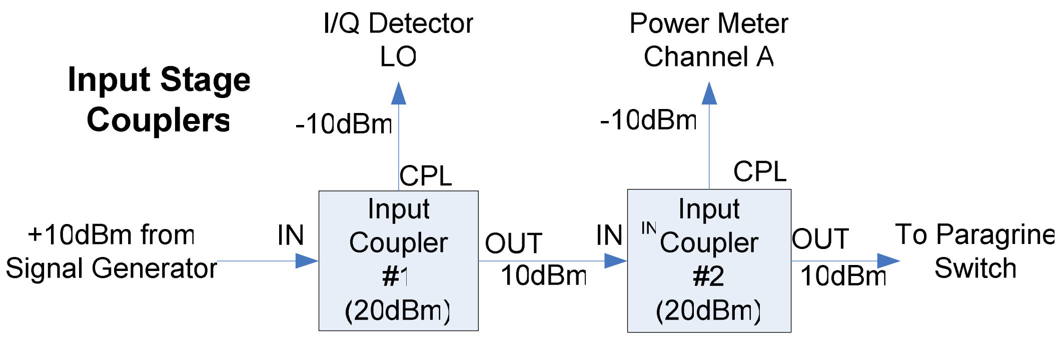

Figure 10: Input Stage Couplers

The output stage of the control box utilizes a 30dB coupler and a 30dB attenuator as shown below. The output of each SSPA is approximately 57dBm and it is attenuated 60dBm using these devices.

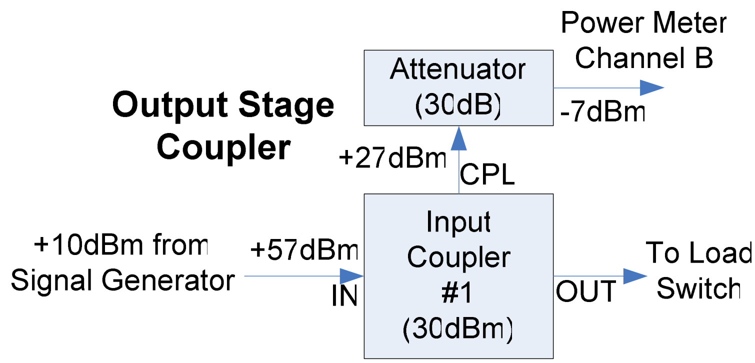

Figure 11: Output Stage Coupler

The overall control box design is shown in the diagram below.

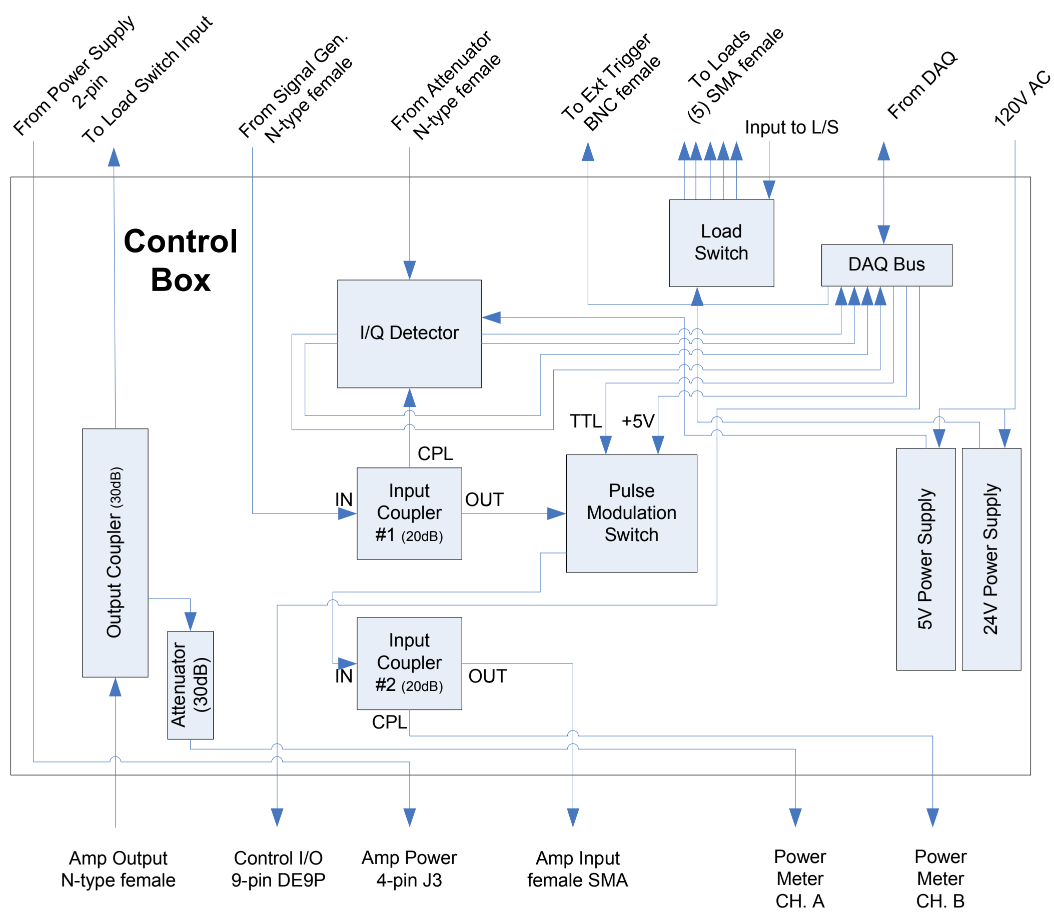

Figure 12: Control Box System Diagram

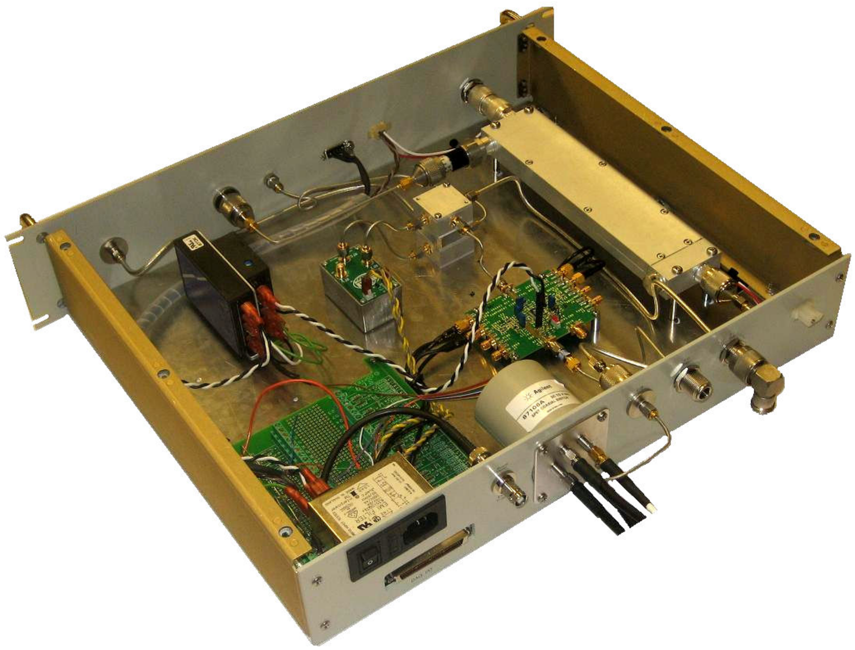

Figure 13: Control Box

The front and back panels of the control box were designed for easy implementation in the rack and in an effort to keep the design simple so a technician can easily approach the rack and use it with little instruction.

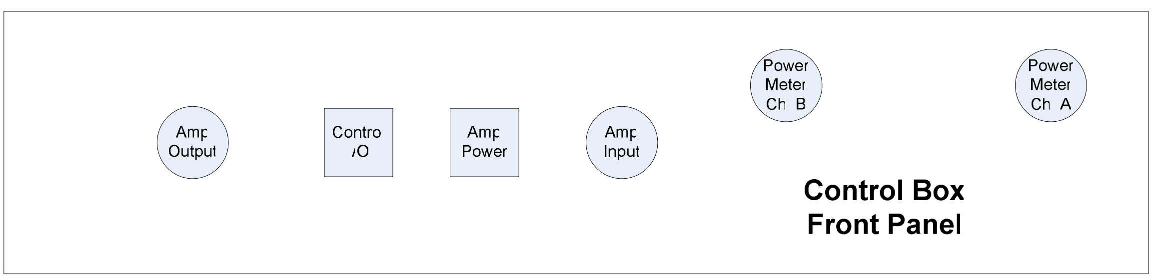

Figure 14: Front Panel of Control Box (Artist Concept)

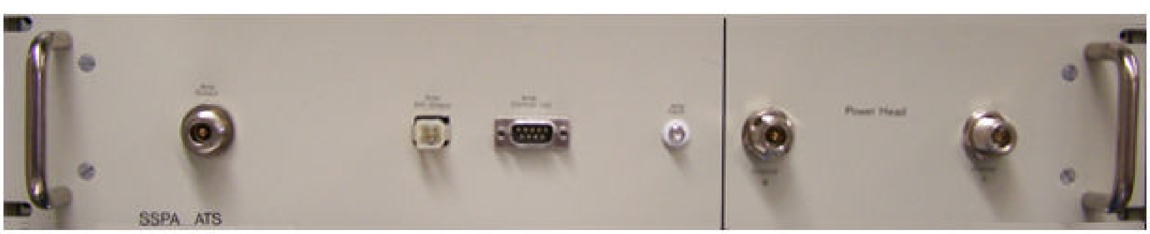

Figure 15: Front Panel of Control Box

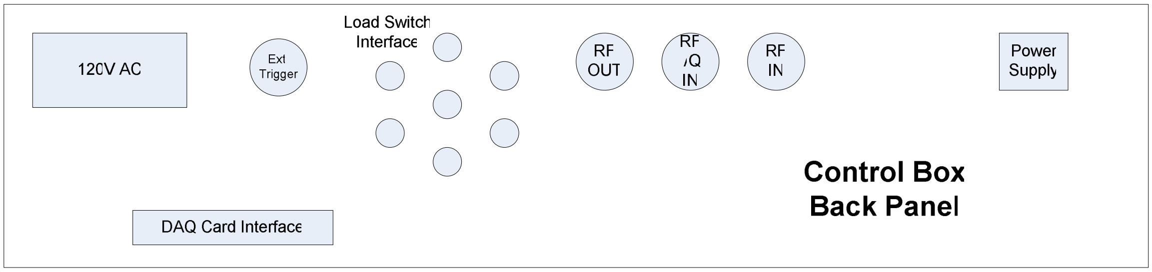

Figure 16: Back Panel of Control Box (Artist Concept)

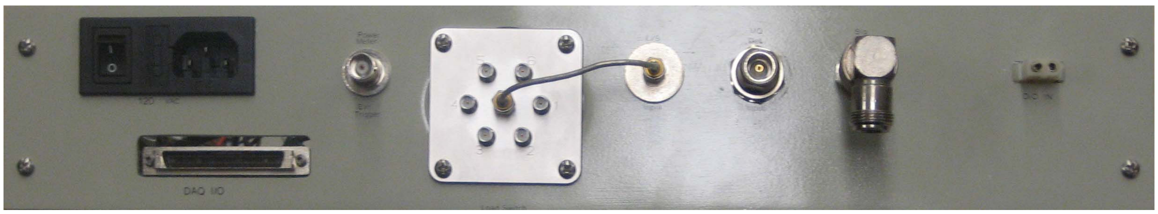

Figure 17: Back Panel of Control Box

I/Q Detector

The control box also contains the I/Q detector circuit which uses an AD8347 demodulator chip implemented using its evaluation board provided by analog devices. The AD8347 chip is an I/Q demodulator that directly splits an RF signal to its in-phase and quadrature phase components based on a local oscillator signal (LO) operating at the same frequency as the RF input. Using these two components, the phase of the RF signal coming from the output of the amplifier can be determined. This is important because the phase an SSPA can be adjusted by either incrementing or decrementing a digital potentiometer. Since the phase of all the amplifiers used within the AMISR needs to be within 5 degrees of each other, it is important that we accurately set the phase of each amplifier to a reference value.

The phase splitting of the RF signal is done by the mixer that mixes the LO and the RF signal. As in the case of any modulation involving a mixer, there are two resultant frequencies viz. the sum of two and the difference of two. For a 440 MHz LO and RF signal, the resultant output frequencies are centered around 880 MHz and DC value. The signal near the DC value is what we are concerned with and this requires an RF filter to filter out the higher frequency.

The evaluation board has pads to which inductors and capacitors can be mounted, however, with this restricts the filter design to a pi-network of inductors in series and capacitors in shunt. The filter was designed with the cut-off frequency of 1 MHz with a Bessel design approach to get the maximally flat phase response for the data acquisition card. The schematic of the filter is shown below in Figure 18.

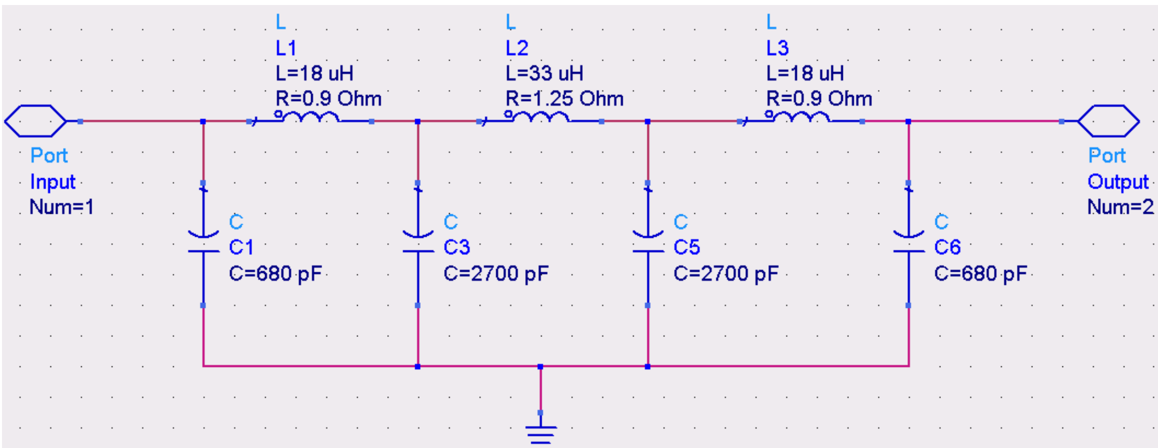

Figure 18. 7th order RF low pass filter

The filter was designed on paper first and then the performance of the filter was simulated using Agilent's Advanced Design System (ADS). The values chosen for the inductors and the capacitors are standard values readily available in Digi-Key's catalog. The simulation results are show below in Figure 19.

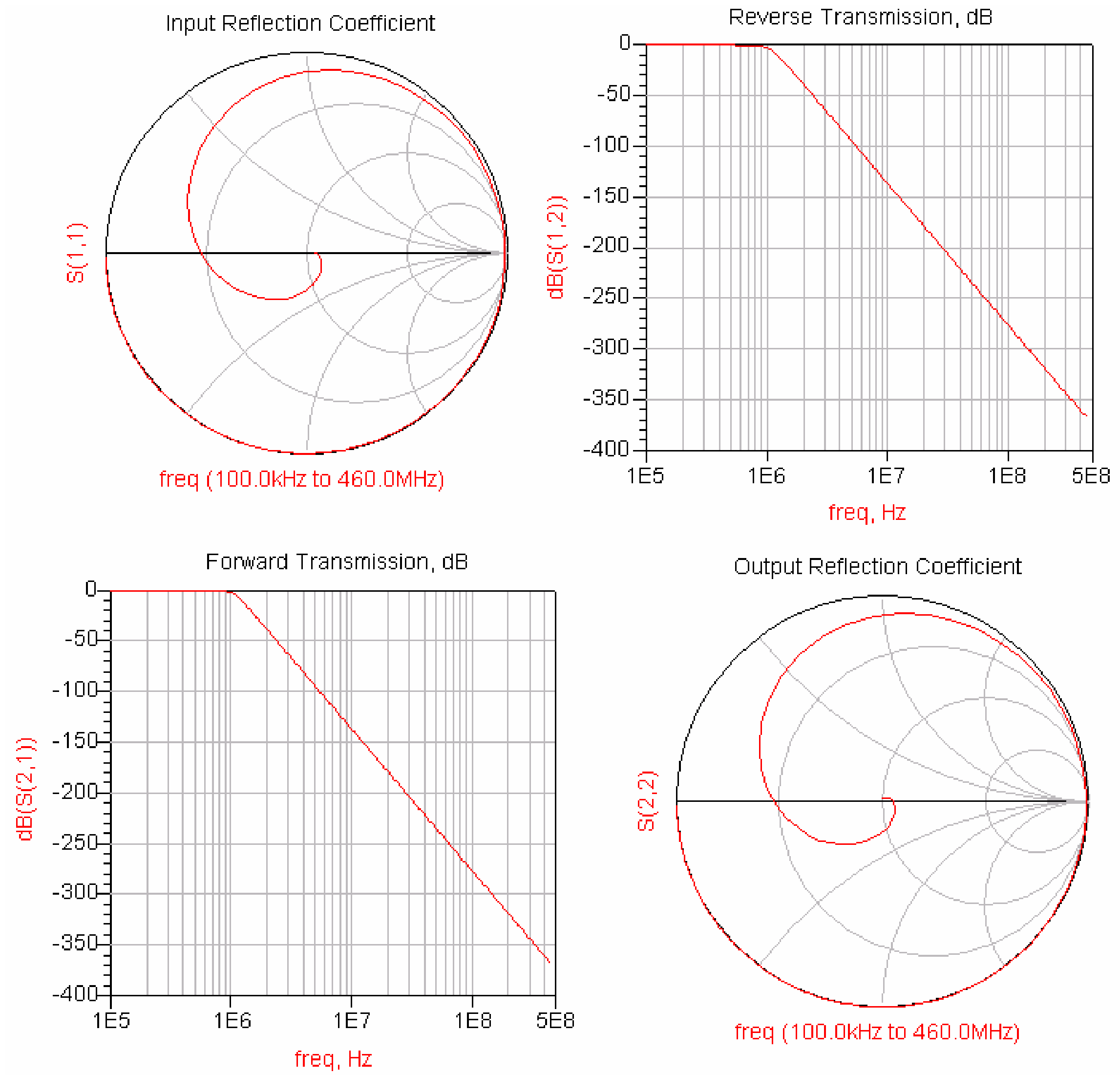

Figure 19. S-parameters vs frequency

The frequency was swept from 100 KHz to 460 MHz for simulation purpose. The S_{11} parameter (or input reflection coefficient) moves outwards from the center of the Smith Chart as the frequency increases, verifying that more power is reflected than transmitted. The S_{21} parameter (or the forward transmission, also known as gain) is flat at 0dB until the cutoff frequency of 1 MHz. After the cutoff frequency, the 7th order filter comes into action with sharp fall off as the filter attenuates approximately 150 dB per decade.

The evaluation board is connected to our DAQ via the breakout board located within the control box. The DAQ card utilizes differential inputs to evaluate both the in-phase and quadrature phase components of our RF signal. Using these two components and some basic mathematics skills, the resultant vector of these two components, the phase of an SSPA output, is found using the following formula.

$$\text{phase angle} = \arctan(Q/I)$$

Pulse Modulation Switch & Load Switch

The Automated Test Suite requires that different loads be implemented within the calibration procedure and during testing. Using a load switch provided by Agilent Technologies, the ATS can switch through five different loads depending on what task is being performed. The load switch is located within the control box and is also interfaced using the DAQ card.

The pulse modulation switch was designed at SRI and is used to pulse modulate the RF input signal. The pulse modulation switch will pulse modulate an input signal based on a TTL input. The RF gate line is applied to the TTL input which will cause the pulse modulation switch to output a RF signal with a duty cycle dependent on the RF gate line.

6.1.7. Rack Design

After careful consideration, a rack that was already owned by SRI International was chosen for the ATS. The rack manufacturer is HP and the rack already contains casters and is large enough to hold the components used in our application. We designed the layout of the rack as shown below to provide a simple interface for a technician who tests amplifiers with our system, but still allowing for access to devices that an engineer could use to trouble shoot amplifiers that failed our tests. As shown in the rack layout, the control box in located directly above the shelf where each SSPA will be located during testing. The four connections that need to be made to the SSPA are located on the front panel of the black box as previously explained. This will allow a technician or engineer to easily exchange SSPAs while using our test system.

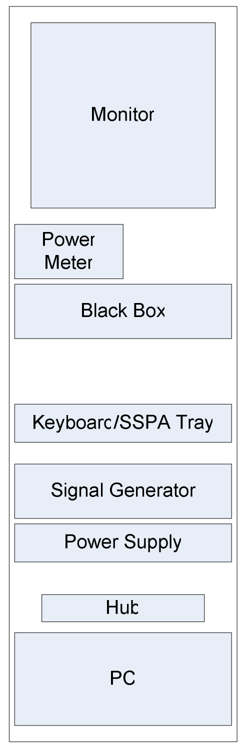

Figure 20: Rack Layout

The layout for the rack, as shown in Figure 20, was also chosen to simplify the installation, wiring, and replacement of components. The system wiring diagram is shown below in Figure 21.

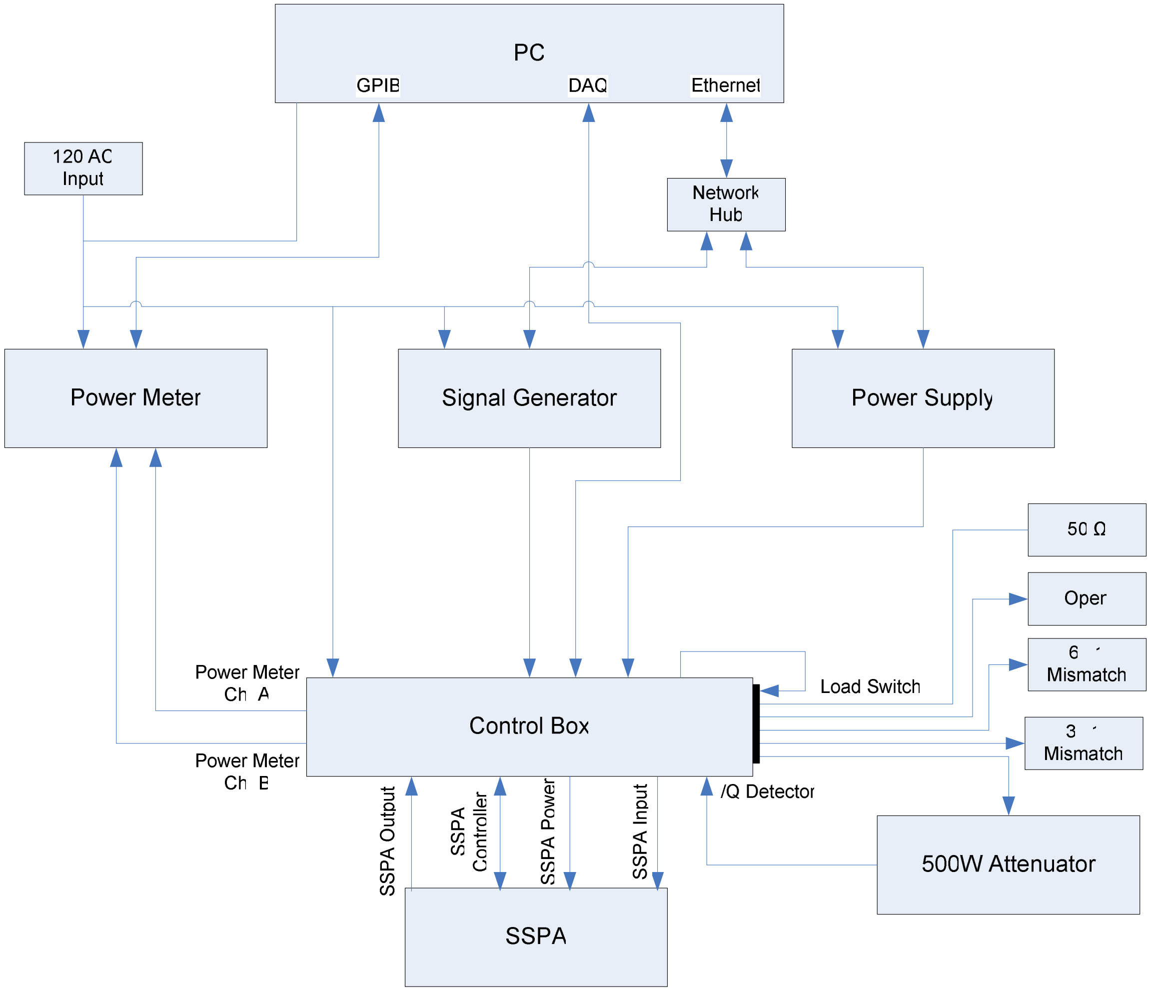

Figure 21: System Wiring Diagram

6.2. *Platform*

Wikipedia has the following description in computing world for the word *Platform*—"In computing, a platform describes some sort of framework, either in hardware or software, which allows software to run. Typical platforms include a computer's architecture, operating system, or programming languages and their runtime libraries."

6.2.1. Hardware Architecture

The Dell OptiPlex GX240 PC used for the ATS comprises Intel® 845 Chipset with an Intel® Pentium® 4 2.0 GHz processor and L2 Cache of 512 KB. It belongs to the

80586 family of processors with the chipset bus speed of 400 MHz. The system memory is limited to 512MB SDRAM with the system memory speed of 133 MHz. Since the computer is an Intel® 80586 computer, with x86 (32-bit) bit architecture, it is able to support both Windows and Linux as an operating system.

6.2.2. Operating System

The automated test suite is driven by a PC running Fedora Core 6 distribution of Linux as an operating system. "Fedora Core is a free operating system that offers the best combination of stable and cutting-edge software that exists in the free software world."[5] The Linux kernel version used in the system is 2.6.19-1.2895. The Fedora Project is Red Hat sponsored open-source version of Red Hat Linux, which actually sets the benchmark for Enterprise Linux. Linux operating systems supports multi-user logins as compared to windows (except for Microsoft® Windows Servers) and hence multiple users can work on the same system without having to depend on one another. Linux does not depend upon RPC[1] unlike Windows which uses RPC for almost every application. Linux has been known to be more stable in comparison to Windows and the ever so important fact of Linux being an open source and free by fat beats Windows by a wide margin.

As everything has advantages and disadvantages, there are some disadvantages in using Linux as an operating system. Since Windows has more than 90% of the market, it is very difficult to find support for Linux, especially for driver installations. As expected, some problems were encountered during the driver installation of the GPIB interface card and the NI-DAQ card. Both cards came in with drivers for Linux but not for Fedora Core. The drivers provided by the National Instruments for both the GPIB and the DAQ cards were supported only for Mandrake 10.1, Mandriva 2006, SUSE 10.0 / 10.1 and Red Hat Enterprise WS 3/4 distributions of Linux.

It is possible to load the drivers for Red Hat Enterprise Distribution on Fedora Core distribution because Fedora Core resembles Red Hat Enterprise distribution. There were some modifications that were made to the install script because the Fedora

[1] Remote Procedure Calls (calls made to other programs using APIs to do some other tasks)

distribution has some files located in different locations when compared to Red Hat. The second step involved patching of the NI-KAL drivers. “NI-KAL is a low-layer driver that is compiled when you install it on your machine. NI-KAL provides "glue" between your Linux kernel and other National Instruments software. A version of NI-KAL is included in every National Instruments Linux driver.” [6] Running the driver updates after the patch resulted in successful installation of both the drivers and a fully operational system.

6.2.3. Programming Language

Out of the various different high level languages available in the commercial market which include Java, C++, Microsoft Visual Studio .NET, Python, and Ruby, Python was chosen for this project solely because the advantages of using Python outweighed the drawbacks. After choosing Linux as the operating system, it was an easy decision to use an open source programming language. Java is the first one that comes to mind when someone talks about powerful open source programming languages, but Python is not far behind either.

Python and Java are very distinct but equally prevailing. Python is essentially a scripting language which can be extended as an object-oriented programming language but the reasons taken into consideration are speed, ease of use, maintenance, and support. Java being a compiler based programming language is faster because the processor only has to load the pre-parsed byte code into the memory to execute the instructions. On the other hand, Python, being an interpreted programming language, is easy to execute and can be done on the fly after changes have been made to the source code; the programmer need not go through the lengthy process of compiling the source code to the object code and then linking the object code with the libraries using a linker. Another big advantage of using Python is that it is dynamically typed (no variable declaration required) whereas Java is statically typed (all variable names along with their types must be explicitly declared). Python also allows the flexibility of assigning a variable with an object of a different type even after it had been assigned to some other type whereas Java’s explicit variable type declaration prohibits it from allowing such feature. The built-in arrays/lists, hashes/dictionaries are significant advantages for Python over Java arrays and its library based collections. Finally, the person who will be involved in maintenance and support of the ATS is highly proficient in Python.

6.2.4. Database Management System (DBMS)

During the process of calibration and various tests performed on the SSPAs, the ATS fetches sets of data for each of them. Storing that data becomes important for the company to determine production yield, or if the designer wants to know the median for various settings. Although saving data in a plain ASCII text file is convenient, it is not convenient when there are thousands of records to handle. It is much easier to make use of DBMS so that the data can be stored in organized manner and can be easily retrieved in the format that the user wants by sunning simple SQL[2] queries. There are many database management software programs available in the market, e.g. Microsoft Access, Oracle, Filemaker, Microsoft SQL Server, MySQL, and PostgreSQL.

PostgreSQL is a powerful, open source relational database system that can be installed as a package during the installation of Fedora Core (project's platform) or can be separately installed. "It has more than 15 years of active development and a proven architecture that has earned it a strong reputation for reliability, data integrity, and correctness. It runs on all major operating systems, including Linux, UNIX (AIX, BSD, HP-UX, SGI IRIX, Mac OS X, Solaris, Tru64), and Windows." [7]

Similar to most of the commercial databases, it is fully ACID[3] compliant, supports foreign keys, table joins, views, triggers, functions, and stored procedures. It also has native programming interfaces for C/C++, Java, .Net, Perl, Python, Ruby, Tcl, ODBC, etc.

MySQL is a very popular open source database system in comparison to PostgreSQL. MySQL, however, has many limitations while PostgreSQL provides those

[2] Structured Query Language
[3] Atomicity, Consistency, Isolation, and Durability (in terms of database management systems)

functionalities and flexibilities. Vita Voom Software talks about the advantages of PostgreSQL over MySQL in their website[4] which has been summarized below.

PostgreSQL is faster and more efficient than MySQL, supports unlimited row sizes, unlimited database sizes, and tables up to 16TB. It also supports inheritance, foreign keys, Unicode and is more resistant to crashes and power failures by using its logging system. PostgreSQL supports functions (which can be used as stored procedures. It supports outer joins and much more complex multi-joins than MySQL. It also supports “limit” SQL keyword that can be used to limit the number of rows returned making queries more responsive and resource economic. It supports subqueries, indexes on functions and has more flexible BLOB field. Last but not the least, it is a RDBMS[5] that has grown alone, instead of MySQL which is a hack of several tools "glued" together (MSQL, Berkeley DB).

To summarize our discussion over the choice of the database management system, the key points that were taken into consideration for choosing PostgreSQL as the DBMS for the project are listed below:

- Doesn't cost money even for commercial use.
- Works at speed about the same as commercial databases.
- Supports a broader subset of SQL than MySQL like sub-selects
- Extremely responsive in high volume environments
- Supports large tables that exceed Linux' file limit.
- Fully Programmable.
- Known to be legendarily reliable and stable

6.3. Software Architecture

Since the test station is automated, it has to be driven by software. Software is the core of this project in terms of control and decision making. The ATS software is capable of controlling all the ATS devices and can perform each and every task the device is capable of programmatically. Software development includes program design, abstraction, device interfacing, implementation and data storage.

[4] http://www.vitavoom.com/postgresql.html
[5] Relational Database Management System

6.3.1. Object Oriented Program Design

The purpose behind object oriented program design is simplification of complex software design and goals. Object oriented design enables programmers to think at a very high level about the available resources, their project goals, and how the goals can be achieved with optimal use of their resources. Objects are essentially real world scenarios or concepts tied together as collection of properties and attributes by object classes. The real advantage of object oriented design is easy maintenance as each object is a stand-alone entity and can be executed independent of others [1]. Another advantage of object oriented programming is the ability to reuse object (or concepts) more than once in the same sequence of instructions.

The SSPA Test Station appears straight forward, however, the logic that automates the calibration and specification procedures are complex. Moreover, the interfaces that communicate with the various drivers are even more intricate.

6.3.2. Device level Abstraction

All the devices that are used in the ATS are programmable. With object oriented design concept, it was easy to segregate each individual device as individual object. The specific properties and attributes of each device were constrained within its own object class and these objects communicated with other object solely by message passing via public methods of the object classes. Abstraction at the device level enabled us to take baby steps one at a time and focus on one particular area at one particular instance.

6.3.3. Device Interfacing

Each device used in the ATS has its own device interfacing object class and hence its own file. The protocol for the main program to communicate to the individual devices was by creating object instances of individual devices and calling the public methods to set or get values to and from the devices. Each device had different means of communication with the PC and was implemented in a different way.

With today's instruments getting more and more complex in terms of development and capabilities, there needs to be a common standard means of communication or interface language between computers and these programmable test instruments. SCPI[6] standard is one typical example of standards that companies are using as interpreter between their hardware and software that controls them. "The SCPI Standard is built on the foundation of IEEE-488.2, Standard Codes and Formats. It requires conformance to IEEE-488.2, but is pure software standard."[2] "IEEE-488.2 standard defines communication protocols that are necessary to effect application-independent and device-dependent message exchanges, and further defines common commands and characteristics useful in instrument system applications. It is intended to apply to small-scale to medium-scale instrument systems comprised mainly of measurement, stimulus, and interconnect devices outside the scope of the instrument system environment."[3]

SCPI command set comprises instructions that are simple and common "English-like" syntax which are pure ASCII texts. With these new devices supporting SCPI, the ease of use has definitely increased. The basic instruction set is common among almost all the devices including the low level or register level programming instructions. Each device can have additional high level instruction sets to accomplish some of the specific tasks for which the device is designed.

GPIB Interface and Ethernet

The power meter connected to the PC via IEEE 488.2 GPIB interface while the power supply and the signal generator were connected via Ethernet. Interfacing the power supply and the signal generator with the PC was straight forward because of the Ethernet connectivity. Using Berkley socket, simple TCP/IP connection was established with the devices to send SCPI commands and receive readings and data as simple ASCII texts. Controlling the GPIB interface card and establishing connection and communicating with the instrument attached to this card required the knowledge of VISA[7].

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[6] Standard Commands for Programmable Instrumentation
[7] Virtual Instrument System Architecture

VISA was originally a specification developed by VXI*plug&play* Systems Alliance as a step towards industry-wide software compatibility for multi-vendor VXI[8] systems. However National Instruments defines VISA as "a standard for configuring, programming, and troubleshooting instrumentation systems comprising GPIB, VXI, PXI, Serial, Ethernet, and/or USB interfaces."[4] National Instruments has also come up with their own implementation of VISA I/O standard—NI-VISA. "NI-VISA includes software libraries, interactive utilities such as NI Spy and the VISA Interactive Control, and configuration programs through Measurement and Automation Explorer for all your development needs."[4]

VISA libraries are C/C++ library files and cannot be used in Python unless a Python wrapper is built around the library. PyVisa package is one such wrapper built for Python over C/C++ libraries that enables the programmer to control all kinds of measurement equipment through various busses (GPIB, RS232, and USB) with Python programs. PyVISA is tailored to work with arbitrary adapters from National Instruments, Agilent, Tektronix, etc by making calls to the external library file bundled with the hardware and the software of corresponding vendors. The use of PyVISA hides a lot of low level programming required for device communication and enables the programmer to think of what-to-do instead of how-to-do.

National Instrument's Data Acquisition Card (DAQ)

The NI-DAQ 6220 card was used for all the functionalities that it was capable of in addition to pure data acquisition and analog to digital conversion. The card is capable of handling digital inputs and outputs along with generating timing pulse chains or streams using its two counters. Both the counters were implemented to generate the TR gating pulse and the RF gating pulse, with the RF gating pulse being 1µs inside the TR gating pulse. Both pulse chains were of 20ms default period with the RF pulse operating at 10% default duty cycle. The TTL outputs from the counters were used to drive the pulse modulation switch for pulse modulation of the RF signal, the trigger for the power meter as well as the trigger for data acquisition from the I/Q detector, which will be

[8] **V**ME e**X**tensions for **I**nstrumentation

discussed later in this section. The digital inputs were used to read in the VSWR fault status and the over temperature status lines from the SSPA. The SP6T[9] load switch uses TTL signals to switch between the 6 output ports. Five of the digital signals required to switch between the five loads used in the ATS were also driven by the DAQ's digital outputs. The digital outputs were also used to drive the control circuitry of the SSPA. Three digital lines were used to switch between different addresses during calibration, one digital output to control the up/down line and one to control the increment line.

There were basically two ways of implementing the various DAQ functionalities in Python; one was writing low level code for direct register level programming to control the DAQ's processor and the other was using C/C++ to code the functionalities using the available library from National Instruments and writing a wrapper to export the functions as shared libraries to Python. The latter option was more desirable as Python is built on C construct and use of the library functions is more efficient and it also hides the gory details involved in low level programming of embedded systems.

6.3.4. Class Modules

The software for the ATS was inherits object oriented design concepts and hence the overall *software* is divided into modules, specifically known as *class modules*. The modules are characterized as hardware controllers and process controllers. The hardware controllers interface and control the programmable hardware, while the program flow controllers organize the overall flow of the software. The hardware controllers are discussed below. More information regarding the process controllers can be found in Section 6.3.5

(a) Power Supply *(PowerSupply.py)*

The PowerSupply class module controls the Agilent power supply of the ATS via the ethernet port. The module uses simple Berkley socket to establish connection and SCPI commands to set voltage and current compliances and also to read the voltage and

[9] Single-Pole-6-Throw

the current draw. The module is also capable of regulating the power on and off from the power supply. The full implementation of the methods and their functionalities belonging to this class can be found in *Appendix D*.

(b) Signal Generator *(SignalGen.py)*

The SignalGen class module manages the Agilent signal generator using the ethernet port as well. The implementation of this module is similar to the PowerSupply module and uses similar concepts. It also uses Berkley socket to establish connection and SCPI commands to set RF power level, frequency compliance values. It is also capable of switching on and off RF output from the device. The full implementation of the methods and their functionalities belonging to this class can be found in *Appendix D*.

(c) Power Meter *(PowerMeter.py)*

The PowerMeter class module interfaces the Agilent power meter using the GPIB card PyVisa python module. The module uses SCPI commands to read and write device settings to and from the power meter. The power meter makes power measurements using SCPI commands as well, but since the power meter is capable of making different types of measurements related to power, specific settings need to be taken care of before making measurements. The module, whenever initialized as an object by any other process module, resets the power meter and sets it to our default settings.

The power meter settings handled by the PowerMeter class are listed below:

- Zero power-heads (both channels)
- Measurement type (peak power, average power)
- Measurement rate (single, double, fast)
- Trigger source (immediate, external)
- Trigger mode (continuous, single, free-run)
- Trigger delay (wait time after trigger before measurement)
- Wait for trigger (wait for external trigger before fetching data)
- Fetch trace data (digitized trace from each channel)
- Gain (correction factor)

The power meter has an advanced feature of getting the power level data trace. The trace however can be fetched from the power meter only if the settings required to enable this feature has been set in a specific order. The power meter has to be in single trigger mode and the trace function has to be enabled. It should also be in wait for trigger mode so that it starts getting the trace as soon as it encounters the external trigger. If these settings are not set in this order, then the power meter throws *Settings Conflict* error.

This trace was used to perform two of the specification tests on an SSPA, namely over-pulse test and droop test. The data fetched from the power meter was fed into MATLAB to verify the results for these specification tests. The plot shown in Figure 22 was used to verify the output pulse limiting capability of the SSPA (within 2.5ms) for any input pulse greater than the normal pulse width (2ms).

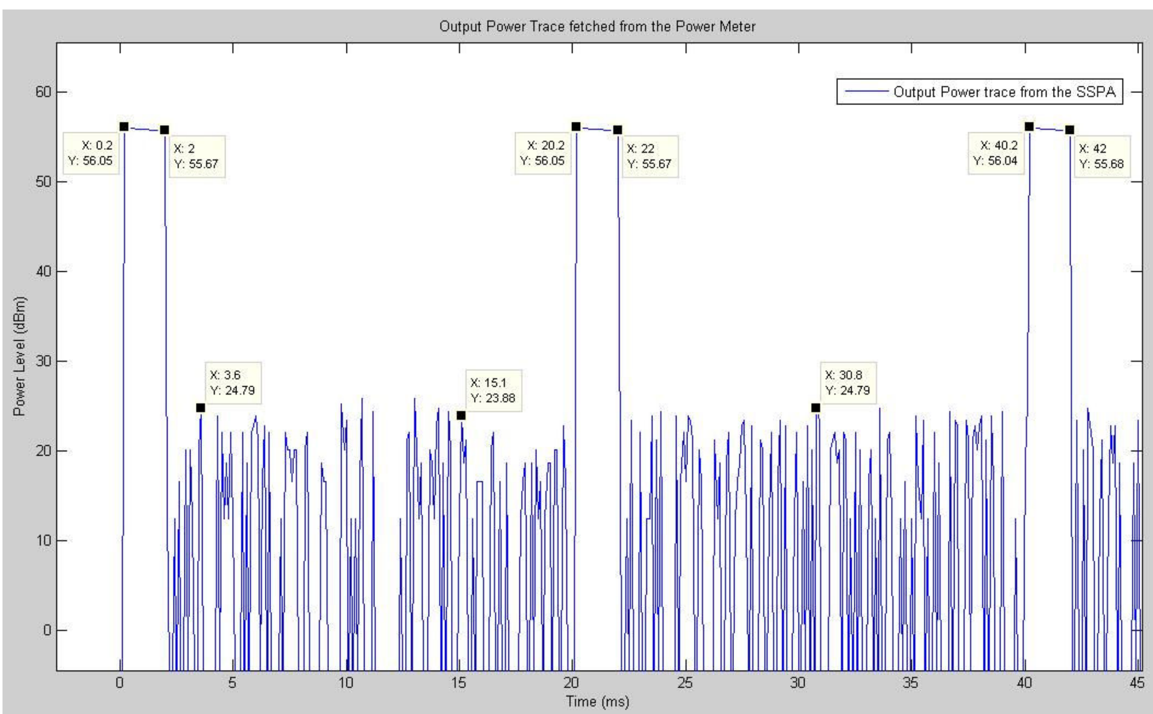

Figure 22. Plot of Output Power Trace (dBm) vs. Time (ms)

The power meter is capable of taking in a value as desired trace length (in seconds) and auto-adjust the resolution of the trace that is returned. Fetching the trace from the power meter with trace length setting of little over 2ms increases the resolution of the output power measurement over a single pulse and hence can be used to calculate the power droop in terms of microseconds inside the pulse as shown in Figure 23.

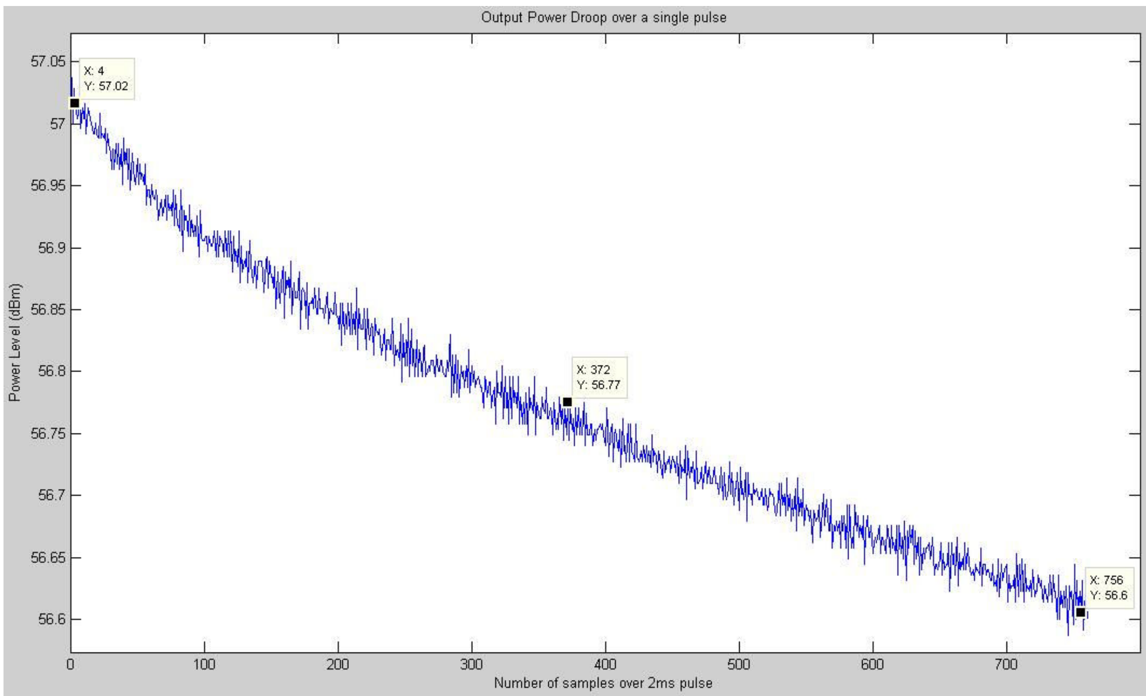

Figure 23. Plot of Output Power vs. number of samples over 2ms pulse

(d) Controller *(Controller.py)*

The Controller class module is the python module that uses the shared library compiled in C to establish communication between the data acquisition card and various other devices of the ATS. This module interfaces with the control circuitry of the SSPA, the load switch, and the pulse modulator, and acquires data from the I/Q detector circuit for phase measurements.

The data acquisition module written in C (DAQ.c) uses the National Instruments' NIDAQmx C library. The library implements all the digital inputs and outputs as well as the analog inputs in seven distinct phases:

- Create a task and channels and declare them as digital or analog
- Add created channels to the task
- Configure clock to be used for the task
- Define trigger source if needed
- Start the task
- Perform digital read, digital write or analog read
- Stop the task

The concept of *tasks* is verbose in the National Instruments' library. Assigning *channels* to a specific task makes it possible to reserve those particular channels and the resources that have been assigned with the task when the task is started. Each task can be run using different clock signals present internally in the DAQ. The base clock is a 20MHz oscillator and all other clocks are derivatives of this clock. Each *task* can also be configured to await trigger signal, either analog or digital, on one of the Programmable Function Interface (PFI) ports. The functions that fetch the data from the I/Q detector (triggered by the RF pulse modulation signal) and the function that generate the RF pulse modulation signal (triggered by the TR gating signal) use this feature. After setting the configuration of the *task* it can be started and digital read/write or analog read can be performed. Finally, it is very necessary to stop the task and release the handle of the resources that were used, or else any subsequent calls would fail as it would not be able to allocate the resource. Although the DAQ retains the output values on the digital output ports, it has a limitation on the timers due to which it cannot retain the gating and the pulse modulation signals. As an exceptional case, the 10% duty-cycle timing functionality is implemented by defining *task* as static. The *task* is not stopped and cleared at the end of the function, but at the beginning of the next function call. This way the handle to the resource can be tracked as well as the timers are freely running.

The load switch, which is used to switch between five different loads during different phases of calibration and production test, is controlled digitally using the digital outputs from the data acquisition card. Five digital output lines go into the SSPA's control circuit to enable switch between different pots as well as to increase and decrease the pot settings. Two digital lines are fed into the digital inputs of the DAQ to sense the VSWR mismatch alarm and the over-temperature alarm given out by the SSPA.

The DAQ is configured to acquire data from the I/Q detector triggered by the RF pulse modulations signal. The I/Q detector uses 1V as its reference voltage and outputs differential voltages for both in-phase component and quadrature-phase componentsl hence the outputs are at an offset of roughly ±1V. The data received from the I/Q detector as read by the data-acquisition card has been presented as a plot below in Figure 24.

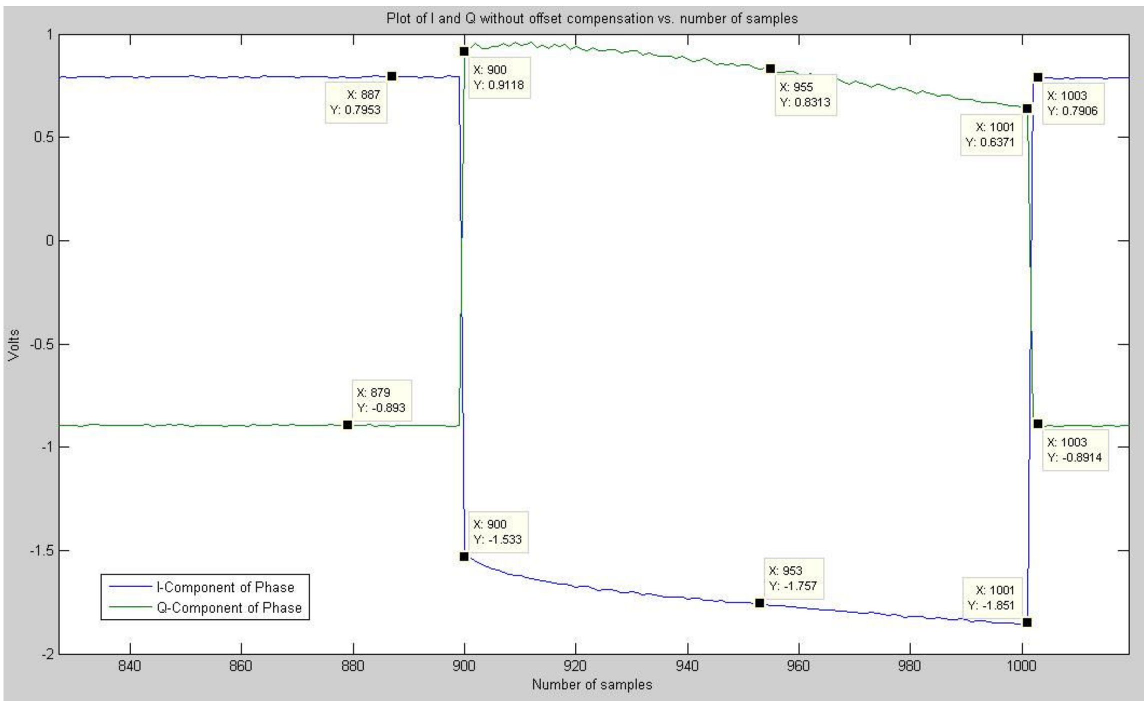

Figure 24. Plot of in-phase and quadrature-phase components of the phase of the RF output signal

As the outputs from the I/Q detector are at an offset, there was the need to acquire data from the RF pulse modulation signal as well. This pulse modulation signal is used as the reference for calculating the bias of individual signals as the pulse modulation signal is just a TTL signal which has two states—low around 0V and high around 5V. The data after filtering out the offset is represented in Figure 25.

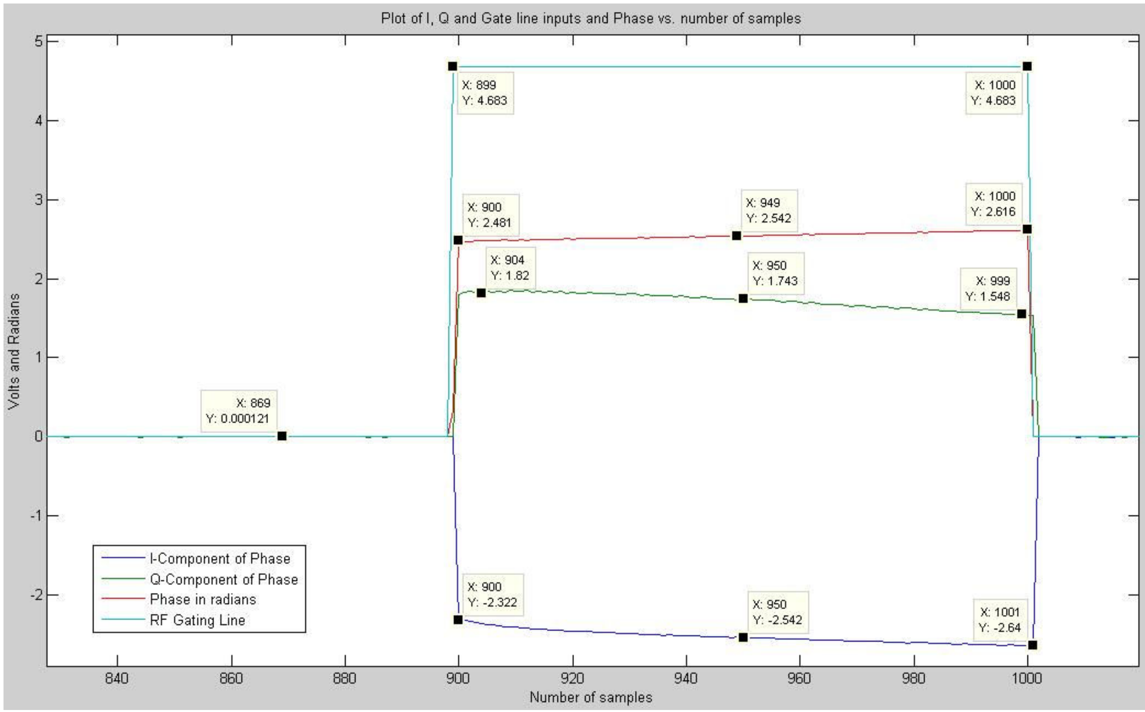

Figure 25. Plot of in-phase, quadrature-phase, pulse modulation signal and phase in radians

(e) TempSensor *(TempSensor.py)*

The TempSensor class module rather than controlling the temperature sensor reads the current temperature as outputted by the built in HTTP server within itself. The temperature sensor is capable of reading 4 thermocouples at a time; for the ATS only one is used. The module reads the data as html strings and parses the html string to read the correct data. The temperatures are read in degree Fahrenheit.

6.3.5. Flow Control

The flow control or process control manages the entry point, exit point(s) and sequential flow between processes. A software package typically has a single entry point and effectively should have one exit point with proper implementation. The entry point into the software execution is generally termed as the *main routine*. The main routine controls the flow of the overall software and makes calls to other supporting procedures by transferring control. While the subordinate procedure does some tasks, the main control waits until it gets the control back. The idea of flow control for any software is self explanatory if presented as a flow diagram or flow chart. The next five flow diagrams represent the core of ATS's software architecture—the first one is the main procedure and the next four implement specific tasks that the ATS has been designed to handle.

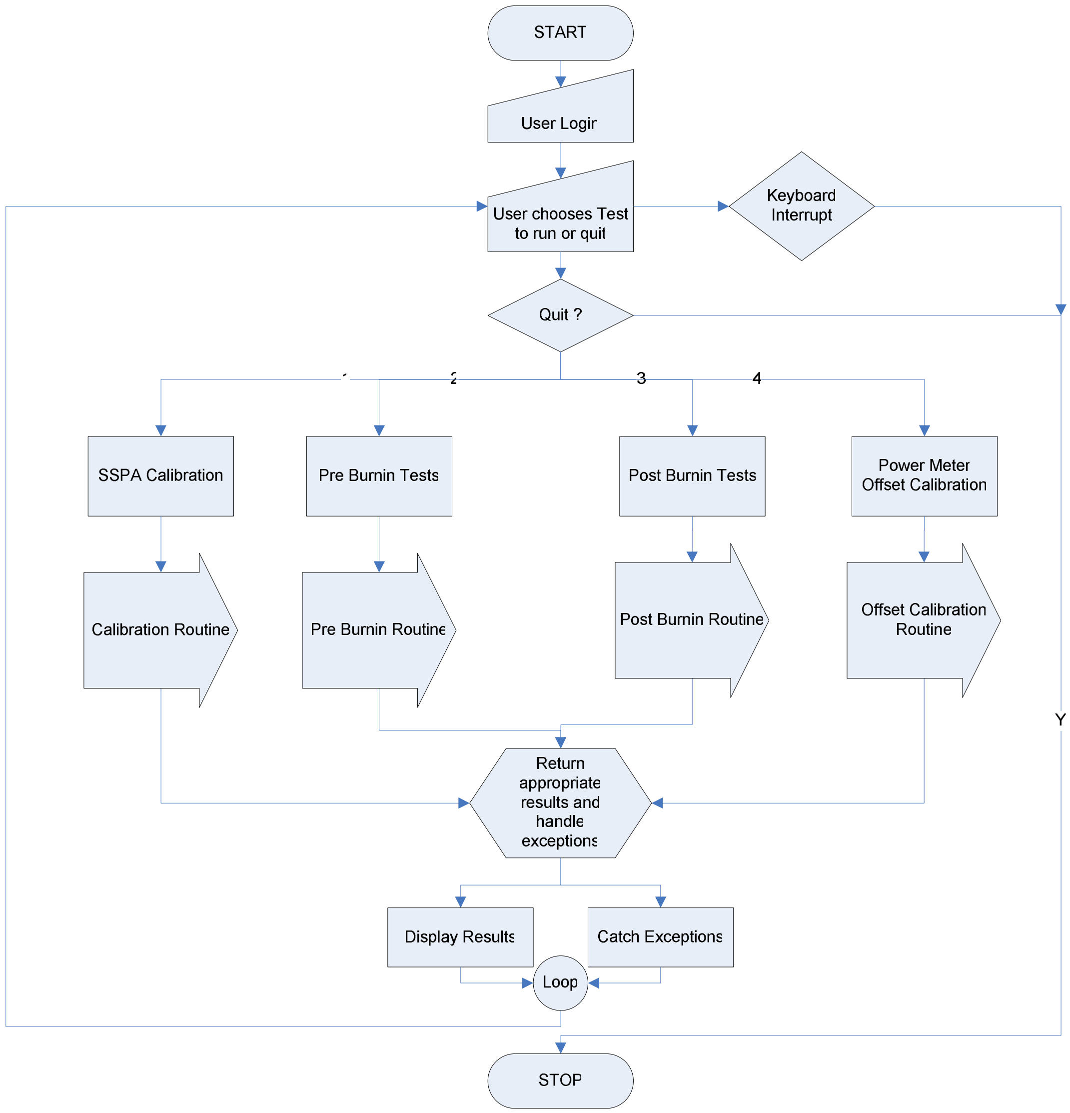

Figure 26. Main Program Flow

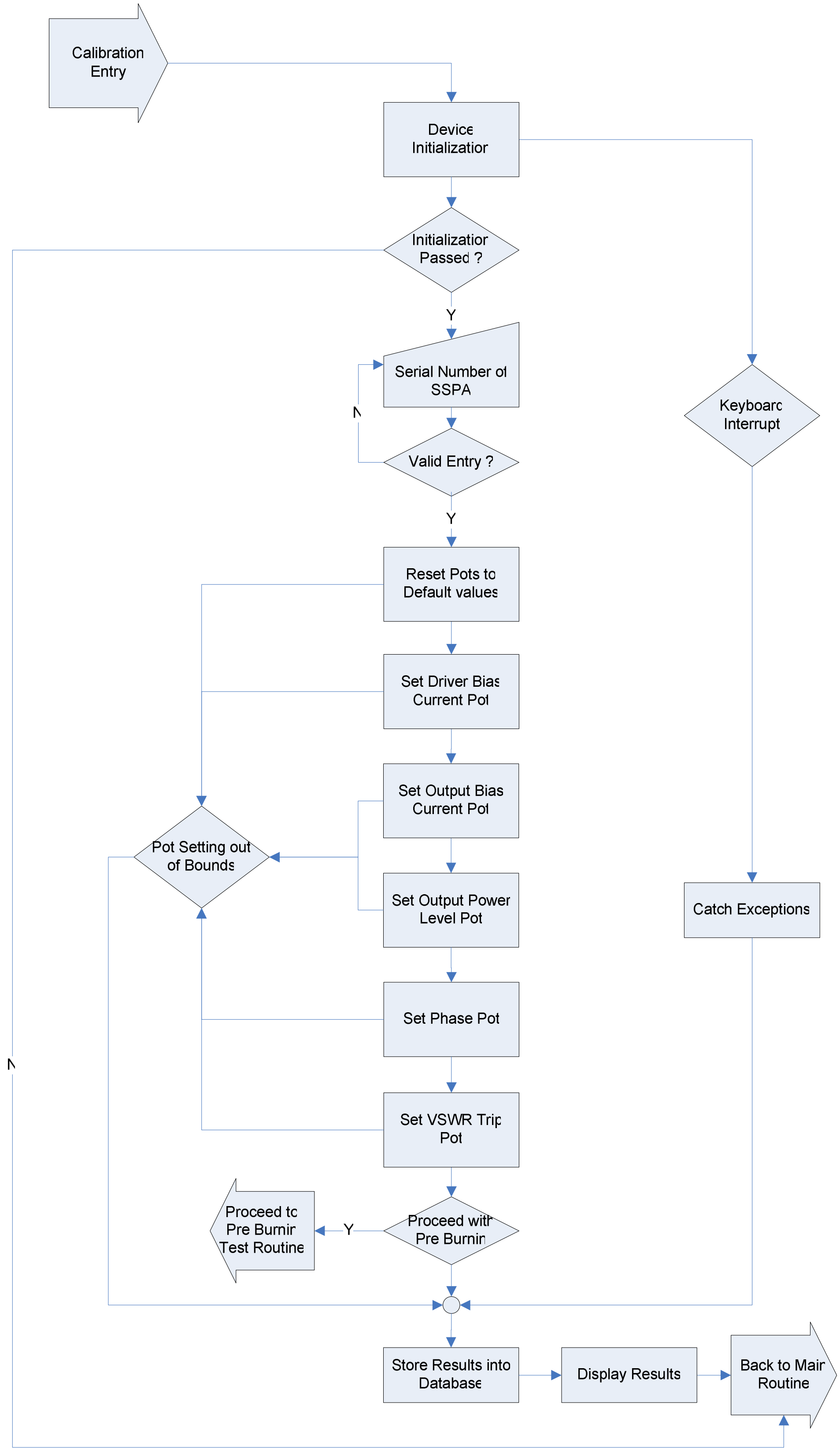

Figure 27: Calibration Process Flow

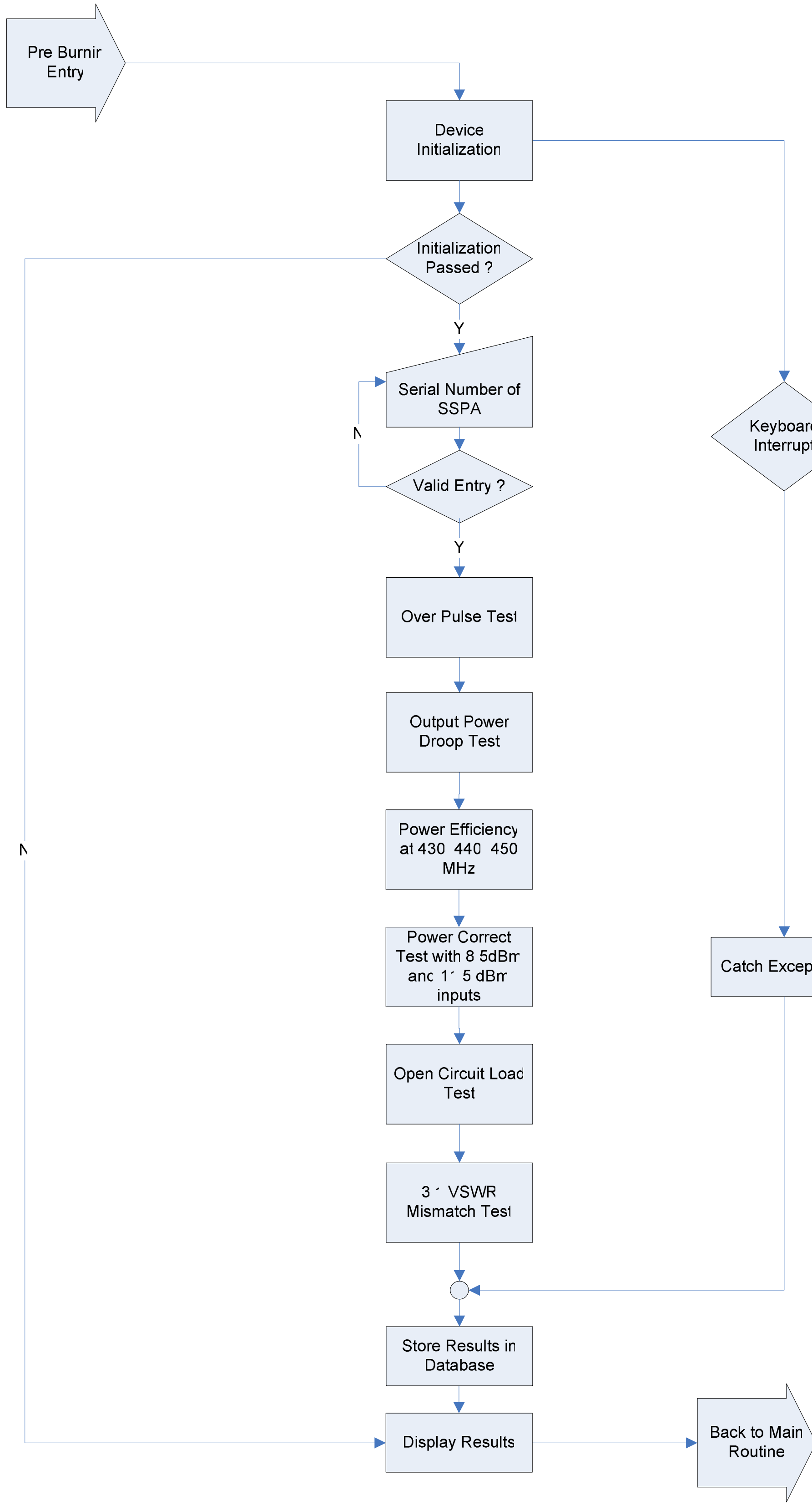

Figure 28: Pre Burn-in Process Flow

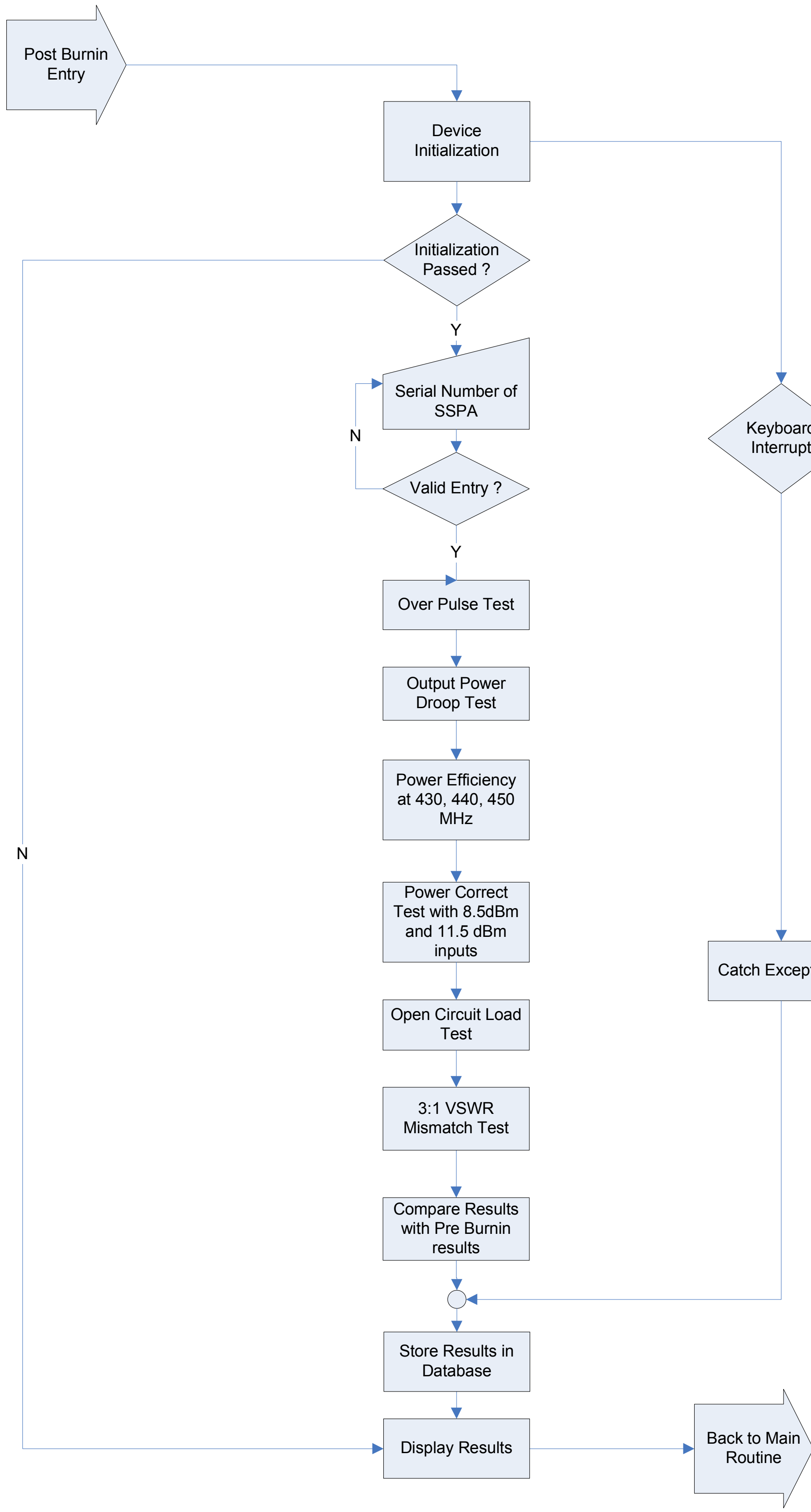

Figure 29: Post Burn-in Process Flow

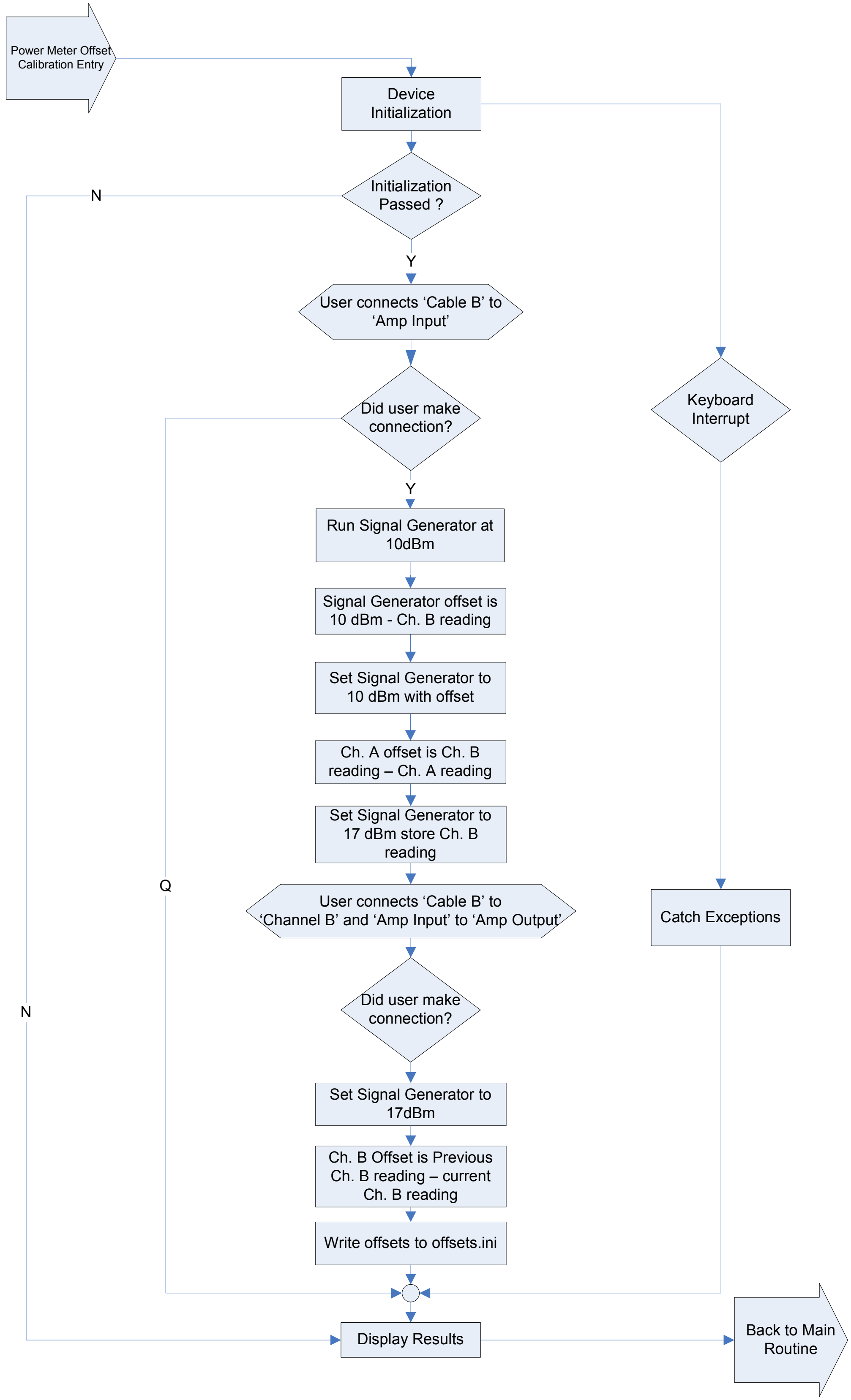

Figure 30: Power Meter Offset Calibration Flow

6.3.6. User Interface

The ATS software is accessible to the user via a terminal based user interface to perform calibration and run various tests on an SSPA. The user interface provides the user with options as main menu where the user just enters the number corresponding to the process to be executed. A screen shot of the terminal based user interface is shown in Figure 31.

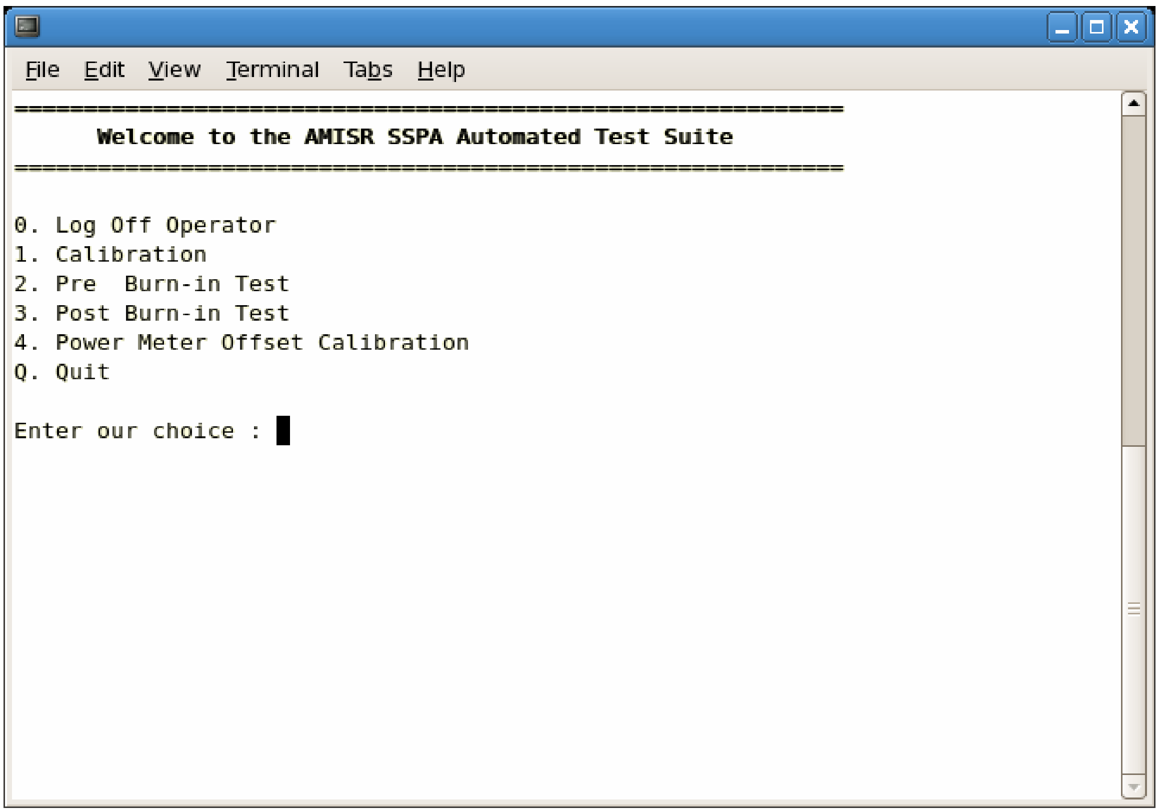

Figure 31: Terminal based User Interface

The power supply, the signal generator and the power meter all had manual controls on the instruments themselves, however, to carry out manual tests having control over these three devices alone is not sufficient; having the control over the TR gating line, RF gating line and to be able to manually switch between various loads is equally important. The Graphical User Interface allows the user to control the gating lines and load switch manually.

The GUI implemented using Python and Tkinter, which is a thin object-oriented layer on top of Tcl/Tk. Tcl (Tool Command Language), is a powerful dynamic programming language suitable for a very wide range of uses, including desktop applications, networking, testing, etc. It is also an open source language that is cross platform compatible. Tk, on the other hand, is a graphical user interface toolkit that is used for developing desktop applications. Tk is the standard GUI for Tcl which can produce rich, native applications that run unchanged across different platforms like Windows, Mac OS X, Linux and many more.

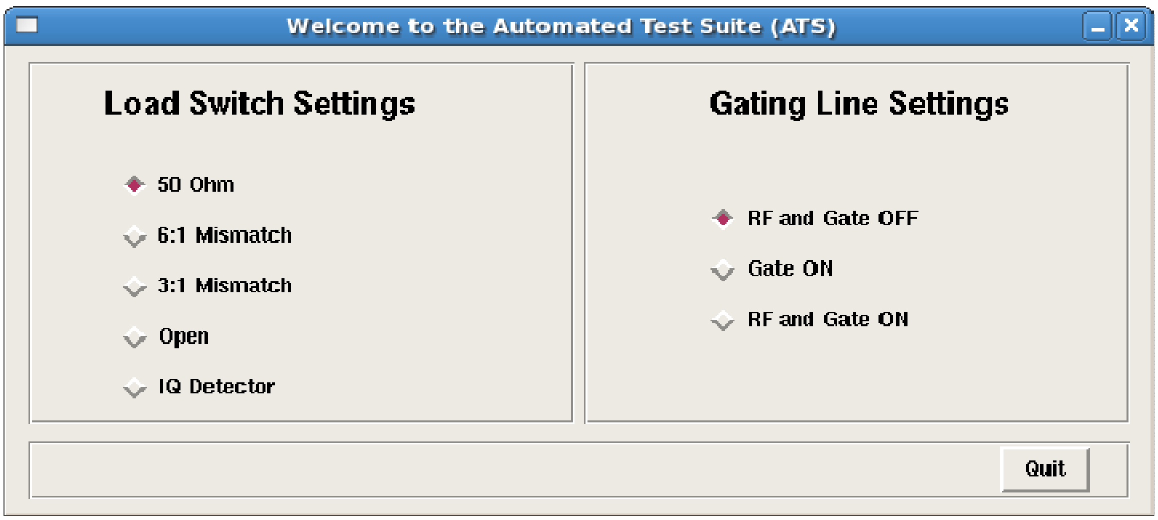

Figure 32. Screenshot of the Manual Controls GUI

6.3.7. Exceptions and Error Handling

High-quality software ensures that the application does not crash due to the actions of the user. It is also appropriate to display useful messages in case the software is able to trap expected errors and exceptions. A program does not need to terminate in the event of errors or exceptions; instead the system can revert back to its default conditions. There are many places during the calibration and testing phases where exceptions can be expected and therefore need to be handled. Typical examples include during initialization of the devices. If the technician forgets to turn on the power supply or the ethernet connection in the back of the signal generator is disconnected, the program should provide warnings and possible solutions to fix the error and then be able to continue from the same spot after the error has been fixed. In order to incorporate such expected cases, a class that extended Python's base Exception class was written implementing a set of custom errors and exceptions. The list of expected and handled exceptions and errors supported by the ATS are listed below.

- *device_error_PowerSupply* : Cannot establish connection to the Power Supply
- *device_error_PowerMeter* : Cannot establish connection to the Power Meter
- *device_error_DAQCard* : Cannot establish connection to the DAQ
- *device_error_SignalGen* : Cannot establish connection to the Signal Generator
- *device_error_SSPA_Power* : Cannot establish connection to the SSPA
- *calib_initialCurrFailed* : Initial current above 0.5A during Calibration
- *calib_gatePulseFailed* : Current is above 0.5A with only gate pulse
- *calib_normalCurrFailed* : Current is below 3A or above 5A
- *calib_driverCurrFailed* : Current out of bounds while setting Driver Bias
- *calib_outputCurrFailed* : Current out of bounds while setting Output Bias
- *calib_outputPowerFailed* : Power out of bounds while setting Address 4
- *calib_phaseFailed* : Phase out of bounds while setting Address 5
- *calib_vswrFailed* : VSWR out of bounds while setting Address 6
- *calib_offsetCalibfailed* : Power Meter Offset Calibration failed
- *offsets_ini_not_found* : Offsets.init not found
- *process_abort_calib* : Abort Calibration Process
- *process_abort_offsetcalib* : Abort Offset Calibration Process
- *process_failed_offsetcalib* : Offset Calibration

6.3.8. Database Programming and Data Storage

The project consists of five distinct test phases; hence the simplest database schema would be to use a table for each type of test to be performed. This separates the recorded measurements of one test from another, avoiding complications and the need to write complex queries. Since the database consists of simple tables, independent of one another, the concept of foreign key was never implemented because no complex relations between tables exist. The database consists of eight separate tables that are unique to the different tests conducted. These tables are listed below. Their respective table names are shown in parenthesis and the data that is stored in each table is listed below each table name.

- Calibration Data (calibration)
    - Serial Number *(sn)*
    - Date & Time *(dt)*
    - Username (uname)
    - Initial Current *(initcurrent)*
    - Current w/ TR only *(trcurrent)*
    - Pot 1 Setting *(pot1_set)*
    - Driver Bias Current *(curr1)*
    - Pot 2 Setting *(pot2_set)*
    - Output Bias Current *(curr2)*
    - Current w/ TR & RF *(trrfcurr)*
    - Initial Power *(initpower)*
    - Pot 4 Setting *(pot4_set)*
    - Final Power *(power4)*
    - Output Current *(curr4)*
    - Initial Phase *(initphase)*
    - Pot 5 Setting *(pot5_settings)*
    - Phase *(phase)*
    - Phase Values *(phase_values)*
    - Pot 6 Setting *(pot6_set)*
    - Calibration Passed? *(passed)*
    - Test Failure Code *(test_fail_code)*

- Pre Burn-in *(preburnin)*
    - Serial Number (sn)
    - Date & Time (dt)
    - Username (uname)
    - Pulse Width (pulsewidth)
    - Overpulse Passed? (overpulse_passed)
    - Initial Droop Power (droop_initpower)
    - Final Droop Power (droop_finalpower)
    - Droop Passed? (droop_passed)
    - Current at 430MHz (current_430)
    - Current at 440MHz (current_440)
    - Current at 450MHz (current_450)
    - Voltage at 430MHz (voltage_430)
    - Voltage at 440MHz (voltage_440)
    - Voltage at 450MHz (voltage_450)
    - Power at 430MHz (power_430)
    - Power at 440MHz (power_440)
    - Power at 450MHz (power_450)
    - Power w/ 8.5dbm input (power_8_5)
    - Power w/ 11.5dbm input (power_11_5)
    - Input Variation Passed? (powercorrect_passed)
    - Open Load Passed? (open_passed)

- Mismatch Load Passed? (mismatch_passed)
- Test Passed? (Test_passed)
- Test Failure Code (fail_reason)

- DVT: Qualification *(dvt_qualification)*
  - Same data types as Pre Burn-in

- DVT: Pre-test Benchmark *(dvt_pretest_benchmark)*
  - Same data types as Pre Burn-in

- DVT: Post-test Benchmark *(dvt_posttest_benchmark)*
  - Same data types as Pre Burn-in

- DVT: Operational Test *(operational)*
  - Serial Number (sn)
  - Date & Time (dt)
  - Username (uname)
  - User Entered Label (label)
  - Current (current)
  - Input Power (power_in0)
  - Output Power (power_out)
  - Minutes Elapsed (mins)
  - Temperature (temp)
  - Temperature Flag (tempflag)
  - VSWR Flag (vswrflag)

- Offset Calibration *(offset_calibration*
  - Serial Number (sn)
  - Date & Time (dt)
  - Username (uname)
  - Pulse Width (pulsewidth)
  - Overpulse Passed? (overpulse_passed)
  - Initial Droop Power (droop_initpower)
  - Final Droop Power (droop_finalpower)
  - Droop Passed? (droop_passed)
  - Current at 430MHz (current_430)
  - Current at 440MHz (current_440)
  - Current at 450MHz (current_450)
  - Voltage at 430MHz (voltage_430)
  - Voltage at 440MHz (voltage_440)
  - Voltage at 450MHz (voltage_450)
  - Power at 430MHz (power_430)
  - Power at 440MHz (power_440)
  - Power at 450MHz (power_450)

o	Power w/ 8.5dbm input	(power_8_5)
o	Power w/ 11.5dbm input	(power_11_5)
o	Input Variation Passed?	(powercorrect_passed)
o	Open Load Passed?	(open_passed)
o	Mismatch Load Passed?	(mismatch_passed)
o	Test Passed?	(Test_passed)
o	Test Failure Code	(fail_reason)

Database Adapter and Data Access Layer

Psycopg2 is a PostgreSQL database adapter for the Python programming language. It is the second version of the adapter which is a complete rewrite of the original code to provide new style classes for connection and cursor objects and some other additional features. Similar to the original psycopg, psycopg2 was written with the aim of being small, fast, and stable.

Psycopg is different from other database adapters as it is designed for heavily multi-threaded applications that create and destroy lots of cursors and make a conspicuous number of concurrent INSERTs or UPDATEs. The sole reason behind using psycopg over any other adapters like PygreSQL or PyPgSQL is because the adapter is very intuitive and a lot of support is available online.

7. Twenty-Four Hour Burn-In System

Burn-in is meant to test a production unit's capability to run under load for an extended amount of time. The concept of burn-in is that you can reduce the probability of a unit being defective in the field by running each production unit while monitoring for malfunctions and errors. An additional benefit to burn-in testing is that it gives the manufacturer more data that can used to judge the quality of production.

7.1. System Requirement

The SSPA's burn-in system must be capable of running ninety-six amplifiers for twenty-four consecutive hours. The amplifier must run at a frequency between 430MHz and 450MHz at ten percent duty cycle. During the burn-in, the VSWR alarm and over-temperature alarm status must be monitored. If an alarm trips during the burn-in test, then the unit fails the burn-in test and the system should alert a technician.

7.2. System Design

The burn-in system needs to be able to run the amplifier under load and monitor the alarm outputs. Each unit will have its own power supply and load because each amplifier produces more than 500W of peak power and draws almost five amps of current. It was decided that there would be one RF signal source and one transmit/receive signal source for all ninety-six amplifiers. One pulse generator will be used and the signals will be split to all amplifiers to minimize costs. The pulse generator must be capable of producing a synchronized transmit/receive signal and RF modulation signal. Because each of the amplifiers has two alarm signals that need to be monitored and the transmit/receive signal needs to be split to each amplifier, it was decided that a distribution circuit would be designed. The distribution circuit needs to latch to the alarm signals from the SSPAs, alert the operator when a unit has been on for twenty-four hours, and split the transmit/receive signal to all SSPAs. We chose to have only sixteen SSPAs connect to each distribution circuit for simplicity.

7.3. *Power Supplies*

Each SSPA will have its own power supply. We will be using Mean Well 27V power supplies. The SSPAs require 32V, so the power supplies will be adjusted up to that voltage level.

7.4. *Loads*

Each SSPA will be producing five-hundred watts peak and needs to have that energy dissipated in a matched load. We chose the MFJ model 264 and ran it at sixty degrees Celsius for twelve hours to make sure that its load characteristics would not change when used in a warm environment for long periods.

7.5. *Signal Sources*

The two signals that are required to operate an SSPA are the transmit/receive signal and the RF signal. The RF signal is a pulse-modulated 10dBm continuous wave. The pulses of RF must be within the pulses of the transmit/receive signal. This signal enables the amplification stage and must be enabled during RF in order to properly operate the SSPA. The RF signal is going to be generated using a phase-locked oscillator (PLO) at 449 MHz. The PLO requires a 10MHz reference that can be provided by the internal trigger of the Stanford Research Systems DG535 pulse generator chosen to create the transmit/receive signal and the pulse modulation signal.

The DG535 is capable of creating the two pulses needed to properly time the burn-in system. To operate an SSPA properly, the transmit/receive pulse must exceed the RF input by at least one microsecond on both sides. The timing diagram can be found in Appendix C.

7.6. Signal Distribution System

Having only one signal source for ninety-six amplifiers means that there needs to be a distribution system that is capable of supplying the transmit/receive signal and 10dBm of RF to each amplifier. For simplicity, it was decided that the signal splitting would be done in two stages.

The first stage of distribution amplifies the RF signal to compensate for power losses due to splitting. This ensures that 10dBm will be present at the input of each SSPA during the burn-in test. The splitter at this stage is an eight-way power splitter with ten decibels of loss. Also in the first distribution stage is an eight-way buffer that is used to split the transmit/receive signal eight ways.

The second stage of the distribution system splits each of the output signals from stage one sixteen ways. The RF will be split using a two-way splitter going to two eight-way splitters. We're using two eight-way splitters instead of a sixteen-way splitter because SRI already has six dual eight-way splitters that were designed and manufactured for the AMISR panels available. Altogether, the loss due to stage two is fourteen decibels.

This stage of the distribution system is also to be used for providing information to the technician running the burn-in tests. There are three indicators for each of the sixteen amplifiers. One indicator shows the status of the VSWR alarm, one shows the status of the over-temperature alarm, and the third shows whether the amplifier has been running in the system for twenty-four hours.

The VSWR and over-temp indicators work identically. The alarm signal goes through an inverter and clocks a flip-flop whose input is tied high. The outputs of the flip-flop drive transistors that in turn drive the bi-color LEDs. The twenty-four hour indicator uses the transmit/receive signal as a time-base to increment a counter. When the counter reaches count 72,000, it clocks another flip-flop that is tied high. This flip-flop controls the bi-color LED in the same manner as before, by driving transistors.

The alarm and time indicators need circuitry so that they can be reset when the technician inserts a new SSPA to test. Instead of requiring the technician to press a reset button for each amplifier he or she turns on, the reset circuitry will be activated by the thirty-two volt supply voltage to the amplifier. The reset circuitry uses a comparator to determine when the voltage supply exceeds twenty-eight volts. The comparator's output is connected to two flip-flops in series that are used with an AND gate to generate a pulse on the rising edge of the comparator's signal. The output of the AND gate is connected to the reset inputs of all the indicators' flip-flops. The benefit of the reset circuitry is to avoid the possibility of the technician forgetting to reset the indicators when testing the units.

8. Results

This section provides a sample of the data that the ATS will collect for each amplifier. Table 9 is a sample of the calibration data that is collected for each SSPA that is calibrated using the ATS. The actual database returns more data for each amplifier than shown below. As shown below, in Tables 9 and 10, an engineer can easily analyze this data and monitor manufacturing trends. The data shown below were collected by running query on the custom views that were created within the database. The views enable the user to view the data in a more readable and customized manner.

SN	Driver Bias Pot	Driver Current	Output Bias Pot	Output Current	Output Power Pot	Output Power	Phase Pot	Phase (rads)	VSWR Pot	Passed
5	74	0.303	77	0.505	69	57.216	75	1.670	24	YES
6	75	0.300	77	0.499	69	57.266	87	1.693	26	YES
7	73	0.295	68	0.501	54	57.209	57	1.745	64	YES
9	73	0.297	71	0.495	57	57.260	58	1.685	66	YES
10	35	0.297	45	0.496	100	56.964				NO

Table 10: Sample Calibration Data

SN	Init Power	Final Power	Droop (%)	PWR @ 430	Eff430 (%)	PWR @ 440	Eff440 (%)	PWR @ 450	Eff450 (%)	PWR 8.5dBm
5	57.135	56.61	11.39	57.72	39.32	57.18	39.32	57.35	39.32	57.13
6	57.294	56.794	10.87	57.90	40.4	57.38	40.4	57.67	40.4	57.27
7	57.29	56.777	11.15	57.51	41.89	57.27	41.89	57.30	41.89	57.26
9	57.269	56.703	12.23	57.38	37.62	57.28	37.62	57.57	37.62	57.25

Table 11: Sample Pre Burn-in Data

The unit that failed calibration during one of the runs (SN 10) as highlighted in Table 9 above, failed due to the power output from the amplifier being less than 57.0dBm after the pot was set to the maximum value of 100. Similarly, the unit that passed calibration during one of the runs, but failed pre burn-in test (SN 9) is highlighted in red in Table 10. The unit failed because the efficiency at all three measurement frequencies—430MHz, 440MHz and 450MHz—was below 38%.

9. Conclusion

Our primary goal was to design a system to be used during production testing of the Solid State Amplifiers (SSPA) used in the Advanced Modular Incoherent Scatter radar (AMISR) being built by SRI International. The system needed to be capable of calibrating each SSPA and conducting multiple tests including a twenty-four hour burn-in test. To accomplish these tasks, we designed two independent systems.

The first system was the Automated Test Suite (ATS) and will be used to calibrate the amplifiers as well as conduct a variety of specification tests. The system is fully operational and is ready to begin testing amplifiers once production begins. The system can also be easily modified to allow engineers to develop new tests in the future. We met all of our goals for this system, including the capability of calibrating and conducting a pre burn-in test in less than 5 minutes. The data collected during calibration and the other test phases is collected and stored in a database that allows it to be easily exported to excel. In the future SRI International will be able to design a custom interface that can be used to monitor the testing of amplifiers from a remote location. There was also a limited supply of amplifiers while we were designing the system. SRI International will need to test more amplifiers to determine the standard for amplifiers being calibrated and tested on the Automated Test Suite.

The second system in know as the Burn-in System. It will be used to conduct a twenty-four hour operational test. The test consists of running ninety-six amplifiers at a 10% duty for a twenty-four hour period. This portion of our project consisted of design a system that could use only one signal generator and a single source for the gate and RF pulse signals to operate ninety-six amplifiers. The system was designed in two stages. Currently the first stage has been completed and tested to verify it functions properly. The second stage has not been finished; the second revision of the distribution board we designed is currently being produced. Once the boards are returned and fully populated, SRI International will need to construct and wire the rack system that will be used to test ninety-six amplifiers.

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Appendix A

Appendix B

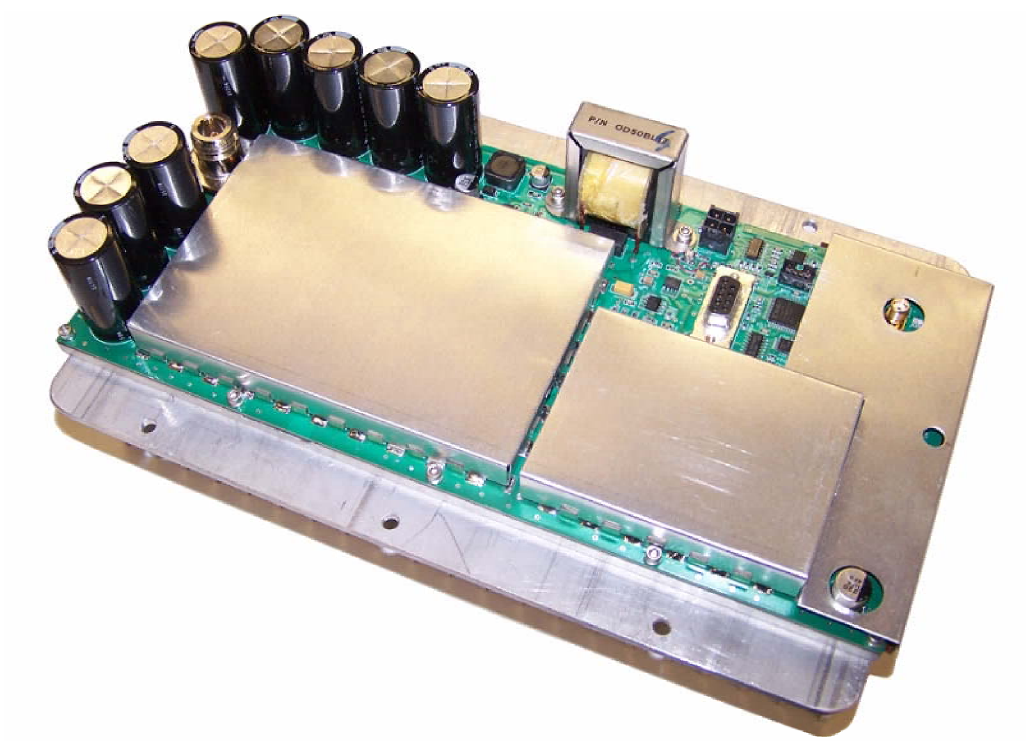
Appendix C

Appendix D

Appendix E

Appendix A

Automated Test Suite User's Guide



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John Scimone
Kaushal Shrestha

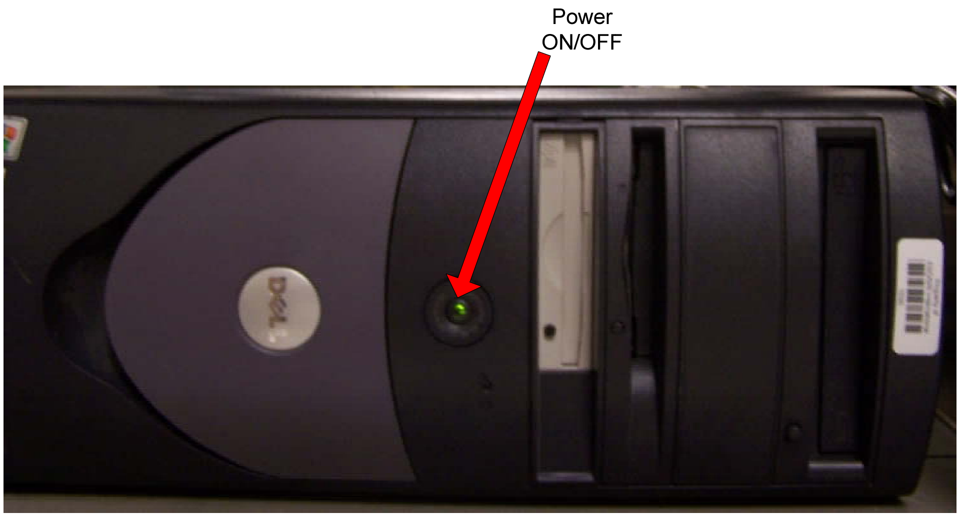
Date: February 26, 2007

Table of Contents

1. System Startup Instructions:

Step 1: Plug grey ATS power cord into electrical outlet.

Step 2: Turn computer on.



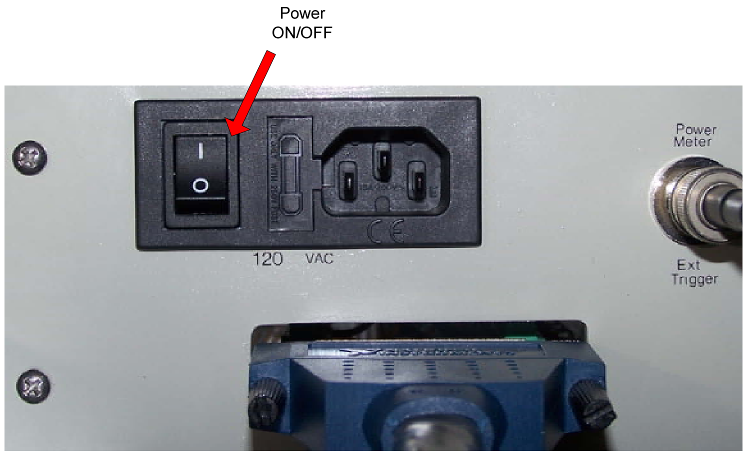
Step 3: Turn computer monitor on.

Step 4: Turn Signal Generator on.

Step 5: Turn Power Supply on.

Step 6: Turn Power Meter on.

Step 7: Turn Control Box on. (Switch located on the rear of box)



Step 8: Verify Power Supply output is OFF.

Step 9: Verify Signal Generator output is OFF.

SYSTEM STARTUP COMPLETE.

2. Using the ATS to test SSPA's.

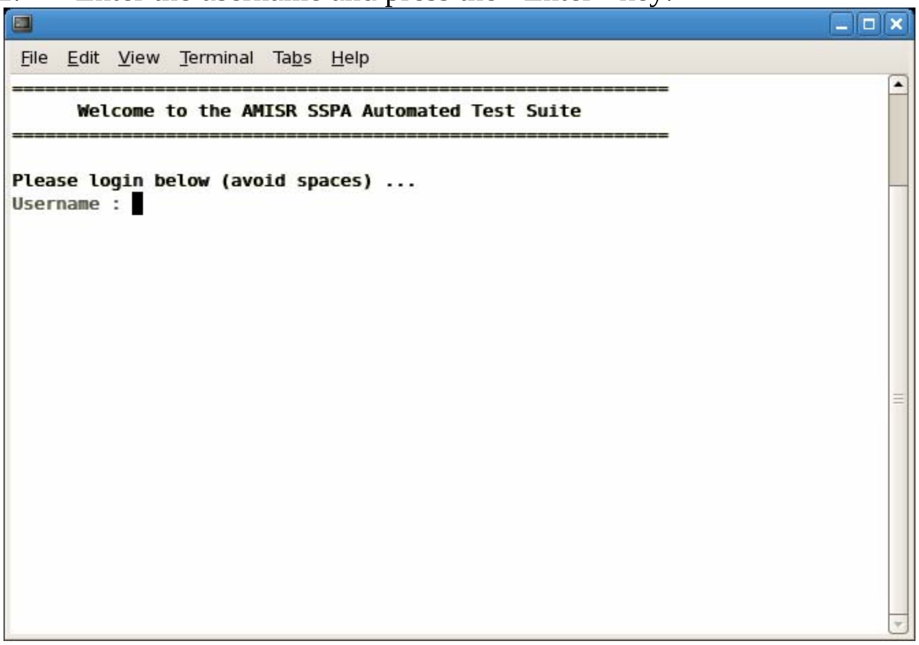
There are 3 test packages available on the ATS.

- Production Test Package
- Design Verification Test Package
- Manual Controls Package

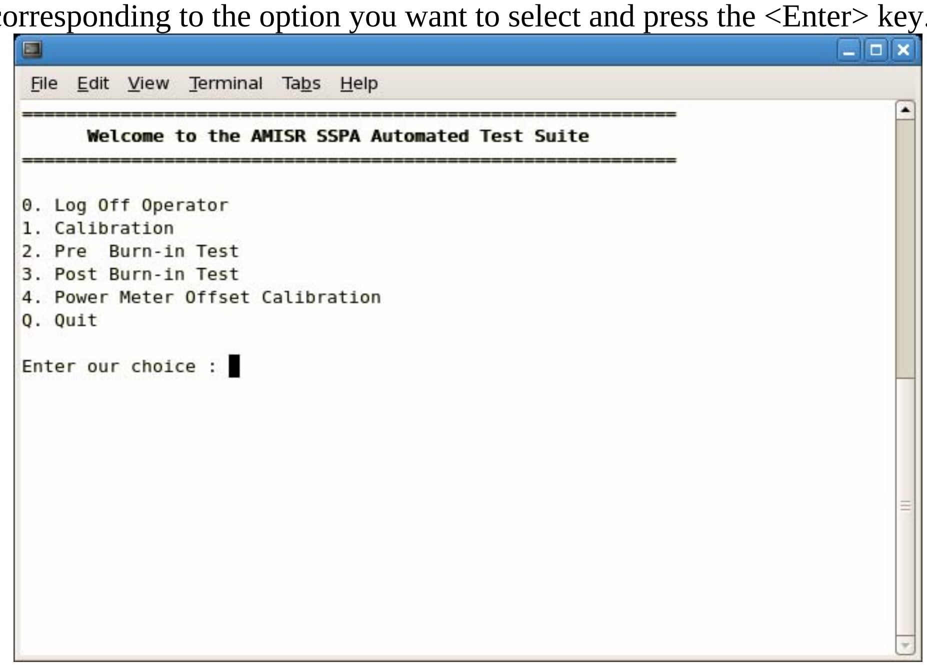
2.1. *Production Test Package*

Step 1: Select the desktop icon labeled “Production Test Package.”

Step 2: Enter the username and press the <Enter> key.



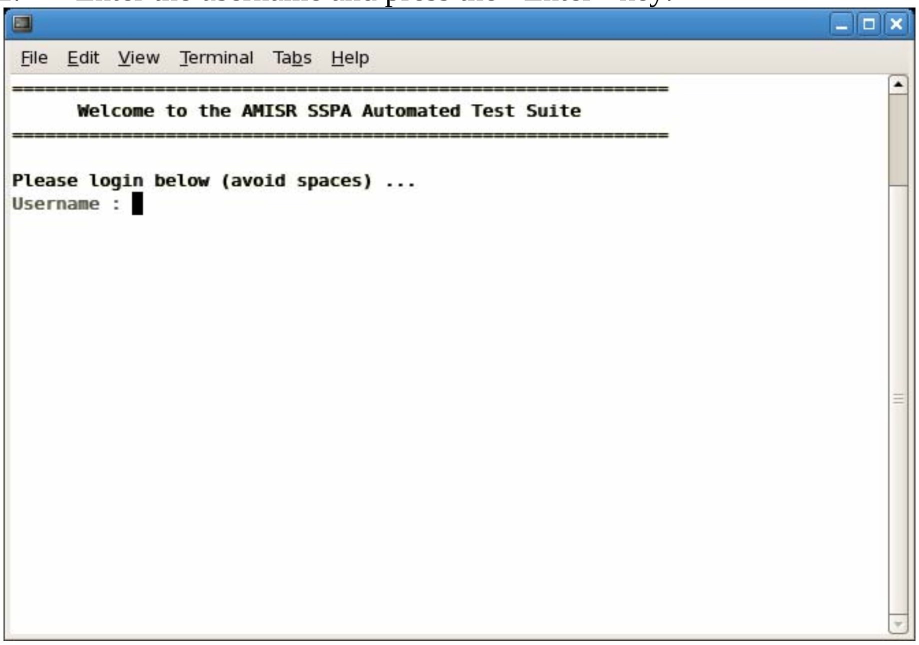
Step 3: To select an option for the main menu, press the number on the keyboard corresponding to the option you want to select and press the <Enter> key.



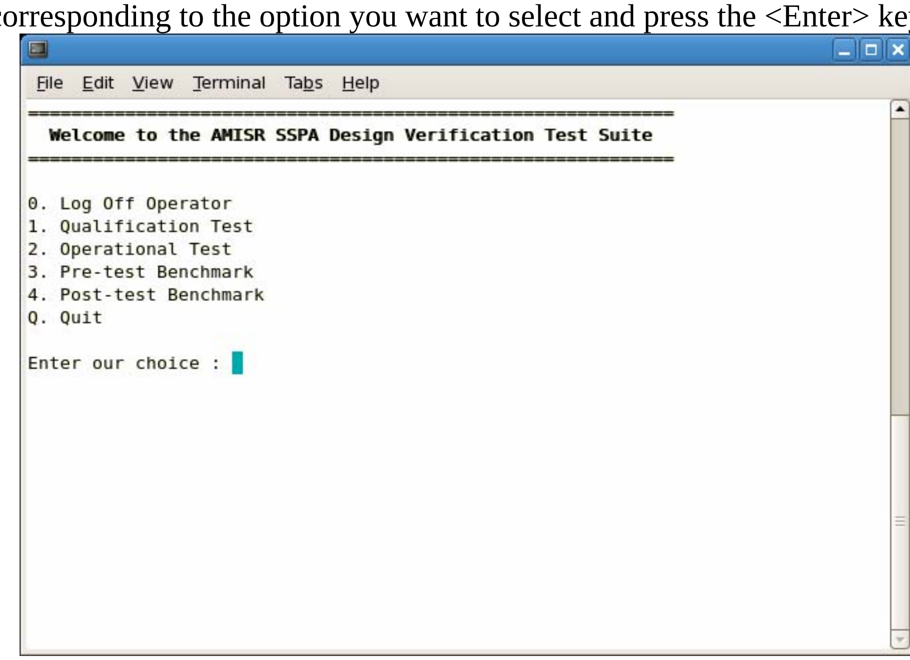
2.2. *Design Verification Test Package*

Step 1: Select the desktop icon labeled “Design Verification Test Package.”

Step 2: Enter the username and press the <Enter> key.



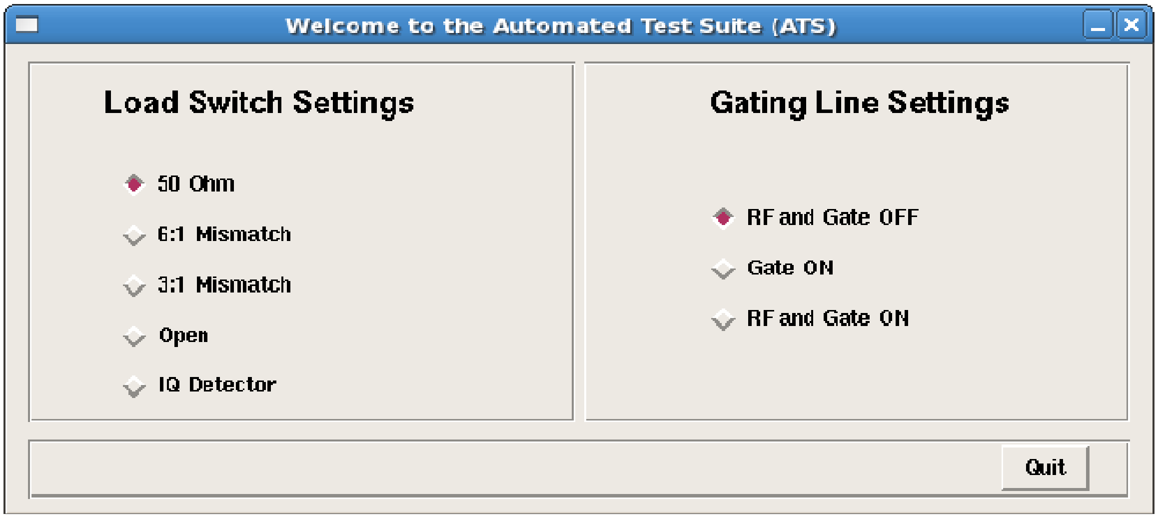
Step 3: To select an option for the main menu, press the number on the keyboard corresponding to the option you want to select and press the <Enter> key.



* If you select operational test, verify the SSPA is conducted and the environmental chamber is ready before starting the test

2.3. Manual Controls Package

Step 1: Select the desktop icon labeled "Manual Controls Package."
Step 2: Use load switch settings and timing card settings to conduct manual tests.



Appendix B

Control Box
Technical Guide

SRI International
Automated Test Suite

Authors:

Jeff Pelligrino
John Scimone
Kaushal Shrestha

Date: February 26, 2007

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1. Control Box Parts List

- Front Panel Connectors
  - N-type to N-type Bulkhead Adaptor (Amp Output).
  - SMA to SMA Bulkhead Adaptor (Amp Input).
  - DB9 Panel Mount Receptacle (Control I/O).
  - 4-Pin Panel Mount Receptacle (Amp DC Output).
  - SMA to N-type Bulkhead Adaptor (Power Meter Ch. A).
  - SMA to N-type Bulkhead Adaptor (Power Meter Ch. B).
  - 120V AC Input with built-in switch and fuse.

- Back Panel Connectors
  - 68-pin SCSI Panel Mount Receptacle (DAQ).
  - BNC to BNC Bulkhead Adaptor (Power Meter Ext. Trigger).
  - Agilent SP6T Load Switch.
  - SMA to N-type Bulkhead Adaptor (I/Q Detector Input).
  - N-type to N-type Bulkhead Adaptor (Load Switch Input).
  - N-type to SMA Bulkhead Adaptor (Signal Generator Input).
  - 2-pin Panel Mount Connector (Power Supply Input).

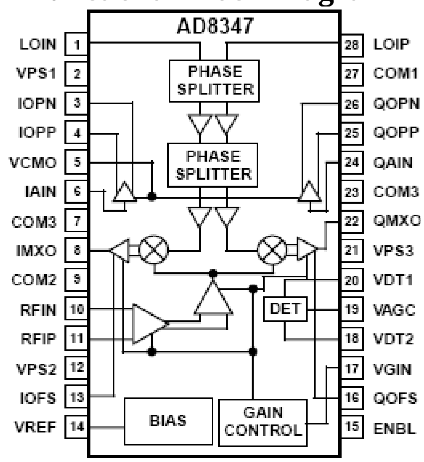
- Internal Components
  - I/Q Detector*
  - Output Coupler: 30dBm
  - Input Coupler 1: 20dBm
  - Input Coupler 2: 20dBm
  - Attenuator: 30dBm
  - DAQ Breakout Box
  - Load Switch TTL Connector
  - Paragrine Switch
  - Power Supply: 5V
  - Power Supply: 24V

* See Section 1.1 of this document for detailed information regarding the I/Q Detector

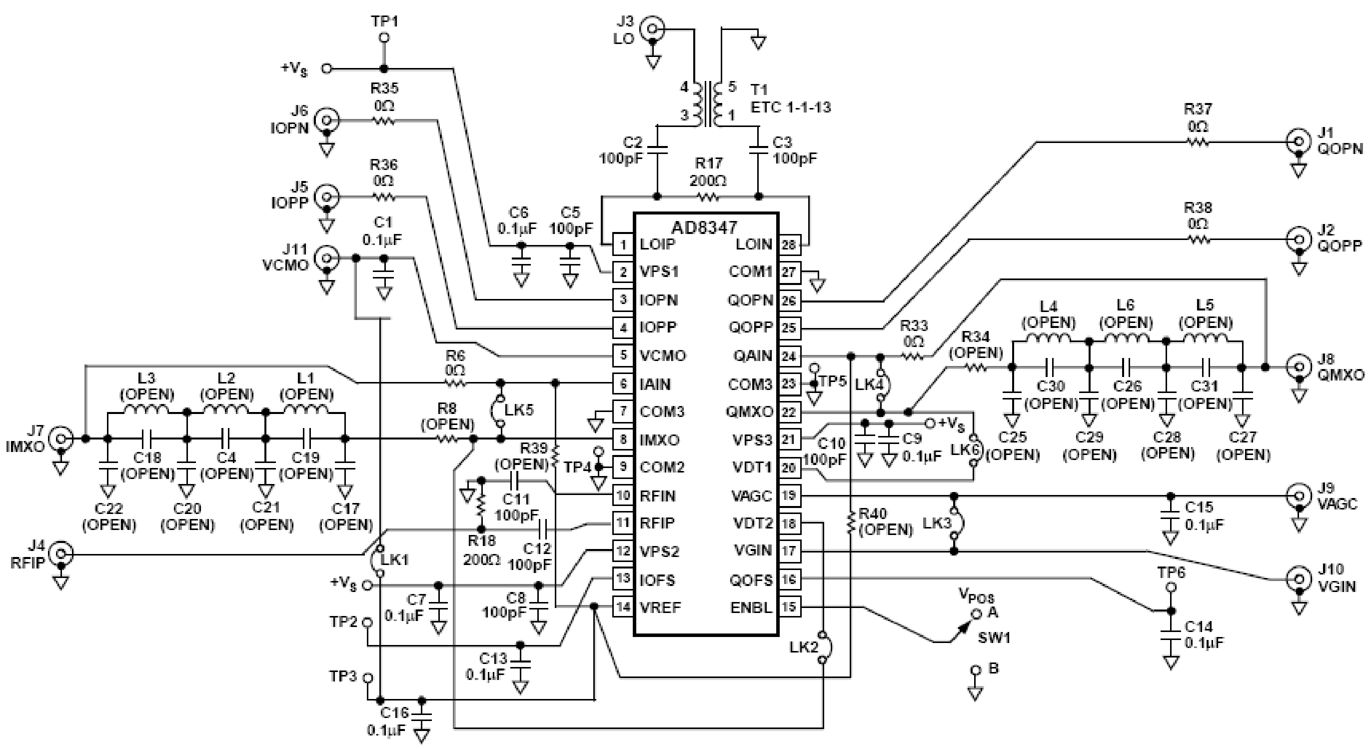
1.1. *I/Q Detector*

The I/Q detector consists of the AD8347 Direct Conversion Quadrature Demodulator chip implemented using its evaluation board. The functional block diagram for the AD8347 is shown below, followed by the evaluation board schematic.

Functional Block Diagram



Evaluation Board Schematic



The evaluation board allows a user to implement filters to in-phase and quadrature-phase signals. In this application low pass filters were implemented on the evaluation board. These filters are shown below.

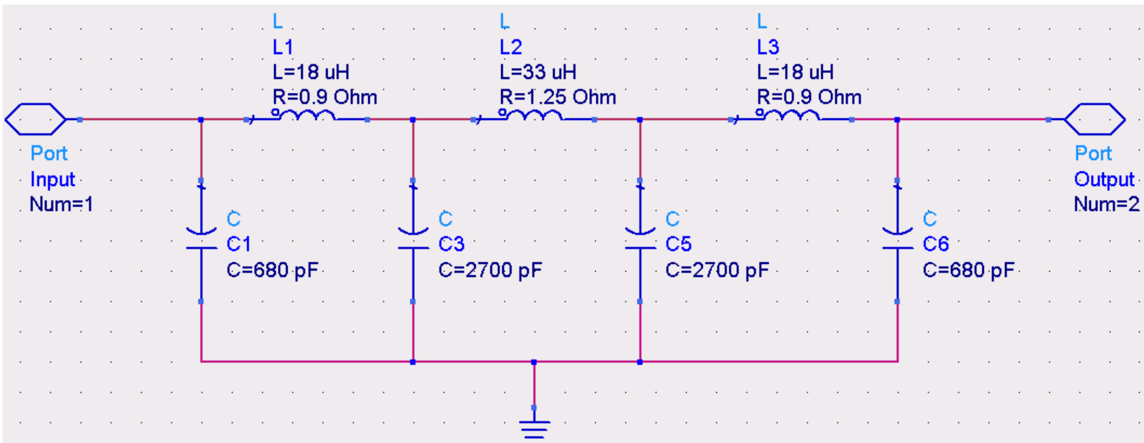


Figure 1: 7th order RF low pass filter

The evaluation board has pads that allow inductors and capacitors to be implemented easily, however, pads are placed in a configuration suitable only for a pi-network of inductors in series and capacitors in shunt. The filter was designed with the cut-off frequency of 1 MHz with Bessel approach to get the maximally flat phase response for the data acquisition card. The filter was designed on paper first and then the performance of the filter was simulated using Agilent's Advanced Design System (ADS). The values chosen for the inductors and the capacitors are standard values taken off Digi-Key's catalog. The simulation results are show below.

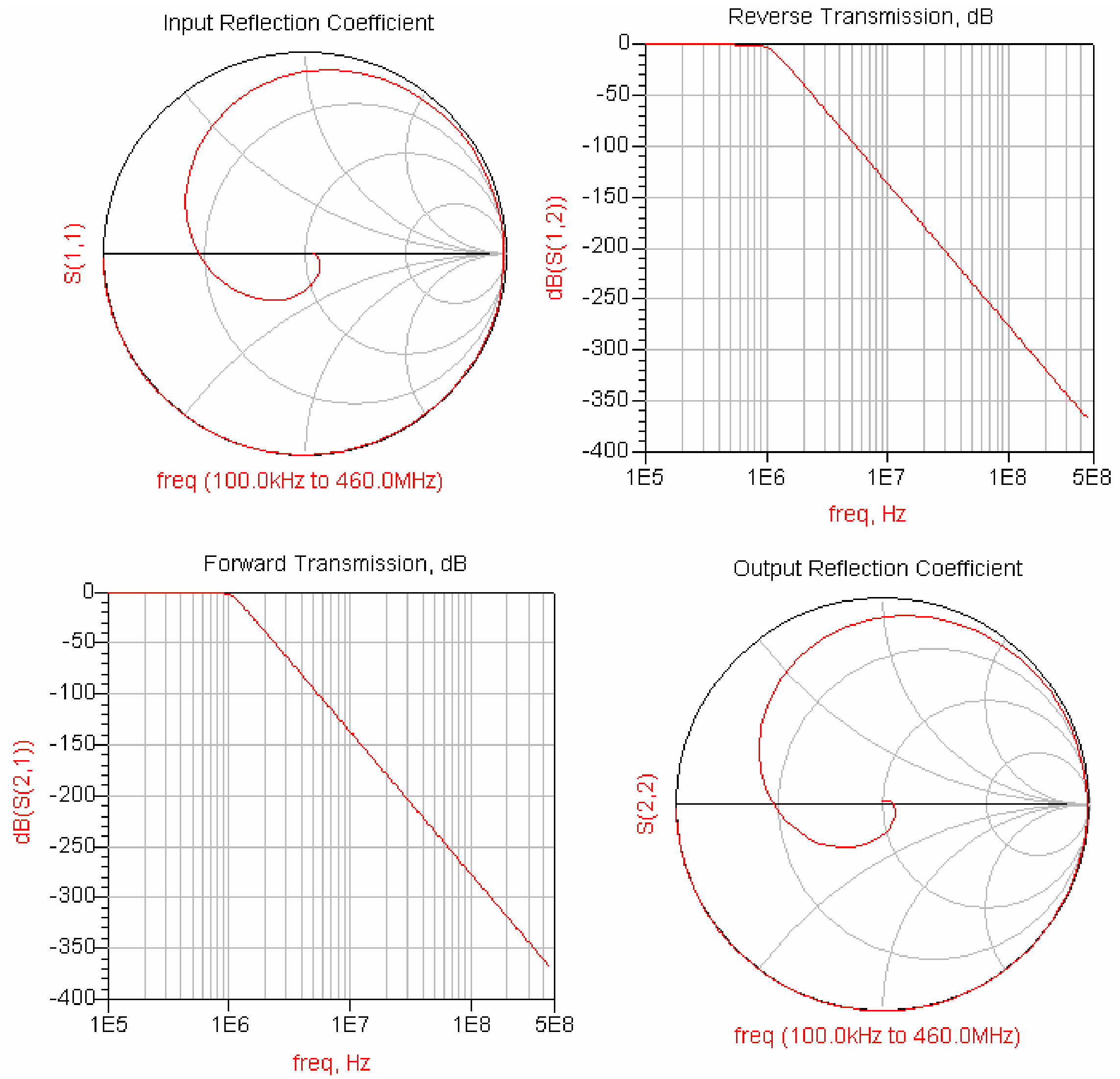


Figure 2: S-parameters vs frequency

The evaluation board also allows connections to be made to the AD8347 using SMA connectors. The connections made to the I/Q detector evaluation board are shown in the table below.

Eval. Board Pin Name	Connection	Signal Desc.
QOPP (J2)	DAQ Pin-33	I/Q Q Pos
IOPN (J6)	DAQ Pin-34	I/Q I Neg
IOPP (J5)	DAQ Pin-68	I/Q I Pos
QOPN (J1)	DAQ Pin-66	I/Q Q Neg
TP1 (+Vs)	Power Supply: +5V	Positive
TP4 (GND)	Power Supply: GND	Ground

2. Control Box Connections

This section outlines connections made within the control box including:

- Data Acquisition Card Connections
- Load Switch Connections
- Paragrine Switch Connections
- Amp DC Output Connections
- Control I/O Connections

2.1. *Data Acquisition Card Connections*

Pin	Pin Name	Signal Name	Connection Name
1	PFI 14/P2.6		
2	PFI 12/P2.4	RF Signal	Paragrine TTL Signal DAQ Pin-11 Power Meter Ext. Trigger
3	PFI 9/P2.1	RF Trigger	DAQ Pin 40
4	D GND		
5	PFI 6/P1.6	Increment	Amp DC Output (Grey)
6	PFI 5/P1.5		
7	D GND		
8	+5 V	(not 5V)	
9	D GND		
10	PFI 1/P1.1	VSWR	Control I/O Pin-3
11	PFI 0/P1.0	IQ Trigger	
12	D GND		
13	D GND		
14	+5 V		Paragrine +5
15	D GND		
16	P0.6	Switch Path 4	Load Switch Logic Pin-9
17	P0.1	Address 1	Control I/O Pin-4
18	D GND		
19	P0.4	Switch Path 2	Load Switch Logic Pin-5
20	NC		
21	NC		
22	NC		
23	AI 15		
24	AI GND		
25	AI 6		
26	AI 13		
27	AI GND		
28	AI 4		
29	AI GND		
30	AI 3	Thermo Cpl 1	
31	AI 10		
32	AI GND		
33	AI 1	I/Q Q Pos	
34	AI 8	I/Q I Neg.	

Pin	Pin Name	Signal Name	Connection Name
68	AI 0	I/Q I Pos	
67	AI GND		
66	AI 9	I/Q Q Neg	
65	AI 2	Thermo Cpl 2	
64	AI GND		
63	AI 11		
62	AI SENSE		
61	AI 12		
60	AI 5		
59	AI GND		
58	AI 14		
57	AI 7		
56	AI GND		
55	NC		
54	NC		
53	D GND		
52	P0.0	Address 0	Control I/O Pin-2
51	P0.5	Switch Path 3	Load Switch Logic Pin-7
50	D GND		
49	P0.2	Address 2	Control I/O Pin-6
48	P0.7	Switch Path 5	Load Switch Logic Pin-11
47	P0.3	Switch Path 1	Load Switch Logic Pin-3
46	PFI 11/P2.3		
45	PFI 10/P2.2		
44	D GND		
43	PFI 2/P1.2	Over Temp	Control I/O Pin-1
42	PFI 3/P1.3		
41	PFI 4/P1.4		
40	PFI 13/P2.5	TR Signal	Control I/O Pin-9
39	PFI 15/P2.7		
38	PFI 7/PP1.7	Up/Down	Amp DC Output (Brown)
37	PFI 8/P2.0		
36	D GND		
35	D GND		

2.2. *Load Switch Connections*

Load Switch TTL Logic Connections

Pin	Func.	Color
1	drive common	brown
2	indicator common	red
3	drive path 1	orange
4	indicator path 1	yellow
5	drive path 2	green
6	indicator path 2	blue
7	drive path 3	violet
8	indicator path 3	grey
9	drive path 4	white
10	indicator path 4	black
11	drive path 5	brown
12	indicator path 5	red
13	drive path 6	orange
14	indicator path 6	yellow
15	Common Ground	green
16	open all paths	blue

Load Switch Path Connections

Load	Connection
Load Input	L/S Input from Black Box
Load 1	50 Ω
Load 2	3:1 Mismatch
Load 3	Short
Load 4	Open
Load 5	I/Q Detector
Load 6	Unused

2.3. Paragrine Switch Connections

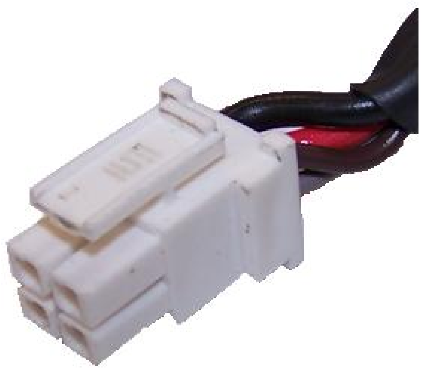
Pin	Connection
J1	Power (5V)
J2	RF Clock
RF1	Not Connected
RF2	RF Input (Signal Generator)
RFC	Input Coupler 1

2.4. Control I/O Connections

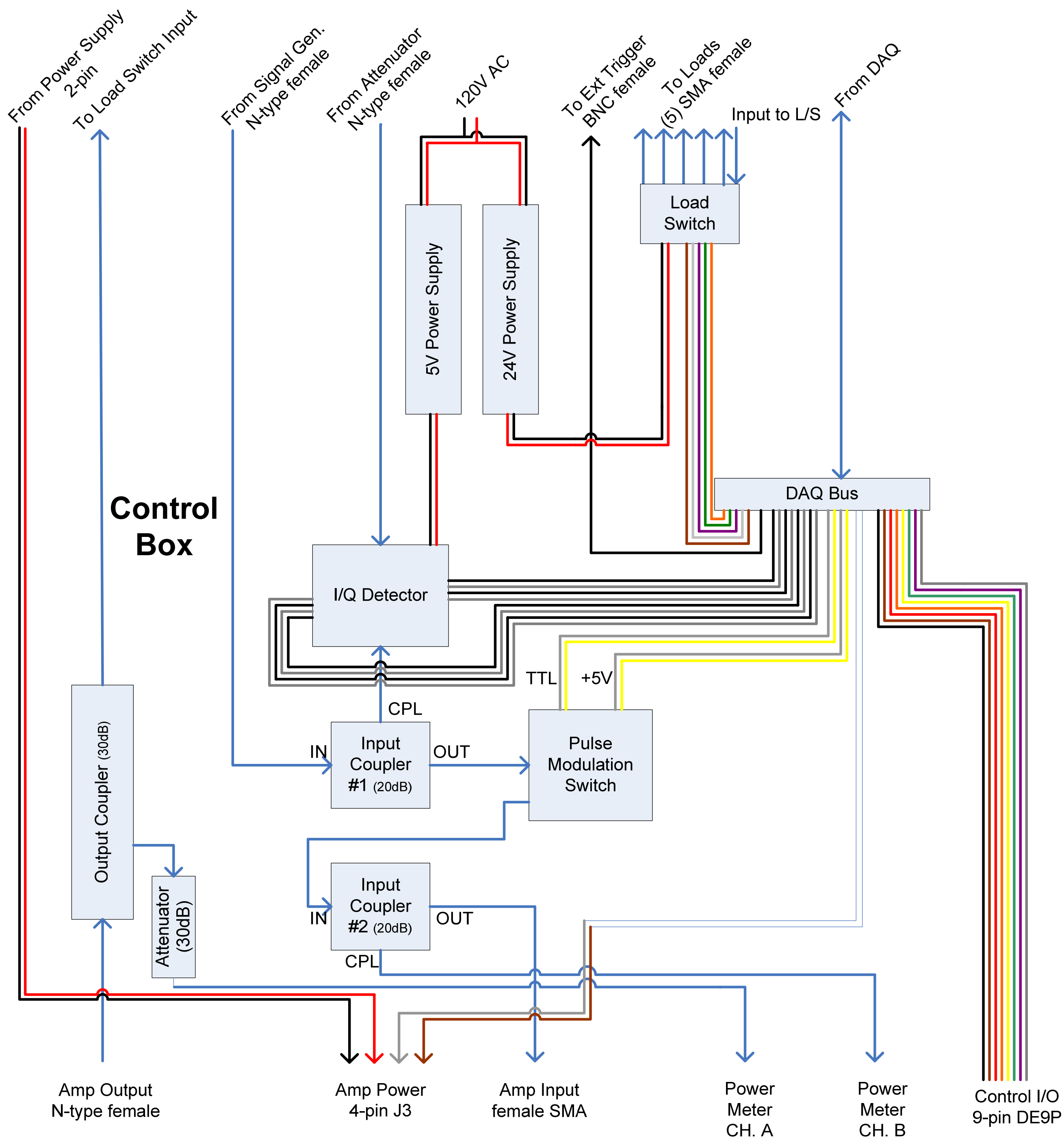
Pin	Color	Connection
1	Black	Temp. Status
2	Brown	Address 0
3	Red	VSWR Status
4	Orange	Address 1
5	Yellow	Gnd
6	Green	Address 2
7	Blue	Not Connected
8	Purple	Gnd
9	Grey	T/R

2.5. *Amp DC Output Connections*

Pin	Color	Connection
1	Red	32V
2	Gray	Increment
3	Black	Gnd
4	Brown	Up/Down



3. Control Box Wiring Diagram

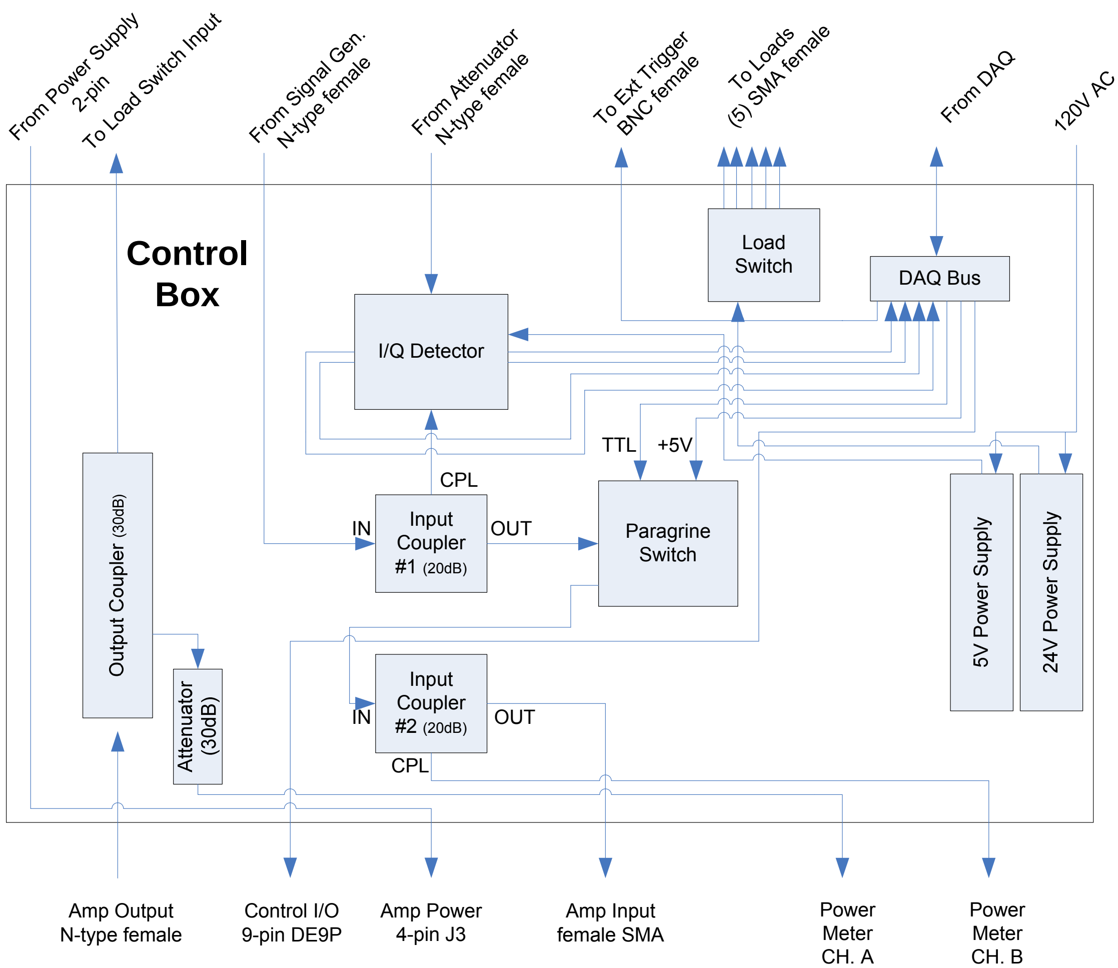


4. Control Box Layout

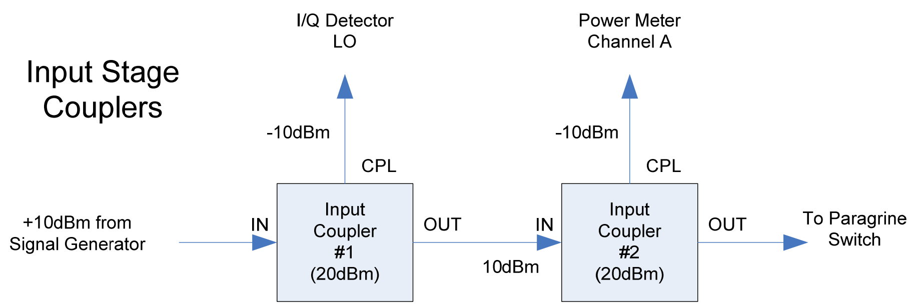
This section describes the layout of the control box including:

- Internal Layout
- Input Stage Couplers
- Output Stage Coupler
- Front Panel
- Back Panel

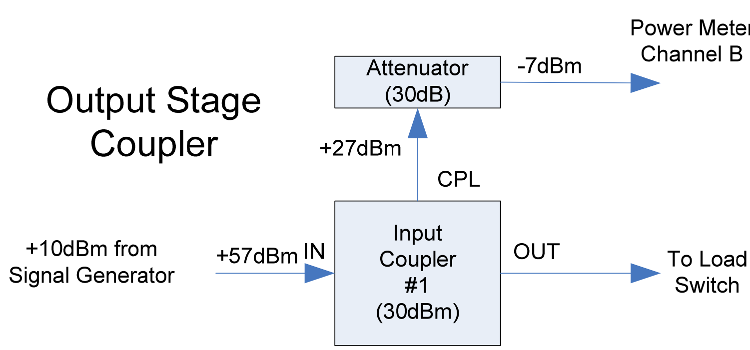
4.1. Internal Layout



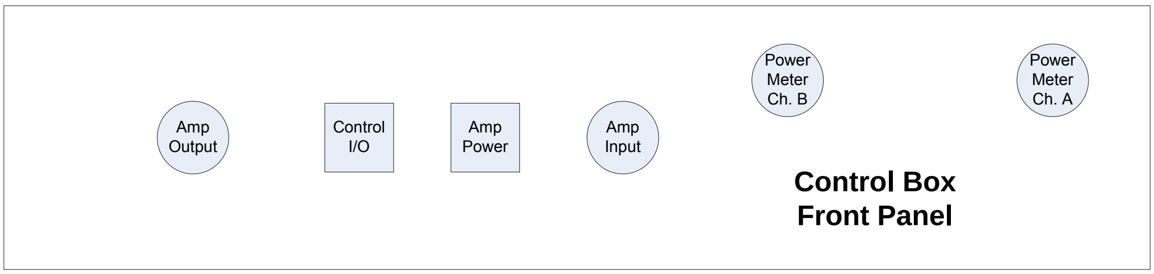
4.2. *Input Stage Couplers*



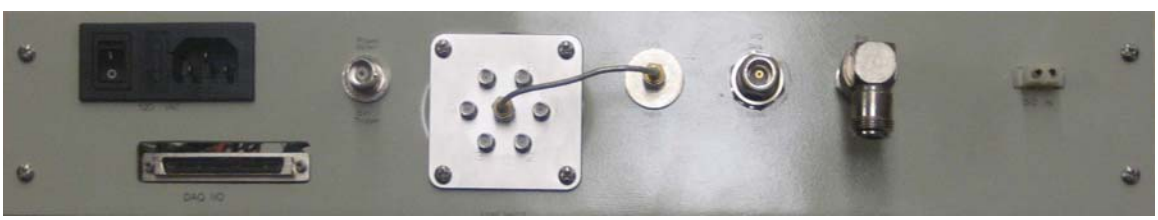
4.3. *Output Stage Coupler*

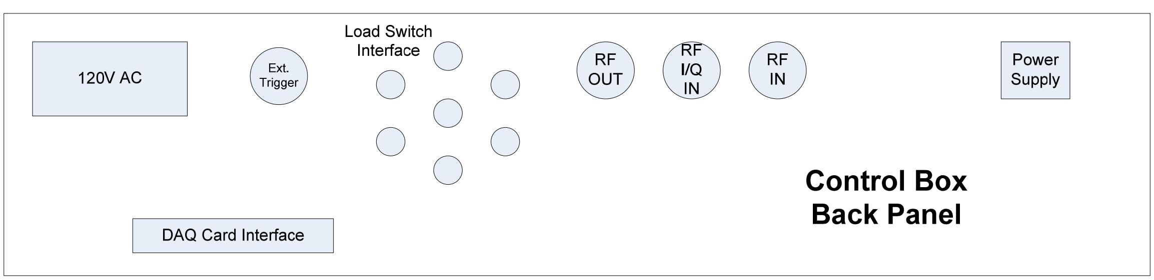


4.4. Front Panel Layout



4.5. Back Panel Layout





Appendix C

Burn-in
Technical Guide

Authors:

Jeff Pelligrino
John Scimone
Kaushal Shrestha

Date: February 26, 2007

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1. Signal Distribution: Stage 1 Diagrams

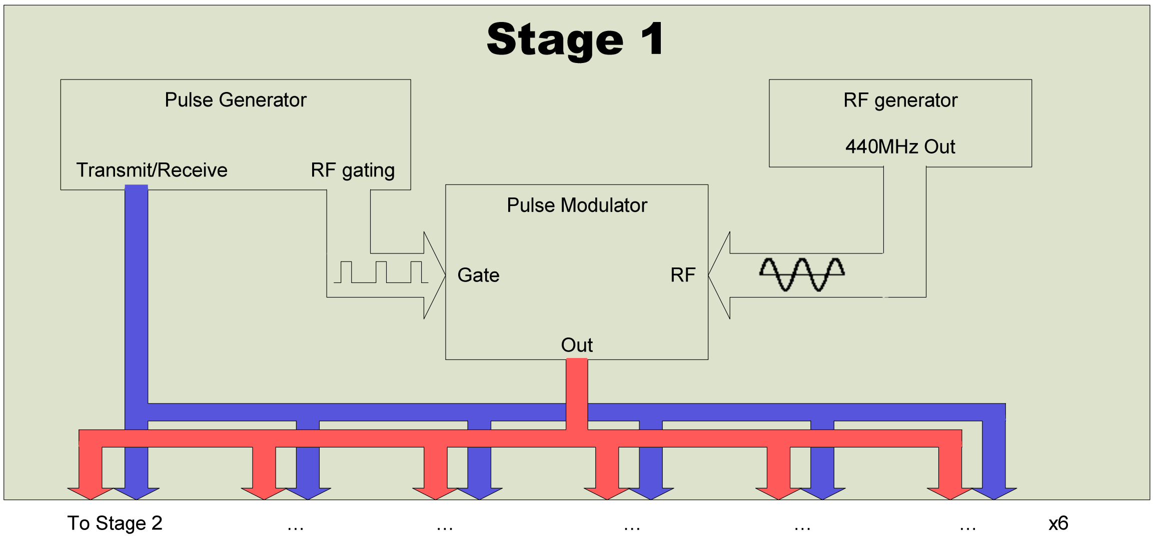

Figure 1: Burn-in Stage 1 Flow Diagram

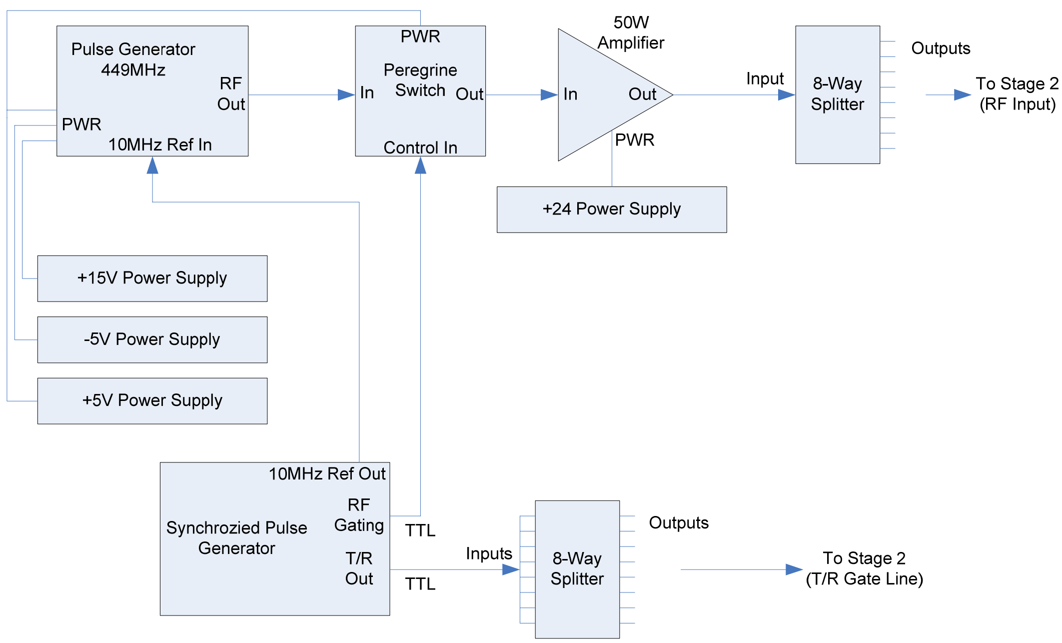

Figure 2: Burn-in Stage 1 Block Diagram

2. Signal Distribution: Stage 2 Diagrams

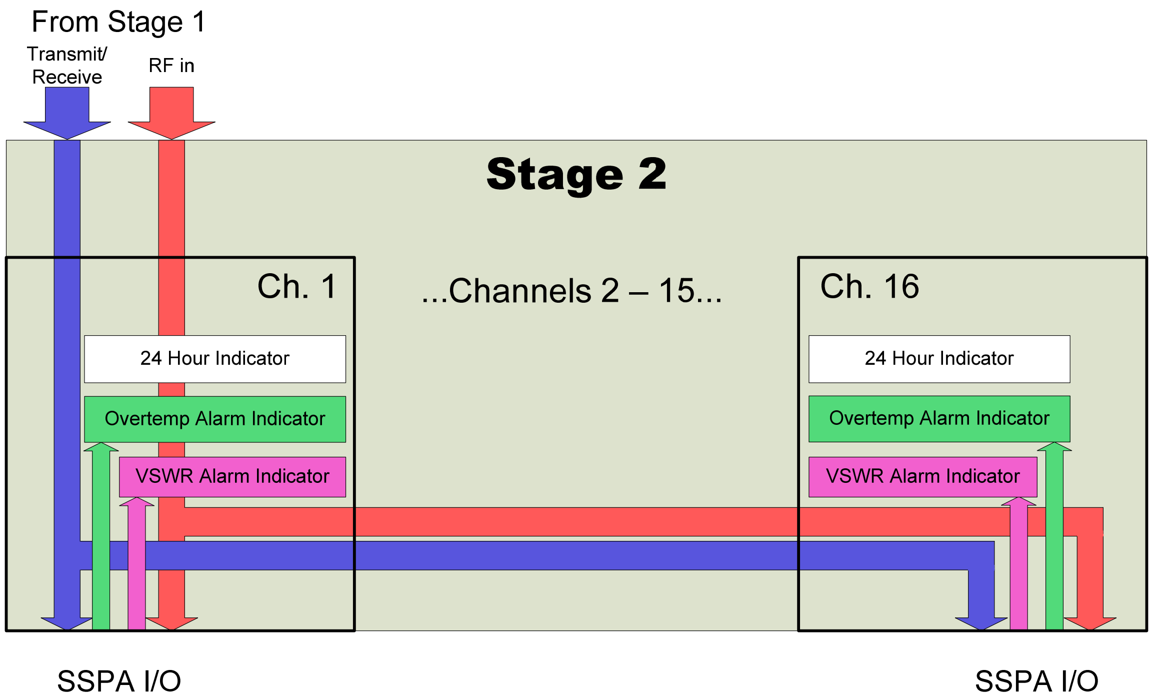

Figure 3: Burn-in Stage 2 Flow Diagram

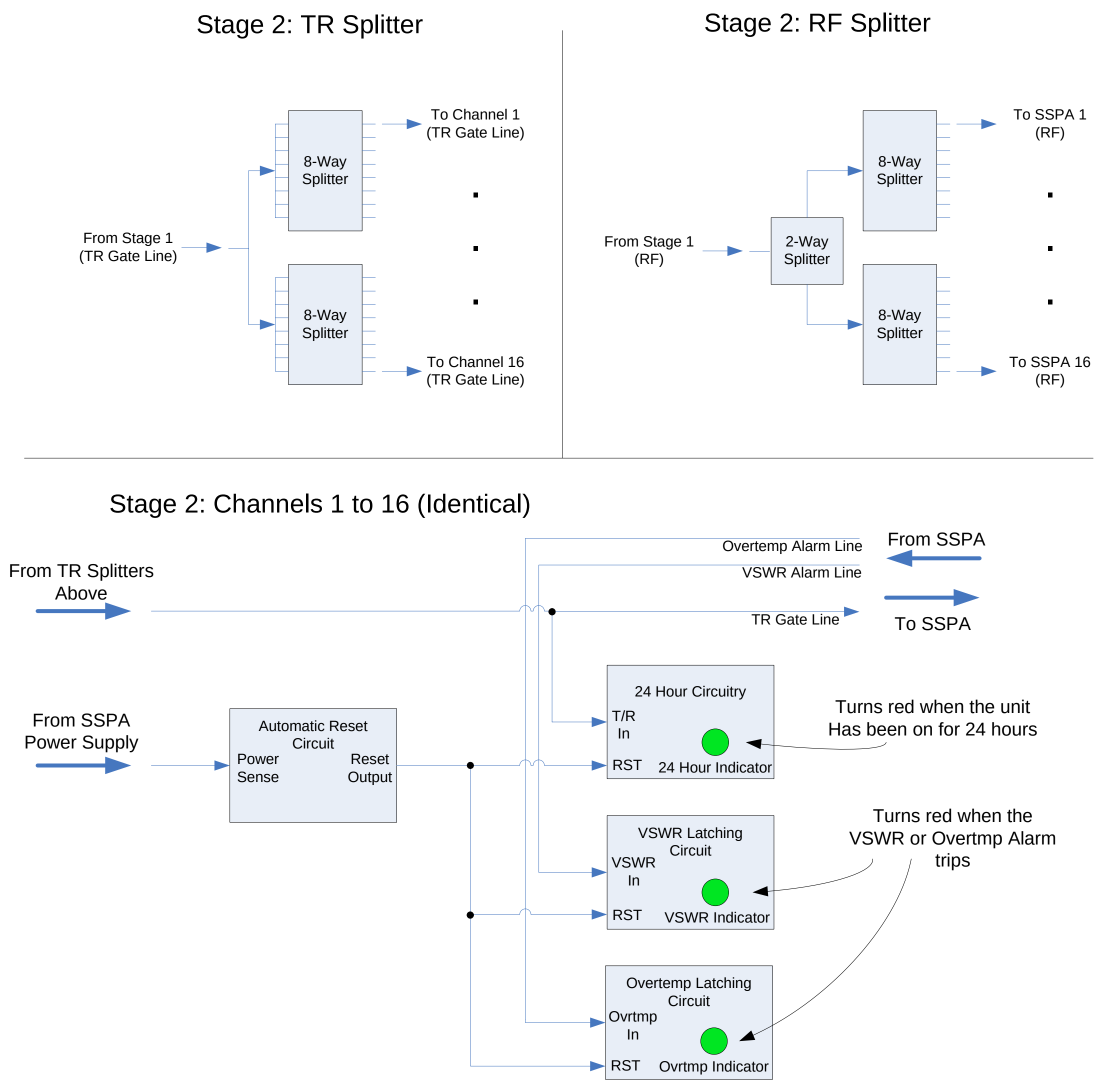

Figure 4: Burn-in Stage 2 Block Diagram

3. Signal Distribution: Stage 2 Schematics

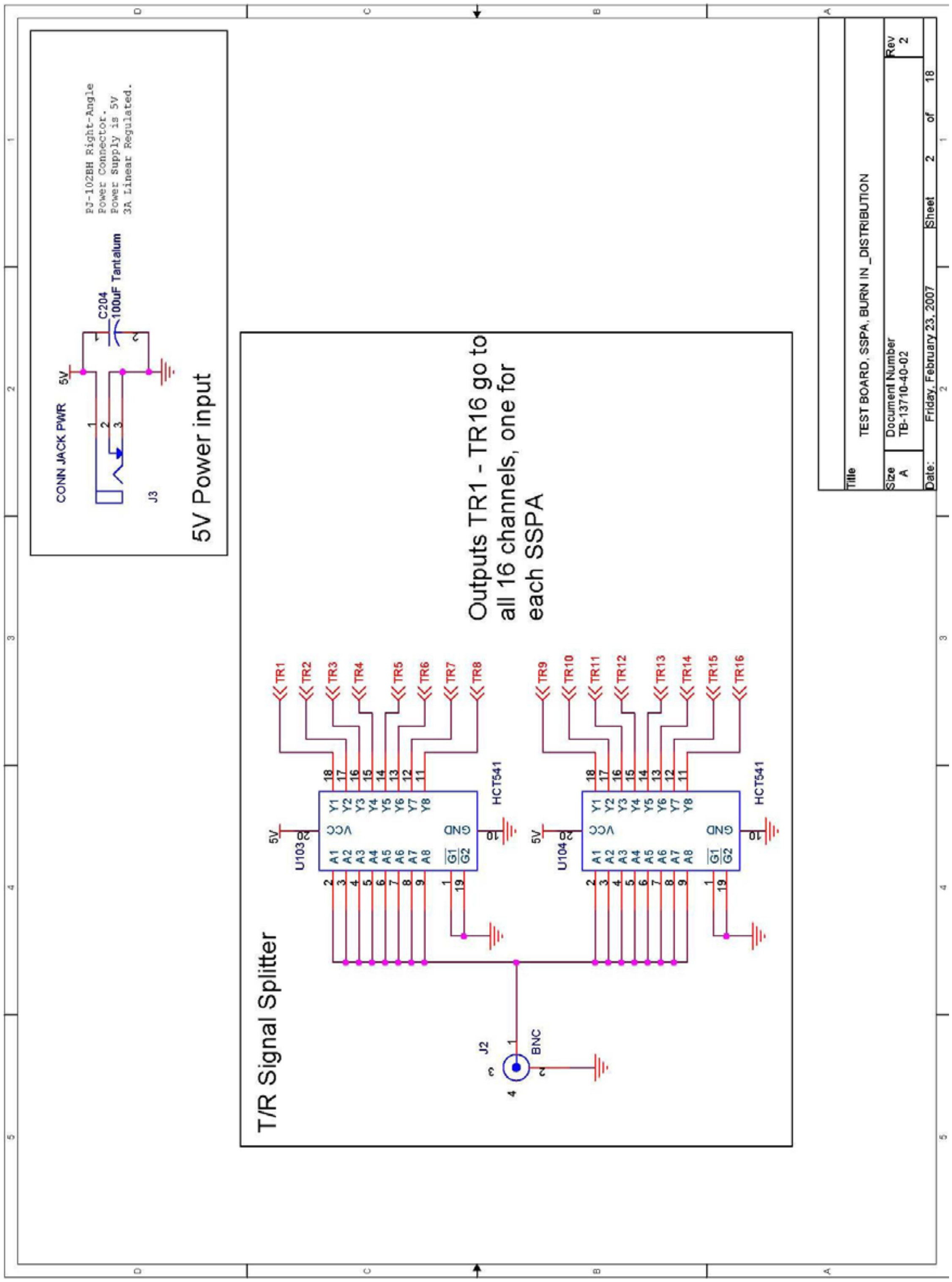

Figure 5: TR Splitter and Power Connection Circuitry

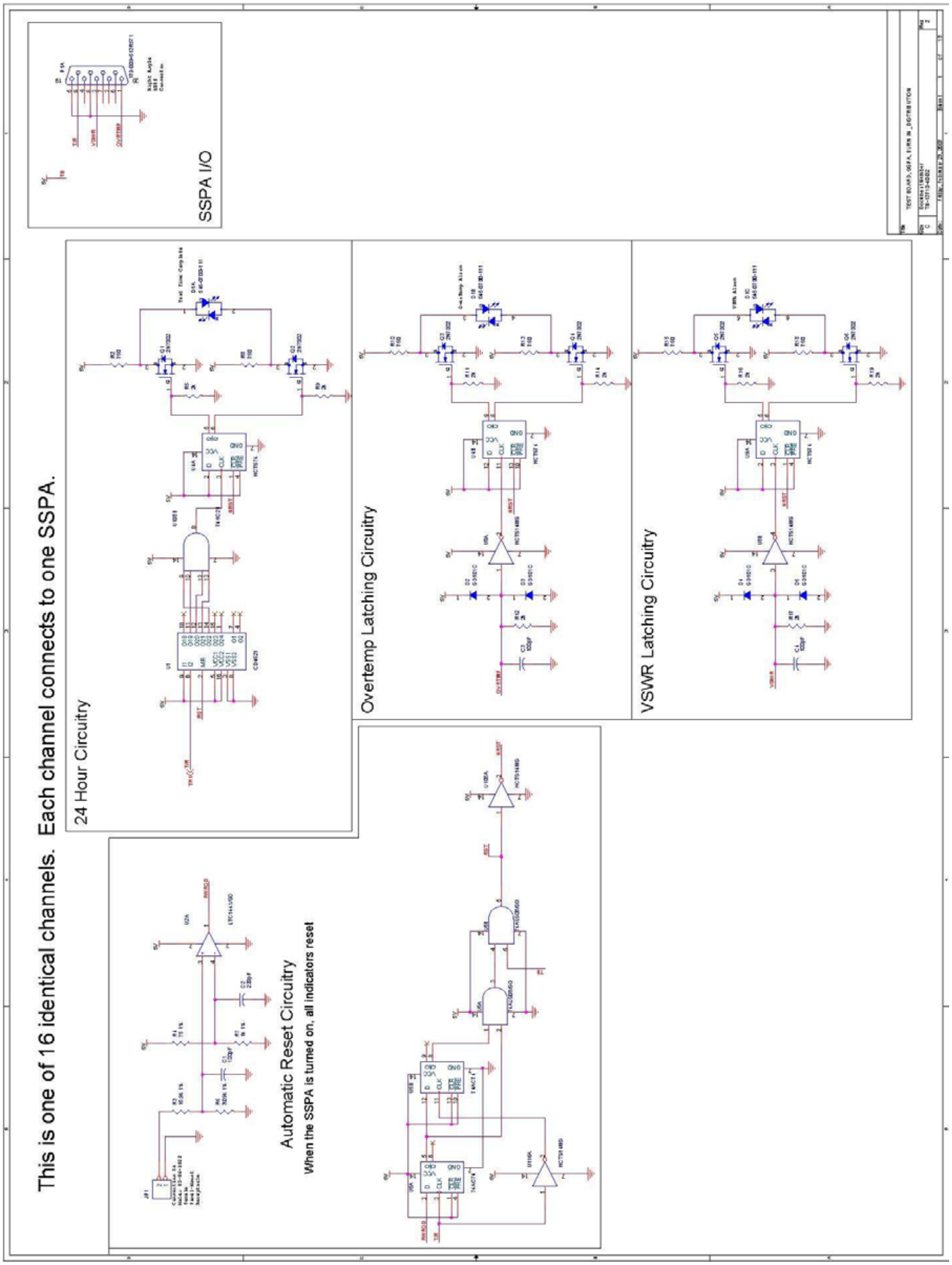

Figure 6: Distribution Channel Circuitry

Appendix D

Programming Guide

SRI International
Automated Test Suite

Authors:

Jeff Pelligrino
John Scimone
Kaushal Shrestha

Date: February 26, 2007

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1 Operating System

Fedora Core 6 is readily available online because it is an open source operating system. The ISO image file of the installation DVD can be downloaded from

1. Fedora's download site (http://fedora.redhat.com/Download/), or
2. Mirror sites (http://fedora.redhat.com/Download/mirrors.html), or
3. BitTorrent (http://fedoraproject.org/wiki/Distribution/Download/BitTorrent).

The complete release notes and the installation guide can be found under Fedora's documentation section at http://fedora.redhat.com/docs/ .

1.1 Installation

The installation process is very easy and intuitive. It is as simple as booting from the DVD and proceeding through the installation with default settings. Do a clean install on the hard drive by selecting to format the partition that you want to install Fedora Core 6 with minimal options.

1.2 Getting the latest updates

Getting the latest update for the working kernel is important along with other updates. Fedora Core has a built in program that searches all the repositories for all available updates that are possible for the current system and configuration. Open up the terminal and as root type the following command to get the updates.

 # yum update

1.3 Driver Installation

All the hardware present in the Automated Test Suite (ATS) PC is detected by Fedora's installer, except for the National Instruments' GPIB card and the DAQ card.

1. Installing NIDAQ card

Step 1: Insert the CD that came with the ATS

Step 2: Create a symbolic link to *asm-offsets.h* by typing the following in the terminal window:

 # ln -s /lib/modules/$(uname -r)/ source/include/asm/asm-offsets.h /lib/modules/$(uname -r)/source/include/asm/asm_offsets.h

Step 3: Open */lib/modules/$(uname -r)/source/include/linux/utsrelease.h* and copy the line **#define UTS_RELEASE "2.6.xx-1.xxxx.fc6"**, into */lib/modules/$(uname -r)/source/include/linux/version.h*, and save it.

Step 4: As root run the install script from the CD and use the default installation paths for everything.

 # <CD-Mount Directory>/NI-DAQ/INSTALL

Step 5: When INSTALL finishes, **do not** reboot.

Instead patch the nikal using the file found in the Patch directory of the CD using the following command.

 # patch -p0 < nikal.patch

Step 6: Copy the modprobe file ***'modpost'*** from the Patch directory of the CD to */lib/modules/$(uname -r)/source/scripts/mod/*

Step 7: Run ***updateNIDrivers*** and reboot.

2. Installing GPIB card

Step 1: Insert the CD that came with the ATS

Step 2: Create a symbolic link to *asm-offsets.h*:

 # ln -s /lib/modules/$(uname -r)/ source/include/asm/asm-offsets.h /lib/modules/$(uname -r)/source/include/asm/asm_offsets.h

Step 3: Open */lib/modules/$(uname -r)/source/include/linux/utsrelease.h* and copy the line **#define UTS_RELEASE "2.6.xx-1.xxxx.fc6"**, into */lib/modules/$(uname -r)/source/include/linux/version.h*, and save it.

Step 4: As root run the install script from the CD and use the default installation paths for everything.

 # <CD-Mount Directory>/NI-488225L/INSTALL

Step 5: When INSTALL finishes, **do not** reboot.

Instead patch the nikal using the file found in the Patch directory of the CD using the following command.

 # patch -p0 < nikal.patch

Step 6: Copy the modprobe file ***'modpost'*** from the Patch directory of the CD to */lib/modules/$(uname -r)/source/scripts/mod/*

Step 7: Run ***updateNIDrivers*** and reboot.

2 Software Packages

Before proceeding with installing software packages that are required to successfully run the ATS software, make sure that Python programming environment was installed during the native installation of Fedora Core 6. In case you forgot to install Python, running yum as root from the shell will install it.

 # yum install python

2.1 PyVISA

PyVISA is needed by the ATS software to communicate with the Agilent power meter via the National Instrument GPIB interface using Python. PyVISA can be downloaded from the internet (http://pyvisa.sourceforge.net/). Alternatively, it can be installed by installing the RPM file from PyVISA directory of the Installation CD. The RPM can be installed by browsing the directory using the GUI and double-clicking the *PyVISA-1.1-1.noarch.rpm* RPM file, or by typing the following command as root.

 # rpm -install PyVISA-1.1-1.noarch.rpm

2.2 NI-VISA

PyVISA is a Python wrapper for National Instruments' VISA Library. The NI-VISA Library must be installed before PyVISA can be functional from within Python. To install NI-VISA library run the install script as root.

 # <CD-Mount Directory>/NI-VISA/INSTALL

2.3 Python Packages

There are some additional Python packages that need to be installed to get the ATS fully operational. The packages namely are python-ctypes, pytz, and python-psyzopg2 which do not come with the native install of Fedora Core 6. They can be installed by running the yum command as root.

 # yum install python-ctypes pytz python-psyzopg2

2.4 Database Server

The ATS uses PostgreSQL as the database server. If the PostgreSQL server was not installed during the installation of Fedora Core, it is readily available via yum. Install the database server using 'yum' as root.

 # yum install postgresql-server

By default, the Postgres databases can only be accessed by root or postgres users. The user should login as root or the postgres and create a database (preferably *'SSPA'*) using the command ***createdb*.**

 # su – postgres

$ createdb sspa

The database can be deleted by using the ***dropdb*** command.

$ dropdb sspa

The default database schema for the ATS is provided in the Installation CD and can be imported into the database created by using ***psql*** (client for PostgreSQL).

$ psql sspa < <CD-Mount Directory>/Database/SSPA-schema.sql

3 Programming Agilent Power Meter

The Agilent Power Meter is controlled specifically by the PowerMeter class in ***PowerMeter.py*** and the methods within the class. The functions available within the power meter class are listed below with their functionalities.

Public Functions:

a. getMeasInput()
   - Gets a peak power measurement from power head channel A.

b. getMeasOutput()
   - Gets a peak power measurement from power head channel B.

c. getTraceData()
   - Gets the trace data from Power Head Channel B.
   - Accepts length of trace (ms).
     - By default, *tracelength = 0.02*.
   - Accepts length of trigger delay (ms).
     - By default, *triggerdelay = 0*.

d. zeroPowerHeads()
   - Zeros power meter channel A and power meter channel B.

e. setFreq()
   - Sets the frequency of power meter channel A and B.
   - Accepts a frequency (MHz).
     - By default, *freq = 440*.

Private Functions:

a. __setCaptureRate()
   - Sets the measurement speed on power meter channel A and B
   - Accepts the measurement speed mode: “NORMAL”, “DOUBLE”, or “FAST”.
     - By default, *mode = “DOUBLE”*

b. __setMeasurementSettings()
   - Sets power measurement mode, trigger mode, and trigger source
   - Accepts measurement mode: “PEAK”, or “AVER”
     - By default, *pow = “peak”*
   - Accepts trigger mode: “CONT”, or “IMM”
     - By default, *mode = “CONT”*
   - Accepts trigger source: “BUS”, “EXT”, “HOLD”, “IMM”, or “INT”
     - By default, *trigger = “EXT”*

c. __setTriggerDelay()

- Sets the trigger delay for power meter channel A and B.
- Accepts a length of time (s).
  - By default, *delay = 100e-6*.
  -

d. __setTraceUnits()

- Sets the trace function units on power meter channel A and B.

e. __enableTrace()

- Enables the trace capture for power meter channel B.

f. __setPowMeasurement()

- Set the power measurement type for power meter channel A and B.
- Accepts a measurement mode: "PEAK" or "AVER"
- By default, type = "PEAK".

g. __setTrigger()

- Sets the trigger mode for power meter channel A and B.
- Accepts a trigger mode: "EXT" or "IMM"
- By default, trigger = "EXT".

h. __waitTrigger()

- Sets power meter channel A and B in wait for trigger state.

i. __getOffsetInput()

- Gets dB loss offset or input stage.

j. __getOffsetOutput()

- Gets dB loss offset for output stage.

4 Programming Agilent Power Supply

The Agilent Power Supply functions are available in the PowerSupply class in the ***PowerMeter.py*** file and the methods within the class control the functionalities provided by the power supply. The functions available within the class are listed below with their functionalities.

Public Functions:

a. setCurr()
   - Sets the current limit.
   - Accepts a current value (A).

b. getVoltageSetpoint()
   - Returns the power supply voltage level setting.

c. setVolt()
   - Sets the voltage limit.
   - Accepts a voltage value (V).

d. getCurr()
   - Returns the power supply current level setting.

e. getVoltageReading()
   - Measures the output voltage.
   - Returns the measured value.

f. setPowerOn()
   - Enables the power supply output and allows the capacitors to charge.

g. setPowerOff()
   - Disables the power supply output.

h. getPowerStatus()
   - Returns the power supply output status (on/off).

5 Programming Agilent Signal Generator

The Agilent Signal Generator functions are available in the SignalGen class in the ***SignalGen.py*** file. These functions / methods within the class control various functionalities of the signal generator. The functions available within the class are listed below with their functionalities.

Public Functions:

a. setRFOff()
    - Disables the RF output of the signal generator.

b. setRFOn()
    - Enables the RF output of the signal generator.

c. setAmplitude()
    - Sets the RF output amplitude of the signal generator.
    - Accepts an amplitude (dBm) between -110dBm and 17dBm.

d. setFreq()
    - Sets the RF output frequency of the signal generator.
    - Accepts a frequency (Hz) between 250kHz and 1GHz.

Private Functions:

a. __getOffsetOutput()
    - Gets dB loss offset for the output stage.

6 Programming NI-6220 Data Acquisition Card

The controller class is used to control the data acquisition card. The functions available within the controller class are shown below. The functions available in the ***Controller.py*** file make calls to the shared object file compiled using GNU C and *nidaqmx* library provided by National Instruments.

Public Functions:

a. getPhase()
   - Gets the phase of an amplifier in radians.

b. getPhaseD()
   - Gets the phase of an amplifier in degrees.

c. getPhaseValues()
   - Gets the in-phase and quadrature phase values in radians.

d. getPhaseValuesD()
   - Gets the in-phase and quadrature phase values in degrees.

e. getVSWR_Flag()
   - Returns the status of the VSWR flag.

f. getTemp_Flag()
   - Returns the status of the temperature flag.

g. setAddr()
   - Sets the address.
   - Accepts a number between 0 and 7 inclusive.

h. setLoad()
   - Sets the load switch path.
   - Accepts a number between 1 and 5 inclusive.

i. setIncr()
   - Sets increment.
   - Accepts either 1 or 0.

j. setUpDown()
   - Sets UpDown.
   - Accepts either 1 or 0.

k. Increment()
- Toggles setIncr() a specified amount while UpDown is high.
- Accepts the number of times setIncr() will be toggled.
  - By default, *number_of_pulses = 1*.

l. Decrement()
- Toggles setIncr() a specified amount while UpDown is low.
- Accepts the number of times setIncr() will be toggled.
  - By default, *number_of_pulses = 1*.

m. setTR()
- Sets the TR gate line pulse.
- Accepts a value for on/off: 0 or 1.
- Accepts the period of the pulse (s).
  - By default, *period = 20e-3**.
- Accepts the pulse width (s).
  - By default, *pw = 2e-3**.

  *Since the RF pulse needs to be within the TR pulse, the python wrapper for the DAQ will increase the period and pulse width of the TR gate line by 2µs. This will envelope the RF gate line within the TR gate line when they use their default pulse widths and periods.

n. setRF()
- Sets the RF gate line pulse.
- Accepts a value for on/off: 0 or 1.
- Accepts the period of the pulse (s).
  - By default, *period = 20e-3*.
- Accepts the pulse width (s).
  - By default, *pw = 2e-3*.

o. setRFHigh()
- Sets the RF gate line high.

p. setRFLow()
- Sets the RF gate line low.

7 Database Module

The database module functions are available in the Database class in the ***Database.py*** file. These functions / methods within the class are used to communicate with the database. The functions available within the class are listed below with their functionalities.

Public Functions:

e. connect()
   - Creates a channel between the code and the database.

f. storeCalibrationReadings()
   - Stores the data collected during calibration.

g. storeOpertionalTestReadings()
   - Stores the data collected during operational tests.

h. storePreBurninReadings()
   - Stores the data collected during pre burn-in tests.

i. storePostBurninReadings()
   - Stores the data collected during post burn-in tests.

j. storeDVTReadings()
   - Stores the data collected during non-operational DVT tests.

k. storeOffsetSettings()
   - Stores the data collected during offset calibration.

l. insertTuples()
   - Inserts data into a database.
   - Accepts table name, field names and their corresponding values.

8 Temperature Sensor Module

The Temperature Sensor functions are available in the TempSensor class in the ***TempSensor.py*** file. These functions / methods within the class are used to receive data from the SensaTronics temperature sensor. The functions available within the class are listed below with their functionalities.

Public Functions:

a. getTemperature()
   - .Calls a private function to get the temperature data.

Private Functions:

a. __getSensaTronicTemp(sensor)
   - Gets temperature reading from the designated sensor.

9 Source Code

SRI International
Automated Test Suite

```python
#!/usr/bin/env python

import Controller
import PowerMeter
import PowerSupply
import SignalGen

import Database

import time
import string
import sys
import math

from TestException import *
from Utilities import *

warmup_period = 3        # S
calibration_freq = 444e6 # Hz
initcurrent_max = 0.6    # A
normcurrent_max = 5      # A
normcurrent_min = 2      # A

class Calibration:
    def __init__(self, uName):
        self.powersupply = PowerSupply.PowerSupply()
        self.siggen = SignalGen.SignalGen()
        self.powermeter = PowerMeter.PowerMeter()
        self.controller = Controller.Controller()

        self.user = uName
        self.siggen.setFreq( calibration_freq ) #Calibration at this freq
        self.powermeter.setFreq( calibration_freq )

    def destructor(self): # Issues with using the default __del__()
        try:
            del self.controller
            del self.siggen
            del self.powersupply
        except Exception, ex:
            raise

    # *******************************************************************
    #
    # Start of  "Public Functions" Block
    #
    # *******************************************************************
    def runCalibration (self, serialno = ""):
        values = {    "sn"              : "",
                      "uname"           : "",
                      "initcurrent"     : "",
                      "trcurr"          : "",
                      "pot1_set"        : "",
                      "curr1"           : "",
                      "pot2_set"        : "",
                      "curr2"           : "",
                      "trrfcurr"        : "",
                      "pot4_set"        : "",
                      "initpower"       : "",
                      "power4"          : "",
                      "curr4"           : "",
                      "pot5_set"        : "",
                      "phase"           : "",
                      "pot6_set"        : "",
                      "initphase"       : "",
                      "phase_values"    : ""
                 }  # Values dictionary

        while serialno == "":
```



```python
            print ""
            sn = raw_input("Please enter the Serial Number of the SSPA :")
            serialno = str(sn).strip().replace(" ","_")
        values['sn']    = "'%s'" % serialno
        values['uname'] = "'%s'" % self.user


        # ========================================
        # First Stage of Calibration
        # Startup
        # ========================================
        sys.stdout.write ( "\nStarting Calibration Process ...\n" )

        self.siggen.setRFOff()          #From signal generator

        self.controller.setLoad(self.controller.load_50_ohms)

        self.powersupply.setPowerOff()
        self.powersupply.setVolt(32)
        self.powersupply.setCurr(1)

        print "Turning on Power Supply for initial current measurement"

        self.powersupply.setPowerOn()
        current = self.powersupply.getCurr()
        sys.stdout.write( "Initial current draw of %.0f mA...\t" % \
                          (current*1000))
        sys.stdout.flush()

        values['initcurrent'] = ("%s" % current)

        if ( current > initcurrent_max ):
            self.__saveCalibrationResults( \
                values, 0, TestException.calib_initialCurrFailed)
            setStyle('bold', 'red')
            sys.stdout.write ( "[ FAILED ]\n" )
            setStyle('default')
            raise TestException(TestException.calib_initialCurrFailed)
        elif (current < 0):
            setStyle('bold', 'red')
            sys.stdout.write ( "[ FAILED ]\n" )
            setStyle('default')
            self.__saveCalibrationResults( \
                values, 0, TestException.device_error_SSPA_Power)
            raise TestException(TestException.device_error_SSPA_Power)
        else:
            setStyle('bold', 'green')
            sys.stdout.write ( "[ OK ]\n" )
            setStyle('default')
        # End of First Stage
        # ========================================


        # ========================================
        # Second Stage of Calibration
        # Initialize Digital Potentiometers
        # ========================================
        print "Initializing digital potentiometers..."
        countAddr1 = 0
        countAddr2 = 0
        countAddr4 = 50
        countAddr5 = 50
        countAddr6 = 50
        # ----------------------------------------
        # Set Addr 1 (Driver Stage -- Bias)
        # ----------------------------------------
        print " Resetting pot 1--driver bias--to %s" % countAddr1
        self.controller.setAddr(1)
        self.controller.setTR(0)
```

```
        self.controller.Decrement(100)

        # ------------------------------------------
        # Set Addr 2 (Output Stage -- Bias)
        # ------------------------------------------
        print " Resetting pot 2--output bias--to %s" % countAddr2
        self.controller.setAddr(2)
        self.controller.setTR(0)
        self.controller.Decrement(100)

        # ------------------------------------------
        # Set Addr 4 (Power Level)
        # ------------------------------------------
        print " Resetting pot 4--power level--to %s" % countAddr4
        self.controller.setAddr(4)
        self.controller.setTR(0)
        self.controller.Decrement(100)
        self.controller.Increment(countAddr4) # Set the pot to the middle

        # ------------------------------------------
        # Set Addr 5 (Phase)
        # ------------------------------------------
        print " Resetting pot 5--phase--to %s" % countAddr5
        self.controller.setAddr(5)
        self.controller.setTR(0)
        self.controller.Decrement(100)
        self.controller.Increment(countAddr5)

        # ------------------------------------------
        # Set Addr 6 (VSWR)
        # ------------------------------------------
        print " Resetting pot 6--vswr alarm--to %s" % countAddr6
        self.controller.setAddr(6)
        self.controller.setTR(0)
        self.controller.Increment(100)
        self.controller.Decrement(countAddr6)

        # ------------------------------------------
        # Set Addr 0 (no pots selected)
        # ------------------------------------------
        self.controller.setAddr(0)
        self.controller.setTR(0)
        self.powersupply.setPowerOff()
        print
        # End of Second Stage
        # ==========================================



        # ==========================================
        # Third Stage of Calibration
        # Set the potentiometers
        # Set Bias
        # ==========================================
        self.powersupply.setPowerOff()
        self.powersupply.setVolt(32)
        self.powersupply.setCurr(1)
        self.powersupply.setPowerOn()
        # Start TR pulse (NO RF!!) and check current
        # This start only the TR gate pulse, the RF pulse remains zero.
        print "Starting TR Gating line only ..."
        self.controller.setTR(1) # only TR running at default dutycycle
        current = self.powersupply.getCurr()
        sys.stdout.write ( "Current measurement of %.0f mA...\t\t" % \
                           ( current*1000 ) )

        values['trcurr'] = ("%s" % current)

        if ( current > initcurrent_max ):
```



```
            setStyle('bold','red')
            sys.stdout.write ( "[ FAILED ]\n" )
            setStyle('default')
            self.__saveCalibrationResults( \
                values, 0, TestException.calib_gatePulseFailed)
            raise TestException(TestException.calib_gatePulseFailed)
        else:
            setStyle('bold', 'green')
            sys.stdout.write ( "[ OK ]\n" )
            setStyle('default')

        # ------------------------------------------
        # Set Addr 1 --  Driver
        # ------------------------------------------
        self.controller.setAddr(1)      # Set to Address 1

        driver_bias = 0.30              # A  Mike's new settings
        driver_bias_range = 0.010       # A

        driver_bias_min = driver_bias - driver_bias_range/2
        driver_bias_max = driver_bias + driver_bias_range/2

        print "Setting Addr1 (Driver Bias) to %.0f mA" % (driver_bias * 1000)

        # Now the first and second stages have passed, set the pot1 to 50
        # so that we can speed up the process of setting pot 1
        countAddr1 += 50
        self.controller.Increment( countAddr1 )

        while ((current < driver_bias_min ) ∨ \
               (current > driver_bias_max )):
            sys.stdout.write( "\r Pot1 : %3s\tCurrent : %.0f mA" % \
                              ( countAddr1, current*1000 ))
            sys.stdout.flush()
            if ((current < driver_bias_min) ∧ (countAddr1 < 100)):
                self.controller.Increment(1)
                countAddr1 += 1
            elif ((current > driver_bias_max) ∧ (countAddr1 > 0)):
                self.controller.Decrement(1)
                countAddr1 -= 1
            else:
                values['pot1_set'] = ("%s" % countAddr1)
                values['curr1']    = ("%s" % current)
                self.__saveCalibrationResults( \
                    values, 0, TestException.calib_driverCurrFailed)
                raise TestException(TestException.calib_driverCurrFailed)
            current = self.powersupply.getCurr()

        sys.stdout.write ( "\r Pot1 : %3s\tCurrent : %.0f mA\n" % \
                           ( countAddr1, current*1000 ) )
        sys.stdout.flush()
        values['pot1_set'] = ("%s" % countAddr1)
        values['curr1']    = ("%s" % current)

        # ------------------------------------------
        # Set Addr 2 -- Output
        # ------------------------------------------
        current = self.powersupply.getCurr()
        self.controller.setAddr(2)

        output_bias = 0.500             # A  Mike's new settings
        output_bias_range = 0.010       # A

        output_bias_min = output_bias - output_bias_range/2
        output_bias_max = output_bias + output_bias_range/2

        print "Setting Addr1 (Output Bias) to %.0f mA" % (output_bias * 1000)

        # Now the first and second stages have passed,
```

```
        # set the pot2 to 50 so that
        # we can speed up the process of setting pot 2
        countAddr2 += 50
        self.controller.Increment( countAddr2 )

        while ((current < output_bias_min) ∨ (current > output_bias_max)):
            msg = "Pot2 : %3s\tCurrent : %.0f mA" % (countAddr2, current*1000)
            sys.stdout.write( "\r %s" % msg )
            sys.stdout.flush()
            if ((current < output_bias_min) ∧ (countAddr2 < 100)):
                self.controller.Increment(1)
                countAddr2 += 1
            elif ((current > output_bias_max) ∧ (countAddr2 > 0)):
                self.controller.Decrement(1)
                countAddr2 −= 1
            else:
                values['pot2_set'] = ("%s" % countAddr2)
                values['curr2']    = ("%s" % current)
                self.__saveCalibrationResults( \
                    values, 0, TestException.calib_outputCurrFailed)
                raise TestException(TestException.calib_outputCurrFailed)
            current = self.powersupply.getCurr()

        sys.stdout.write ( "\r Pot2 : %3s\tCurrent : %.0f mA\n" % \
                           ( countAddr2, current*1000 ) )

        values['pot2_set'] = ("%s" % countAddr2)
        values['curr2']    = ("%s" % current)

        print "Driver and Output Bias Calibration Complete......\n"

        # End of Third Stage
        # ==========================================


        # ==========================================
        # Fourth Stage of Calibration
        # Measure and Set Output
        # ==========================================

        # Set Current to 5A
        self.powersupply.setPowerOff()
        self.powersupply.setVolt(32)
        self.powersupply.setCurr(5)

        # Setting address to normal working conditions
        self.controller.setAddr(0)
        self.controller.setLoad( self.controller.load_50_ohms )

        # Turn Power on
        self.powersupply.setPowerOn()

        # Start RF signal
        self.siggen.setRFOn()

        # Start RF Input and TR gating
        print "Turning on RF Gating line..."
        self.controller.setRF(1)    # RF and TR running at default values
        time.sleep( warmup_period ) # Time delay before current measurement

        # ------------------------------------------
        # Measure Current and Adjust Output Power
        # ------------------------------------------
        current = self.powersupply.getCurr()
        sys.stdout.write( "Current drawn with RF : %s A...\t" % current )
        sys.stdout.flush()

        """
    We wish to save the initial, pot = 50, curret draw and output power
```



```
    and see how this trends over the amplifiers.  This should stay in
    control over the production of the amp.
    """
        values['trrfcurr'] = ("%s" % current)

        if ((current < normcurrent_min) ∨ (current > normcurrent_max)):
            self.__saveCalibrationResults( \
                values, 0, TestException.calib_normalCurrFailed)
            setStyle('bold', 'red')
            sys.stdout.write( "[ FAILED ]\n" )
            setStyle('default')
            raise TestException(TestException.calib_normalCurrFailed)
        else:
            setStyle('bold', 'green')
            sys.stdout.write( "[ OK ]\n" )
            setStyle('default')


        sys.stdout.write( "Setting Addr 4 (Power Level) ...\n" )

        power_lowend  = 57.2
        power_highend = 57.3

        self.controller.setAddr(0)
        power = self.powermeter.getMeasOutput()

        values[ 'initpower' ] = ("%s" % power)

        # Simple Search Algorithm
        # Initial bounds for search algorithm
        lowerbound = 0
        upperbound = 100

        while (( power < power_lowend ) ∨ ( power > power_highend )):
            sys.stdout.write( "\r Pot4 : %3s\tPower : %.5f dBm" % \
                              ( countAddr4, power ) )
            sys.stdout.flush()
            self.controller.setAddr(4)
            if ( power < power_lowend) ∧ (countAddr4 < 100):
                step = int(math.floor((upperbound − countAddr4)/2))
                if step ≡ 0:
                    step = 1
                # Now shift the lowerbound to the value of countAddr4
                lowerbound = countAddr4
                self.controller.Increment( step )
                countAddr4 += step
            elif (( power > power_highend) ∧ (countAddr4 > 0)):
                step = int(math.floor((countAddr4 − lowerbound)/2))
                if step ≡ 0:
                    step = 1
                # Now shift the lowerbound to the value of countAddr4
                upperbound = countAddr4
                self.controller.Decrement( step )
                countAddr4 −= step
            else:
                values['pot4_set'] = ("%s" % countAddr4)
                values['power4']   = ("%s" % power)
                self.__saveCalibrationResults( \
                    values, 0, TestException.calib_outputPowerFailed)
                raise TestException(TestException.calib_outputPowerFailed)

            self.controller.setAddr(0)
            power = self.powermeter.getMeasOutput()

        sys.stdout.write( "\r Pot4 : %3s\tPower : %.5f dBm\n" % \
                          ( countAddr4, power ) )

        values['pot4_set'] = ("%s" % countAddr4)
        values['power4']   = ("%s" % power)
```

```
        self.controller.setAddr(0)
        current = self.powersupply.getCurr()

        values['curr4']    = ("%s" % current)

        sys.stdout.write( "Current after setting power: %.3f A\t" % \
                          ( current ))
        if ((current < normcurrent_min) ∨ (current > normcurrent_max)):
            self.__saveCalibrationResults( \
                values, 0,  TestException.calib_normalCurrFailed)
            setStyle( 'bold', 'red' )
            sys.stdout.write( "[ FAILED ]\n" )
            setStyle( 'default' )
            raise TestException(TestException.calib_normalCurrFailed)
        else:
            setStyle( 'bold', 'green' )
            sys.stdout.write( "[ OK ]\n" )
            setStyle( 'default' )

        print "Power Level Calibration Complete......\n"
        # End of Fourth Stage
        # ============================================


        # ============================================
        # Fifth Stage of Calibration
        # Set Phase
        # ============================================
        sys.stdout.write( "Setting Addr 5 (Phase Level) ...\n" )
        sys.stdout.write( "Switching load to IQ detector...\n" )
        self.controller.setTR(0)
        self.siggen.setRFOff()
        self.powersupply.setPowerOff()
        self.powersupply.setVolt(32)
        self.powersupply.setCurr(5)
        self.controller.setLoad(self.controller.load_IQ)

        # Turn on the powers
        self.powersupply.setPowerOn()

        sys.stdout.write( "Waiting for RF Signal ...\n" )

        # Start RF signal
        self.siggen.setRFOn()

        # Start RF Input and TR gating
        print "Turning on RF Gating line ..."
        self.controller.setRF(1)    # RF and TR running at default values
        time.sleep( warmup_period ) # Time delay before measuring current

        self.controller.setAddr(0)
        phase = self.controller.getPhase() # Phase measurement at pot 50

        print "Phase reading at Pot setting of %s is %.5f radians." % \
              (countAddr5, phase)
        values [ 'initphase' ] = "'%s'" % phase

        phase_ref  = 1.75                 # Reference SSPA phase measurement
        phase_tol  = 0.017453             # 1 degrees
        phase_low  = phase_ref − phase_tol
        phase_high = phase_ref + phase_tol

        print "Aligning phase between %.5f and %.5f radians(%.5f +/− %.5f)" % \
                  (phase_low, phase_high, phase_ref, phase_tol)


        # Simple Search Algorithm
        # Initial bounds for search algorithm
```



```
        lowerbound = 0
        upperbound = 100

        while ( (phase < phase_low) ∨ (phase > phase_high) ):
           msg = "Pot5 : %3s\tPhase : %.5f radians" % ( countAddr5, phase)
            sys.stdout.write( "\r %s" % msg )
            sys.stdout.flush()
            self.controller.setAddr(5)

            if ((phase < phase_low) ∧ (countAddr5 < 100)):
                step = int(math.floor((upperbound − countAddr5)/2))
                if step ≡ 0:
                    step = 1
                # Now shift the lowerbound to the value of countAddr4
                lowerbound = countAddr5
                self.controller.Increment( step )
                countAddr5 += step
            elif ((phase > phase_high) ∧ (countAddr5 > 0)):
                step = int(math.floor((upperbound − countAddr5)/2))
                if step ≡ 0:
                    step = 1
                # Now shift the lowerbound to the value of countAddr4
                upperbound = countAddr5
                self.controller.Decrement( step )
                countAddr5 −= step
            else:
                values['phase']  = ("%s" % phase)
                values['pot5_set'] = ("%s" % countAddr5)
                self.__saveCalibrationResults( \
                    values, 0, TestException.calib_phaseFailed)
                raise TestException(TestException.calib_phaseFailed)
            self.controller.setAddr(0)
            phase = self.controller.getPhase()

        sys.stdout.write( "\r Pot5 : %3s\tPhase : %.5f radians\n" % \
                          ( countAddr5, phase) )
        phase_values = self.controller.getPhaseValues()

        # Don't want the Save Routine to replace the spaces
        # between two consecutive values
        phase_values = str(phase_values).replace(" ", "")
        values[ 'pot5_set'     ] = ("%s" % countAddr5)
        values[ 'phase'        ] = ("%s" % phase)
        values[ 'phase_values' ] = ("'%s'" % phase_values)

        print "Phase Calibration Complete......\n"
        # End of Fifth Stage
        # ============================================



        # ============================================
        # Sixth Stage of Calibration
        # Set VSWR
        # ============================================

        print  "Setting Addr 6 (VSWR Mismatch Level) ..."
        print "Switching to Mismatch Load for VSWR Calibration"

        # Cold switching
        self.controller.setTR(0)
        self.siggen.setRFOff()
        self.powersupply.setPowerOff()
        self.controller.setLoad(self.controller.load_6_1_mismatch)

        self.controller.setAddr(6)
        self.siggen.setRFOn()
        self.powersupply.setPowerOn()
```

```
        self.controller.setRF(1)

        print "Setting VSWR Mismatch level to 6:1"
        # If we start in the middle and initially if it trips then
        # it has been set to a lower tolerance and hence we need to
        # increase the tolerance

        # Simple Search Algorithm
        # Initial bounds for search algorithm
        lowerbound = 0
        upperbound = 100
        step       = 100 # Just make sure it is not 0 or 1
        while True:
            vswr_fault = self.controller.getVSWR_Flag()
            sys.stdout.write("\r Pot6 : %3s\t6:1 mismatch reached: %s  " %\
                             ( countAddr6, ¬(bool(vswr_fault))) )
            sys.stdout.flush()
            if ( vswr_fault ≡ 1 ):
                step = int(math.floor((upperbound − countAddr6)/2))
                if step ≡ 0:
                    break
                # Now shift the lowerbound to the value of countAddr4
                lowerbound = countAddr6
                self.controller.Increment( step )
                countAddr6 += step
            elif ( vswr_fault ≡ 0 ):
                step = math.floor((upperbound − countAddr6)/2)
                if step ≡ 0:
                    # Decrement 1 more time
                    self.controller.Decrement(1)
                    countAddr6 −= 1
                    break
                else:
                    step = int(step)
                # Now shift the lowerbound to the value of countAddr4
                upperbound = countAddr6
                self.controller.Decrement( step )
                countAddr6 −= step
            if ( step ≡ 0 ∧ vswr_fault ≡ 0 ): #does not trip
                values[ 'pot6_set' ] = ( "%s" % countAddr6 )
                self.__saveCalibrationResults( \
                    values, 0, TestException.calib_vswrFailed )
                raise TestException(TestException.calib_vswrFailed)

        sys.stdout.write( "\r Pot6 : %3s\t6:1 mismatch reached: %s  \n" % \
                              ( countAddr6, bool(vswr_fault)) )

        values['pot6_set'] = ("%s" % countAddr6)  # VSWR POT
        print "VSWR Mismatch Calibration Complete......\n"

        # SAVE DATA TO THE DATABASE
        self.__saveCalibrationResults(values)
        # ========================================
        # Seventh Stage of Calibration
        self.controller.setAddr(7)
        self.controller.setIncr(1)
        # Shutdown
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        self.powersupply.setPowerOff()
        self.powersupply.setVolt(32)
        self.powersupply.setCurr(1)

        self.controller.setTR(0)

        # Cold switching
        self.siggen.setRFOff() #From signal generator
        self.controller.setLoad(self.controller.load_50_ohms)

        # End of Seventh Stage
```



```
        # ========================================


        # ========================================
        # End of Calibration Procedure
        print ""
        setStyle('bold', 'green')
        print 35 * '−'
        print " Calibration Process Completed !!!"
        print 35 * '−'
        setStyle('default')
        # ========================================

        return serialno

    # *******************************************************************
    # End of Public Functions Group
    # *******************************************************************



    # *******************************************************************
    #
    # Start of Private Functions Block
    #
    # *******************************************************************
    def __saveCalibrationResults(self, results, passed=1, failcode='NULL'):
        # By default the test passes and the fail code is 'NULL'
        failMsg = "NULL"
        if failcode ≠ "NULL":
            failMsg = TestException( failcode ).__str__()

        names  = [ ]
        values = [ ]
        for fieldname, value in results.items():
            names.append( "%s" % fieldname )
            values.append( "%s" % value.replace("",'NULL'))

        names_str = string.join(names, ',') + ', passed, test_fail_code'
        values_str = string.join(values, ',') + ", '%s', '%s'" % \
                     (passed, failMsg)

        db = Database.Database()
        db.storeCalibrationReadings(names_str, values_str)

        if failcode ≠ "NULL":
            setStyle('bold', 'red')
            print "\nCalibration of the amplifier Failed !!!"
            setStyle('default')

    # *******************************************************************
    #
    # End of Private Functions Block
    #
    # *******************************************************************
```

```
#! /usr/bin/env python

import DAQ
import time
import math

from Utilities import *

def int2bin(integer, bits = 5):
    # Convers integer value to binary value
    bin = ''
    while (True):
        bin = str(integer % 2) + bin
        integer = int(integer / 2)

        if (integer ≡ 0):
            break
    return str(("%0" + ("%s" % bits) + "d") % int(bin))


class Controller:
    # Load enumerations
    load_50_ohms      = 1  # Load switch 1
    load_3_1_mismatch = 2  # Load switch 2
    load_6_1_mismatch = 3  # Load switch 3
    load_open         = 4  # Load switch 4
    load_IQ           = 5  # Load switch 5


    def __init__(self):
        self.setTR(0)
        self.setAddr(0)
        self.setLoad(1)
        self.setIncr(1)
        self.setUpDown(0)


    def __del__(self):
        self.setTR (0)

    # ==================================================
    # Analog Input
    # ==================================================
    def getPhase(self):
        phase = self.getPhaseValues()
        phase = phase[int(0.40*len(phase)):int(0.60*len(phase))]
        phase_avg = sum(phase)/len(phase)

        return phase_mean


    def getPhaseValues(self):

        """
    The I and Q measurements are biased by the demo board and this
    bias must be eliminated from each before the phase is calculated.
    The I bias is around 0.8 V and the Q bias is around −0.8 V.  To
    determine the exact bias we sample the signals some amount of time
    before the rf pulse by pre−triggering in the DAQ and calculate
    the average signal levels during this pre−pulse time.

    To determine which portion of the I and Q values comprise the
    pre−pulse interval we also sample the RF pulse modulation signal,
    which ranges between 0 V and 4.7 V to swich the modulator.  Below
    2.5 V the modulator is switched off and the I and Q values are at
    their bias levels, thus we calculate the exact biasing.  Above
    2.5 V the modulator is switched on and the I and Q values are at
    telling us the phase.
    """
```



```
        # Not sure if this is needed
        time.sleep(0.25)

        """ Call the DAQ to get the I, Q, and pulse mod values
    data[0] = list of i values
    data[1] = list of q values
    data[2] = list of rf pulse modulation values
    """
        data = DAQ.acquireData(1000, 0.06)

        q_offsets = []
        i_offsets = []

        i_values     = []
        q_values     = []
        phase_values = []

        for i,q,rf_pulse in zip(data[0],data[1],data[2]):
            if rf_pulse < 2.5 : # Low on the RF Gate
                # RF pulse low, 0 W, I and Q at their bias levels
                i_offsets.append(i)
                q_offsets.append(q)
            else:
                # RF pulse high, 57dBm, I and Q tell us phase
                i_values.append(i)
                q_values.append(q)

        i_offset = sum(i_offsets)/len(i_offsets)
        q_offset = sum(q_offsets)/len(q_offsets)

        for i, q in zip(i_values, q_values):
            i −= i_offset
            q −= q_offset
            temp = math.atan2(q ,i)
            if temp < 0:
                temp += 2 * math.pi
            phase_values.append( temp )

        return phase_values


    def getPhaseValuesD(self):
        phase = self.getPhaseValues()
        phaseDeg = []
        for p in phase:
            phaseDeg.append ( p * 180 / math.pi )
        return phaseDeg

    # ==================================================
    # Digital Inputs
    # ==================================================
    def getVSWR_Flag(self):
        time.sleep(0.5) # Wait before taking the sample
        vals =[]
        for i in range(0,200):
            val = DAQ.readDigital()[0]
            vals.append(val)

        #print vals.count(1) ,"1s and ", vals.count(0), "0s"
        if (vals.count(0) > 10): # Probability of Error ;)
            return 1
        else:
            return 0

    def getTemp_Flag(self):
        time.sleep(0.5) # Wait before taking the sample
        vals =[]
        for i in range(0,200):
```

```
            val = DAQ.readDigital()[1]
            vals.append(val)

        # print vals.count(1) ,"1s and ", vals.count(0), "0s"
        if (vals.count(0) > 10): # Probability of Error ;)
            return 1
        else:
            return 0

    # ====================================================
    # Digital Outputs
    # ====================================================
    def setAddr(self,addr):
        # Mask with 0000 0111 to ensure addr is from 000 − 111
        addr = 0x07 & addr
        #print int2bin(addr, 3)
        DAQ.writeDigital(0, "2:0", int2bin(addr, 3))

    def setLoad(self,switchno = 1):
        # Switch can be from 1 to 5
        self.setTR(0)     # Makes sure of cold switching
        time.sleep(0.25)
        switchno =  1 << (switchno − 1)
        DAQ.writeDigital(0, "7:3", int2bin(switchno, 5))
        time.sleep(0.25)


    def setIncr(self,value):
        # Value takes in a 1 or a 0
        # Incrementf.setIncr(1) is Bit number 3 in the 8 bit DIO
        if (bool(value) ≡ True):
            DAQ.writeDigital(1, "6", "1")
        else:
            DAQ.writeDigital(1, "6", "0")

    def setUpDown(self,value):
        # Value takes in a 1 or a 0
        # UpDown is Bit number 4 in the 8 bit DOUT
        if (bool(value) ≡ True):
            DAQ.writeDigital(1, "7", "1")
        else:
            DAQ.writeDigital(1, "7", "0")

    def Increment(self,number_of_pulses=1):
        """
    This function toggles setIncr a speified amount
    while self.setUpDown is set to one.

    number_of_pulses is the number of times you want the Incr Line to
    toggle from 1 to 0
    """
        self.setUpDown(1)
        timedelay = 0.0625
        time.sleep(timedelay)
        self.setIncr(1)
        for i in range(0,2*number_of_pulses):
            self.setIncr(i % 2)
            time.sleep(2e−6)
        self.setIncr(1)
        time.sleep(timedelay)

    def Decrement(self,number_of_pulses=1):
        """
      This function toggles setIncr a specified amount
      while self.setUpDown is set to zero.

      number_of_pulses is the number of times you want the Incr Line to
      toggle from 1 to 0
    """
```



```
        self.setUpDown(0)
        timedelay = 0.0625
        time.sleep(timedelay)
        self.setIncr(1)
        for i in range(0,2*number_of_pulses):
            self.setIncr(i % 2)
            time.sleep(2e−6)
        self.setIncr(1)
        time.sleep(timedelay)

    # ====================================================
    # Timers (Gating Signals)
    # ====================================================
    def setTR(self, val, period = 20e−3, pw = 2e−3):
        if val ≡ 0:
            DAQ.stopTimers()
        elif val ≡ 1:
            DAQ.loadTimers(0,period,pw)

    def setRF(self, val, period = 20e−3, pw = 2e−3):
        # 10 % duty cycle
        if val ≡0:
            DAQ.stopTimers()
            #DAQ.loadTimers(0,period,pw)
        elif val ≡ 1:
            DAQ.loadTimers(1,period,pw)

    def setRFHigh(self):
        self.setTR(0)
        DAQ.writeDigital( 2 ,          # port
                         "4",          # lines
                         "1" )         # value

    def setRFLow(self):
        DAQ.writeDigital(2, "4", "0")
```

```python
#!/usr/bin/env python

import sys
import string
import datetime
import pytz
import psycopg2

# load the psycopg extras module
import psycopg2.extras

UTC = pytz.timezone( 'UTC' )

class Database:
    def __init__(self):
        self.dbcon = self.connect()

    def connect(self):
        dbcon = None
        try:
            dbhost = None     # None or hostname
            dbname = "sspa"   # Database name
            dbuser = None     # "postgres"

            if dbhost:
                # if host is given then auth mechanism is different
                connect_string = 'host=%s dbname=%s user=%s' % \
                                 ( dbhost, dbname, dbuser )
            else:
                if dbuser:
                    connect_string = 'dbname=%s user=%s' % \
                                     ( dbname, dbuser )
                else:
                    connect_string = 'dbname=%s' % \
                                     ( dbname )

            dbcon = psycopg2.connect( connect_string )
        except psycopg2.OperationalError, inst:
            msg = "%s db dbcon failed: %s"% (__name__,inst)
            print msg
            raise
        return dbcon


    def storeCalibrationReadings(self, names_str, values_str):
        names_str  = names_str  + ',dt'
        values_str = values_str + ",'%s'" % datetime.datetime.utcnow()
        self.insertTuples( "calibration", names_str, values_str)

    def storeOvenTestReadings(self, names_str, values_str):
        names_str  = names_str  + ',dt'
        values_str = values_str + ",'%s'" % datetime.datetime.utcnow()
        self.insertTuples( "oventest", names_str, values_str )

    def storePreBurninReadings(self, names_str, values_str):
        names_str  = names_str  + ',dt'
        values_str = values_str + ",'%s'" % datetime.datetime.utcnow()
        self.insertTuples( "preburnin", names_str, values_str )

    def storePostBurninReadings(self, names_str, values_str):
        names_str  = names_str  + ',dt'
        values_str = values_str + ",'%s'" % datetime.datetime.utcnow()
        self.insertTuples( "postburnin", names_str, values_str )

    def storeDVTReadings(self, names_str, values_str, tablename):
        names_str  = names_str  + ',dt'
        values_str = values_str + ",'%s'" % datetime.datetime.utcnow()
        self.insertTuples( tablename, names_str, values_str )
```



```python
    def storeOffsetSettings(self, names_str, values_str):
        names_str  = names_str  + ',dt'
        values_str = values_str + ",'%s'" % datetime.datetime.utcnow()
        self.insertTuples( "offset_calibration", names_str, values_str )

    def insertTuples( self, tablename, names_str, values_str ):
        dbcur = self.dbcon.cursor()
        strSQL = "INSERT INTO %s (%s) VALUES (%s)" % \
                 ( tablename, names_str, values_str )
        try:
            dbcur.execute(strSQL)
        except psycopg2.ProgrammingError, e:
            msg = "ProgrammingError: %s" % e
            print msg
            self.dbcon.rollback()
            raise

        try:
            self.dbcon.commit()
        except psycopg2.ProgrammingError, e:
            msg = "ProgrammingError %s, not committing" % e
            print msg
            self.dbcon.rollback()
            raise
        dbcur.close()


if __name__ == "__main__":
    db=Database()
    for i in db.fetchData():
        print i
```

```
#!/usr/bin/env python

import DVTTests
import OperationalTest

import string
import os
import sys
import time

from TestException import *
from Utilities import *


class DVT:
    def __init__(self):
        os.system('reset')
        self.WelcomeScreen()

    def WelcomeScreen(self):
        os.system('clear')
        setStyle('bold')
        print 60 * "="
        print " Welcome to the AMISR SSPA Design Verification Test Suite"
        print 60 * "="
        setStyle('default')


    def Login(self):
        print ""
        print "Please login below (avoid spaces) ... "
        LoginName = ""
        while LoginName ≡ "":
            try:
                LoginName = str(raw_input("Username : "))
                LoginName = LoginName.strip().replace(" ","_")
            except KeyboardInterrupt:
                print "\n"
                setStyle('default')
                sys.exit(1)
        self.UserName = LoginName

    def run (self):
        while True:
            self.Login()
            self.WelcomeScreen()
            while ¬ (self.UserName ≡ ""):
                print ""
                print "0. Log Off", self.UserName
                print "1. Qualification Test"   # Pre−burnin
                print "2. Operational Test"     # Oventest
                print "3. Pre−test Benchmark"   # Pre−burnin
                print "4. Post−test Benchmark" # Post−burnin
                print "Q. Quit\n"

                inp = ""
                while inp ≡ "":
                    try:
                        inp = raw_input("Enter our choice : ")
                        inp = string.lower( str(inp) )
                        inp = inp.strip()
                    except KeyboardInterrupt:
                        setStyle( 'bold', 'red' )
                        print "\n\nForced Termination By the User ... \n"
                        setStyle( 'default' )
                        sys.exit(1)

                if ( inp ≡ "q" ):
                    return
```



```
                elif ( inp ≡ "0" ):
                    self.UserName = ""                    break
                try:     # Try .. Finaly block
                    try: # Try .. Except block
                        if ( inp ≡ "1" ):
                            proc =  DVTTests.DVTTests(self.UserName)
                            proc.runDVT( proc.qualification_test )
                        elif ( inp ≡ "2" ):
                            proc = OperationalTest.OperationalTest \
                                   (self.UserName)
                            proc.runOperationalTest()
                        elif ( inp ≡ "3" ):
                            proc =  DVTTests.DVTTests(self.UserName)
                            proc.runDVT( proc.pretest_benchmark )
                        elif ( inp ≡ "4" ):
                            proc =  DVTTests.DVTTests(self.UserName)
                            proc.runDVT( proc.posttest_benchmark )
                    except KeyboardInterrupt:
                        setStyle( 'bold', 'red' )
                        print "\n\nProcess Terminated By User ... \n"
                        setStyle( 'default' )
                    except Exception, err:
                        setStyle('bold', 'red')
                        print "\n", 65 * "−"
                        msg = err.__str__().split("\n")
                        for _msg in msg:
                            print ' ' + _msg
                            print 65 * "−"
                        setStyle( 'default' )
                finally:
                    # Delete the object so that it calls its destructor
                    # to restore settings to default
                    try:
                        proc.destructor()
                        del proc
                    except:
                        pass


if  __name__ ≡ "__main__":
    DVT().run()
    print "\nPlease wait while the system shuts down ... \n\n"
```

```
#! /usr/bin/env python

import SpecTests
import Database

import time
import string
import sys
import math

from TestException import *
from Utilities import *


####################################################################
##
## Specifications Tests for Design Verification Test
##
####################################################################

class DVTTests:
    qualification_test = 1
    pretest_benchmark  = 2
    posttest_benchmark = 3

    dict_tests = { qualification_test : "Qualification Test",
                   pretest_benchmark  : "Pre−test Benchmark",
                   posttest_benchmark : "Post−test Benchmark"
                 }

    def __init__(self, username):
        try:
            self.spectest = SpecTests.SpecTests(username)
            self.user     = username
        except Exception:
            raise

    def __del__(self):
        try:
            del self.spectest
        except:
            pass


    # ********************************************************************
    #
    # Start of  "Public Functions" Block
    #
    # ********************************************************************

    # ====================================================================
        """
    Qualification Test / Pre−test Benchmark / Post−test Benchmark

    1. OverPulse Test
    2. Droop Test
    3. Power Efficiency Test
    4. Power Correct Test
    5. Open Load Test
    6. Mismatch Load Test
    """
    def runDVT(self, testType ):
        values = {   "sn"                   : " ",
                     "uname"                : " ",

                     "pulsewidth"          : " ",
                     "overpulse_passed"    : " ",

                     "droop_initpower"      : " ",
```



```
                     "droop_finalpower"    : " ",
                     "droop_passed"        : " ",

                     "current_430"         : " ",
                     "voltage_430"         : " ",
                     "power_430"           : " ",

                     "current_450"         : " ",
                     "voltage_450"         : " ",
                     "power_450"           : " ",

                     "current_440"         : " ",
                     "voltage_440"         : " ",
                     "power_440"           : " ",

                     "power_8_5"           : " ",
                     "power_11_5"          : " ",
                     "powercorrect_passed": " ",

                     "open_passed"         : " ",
                     "mismatch_passed"     : " "
                  }  # Values dictionary

        testFailFlag = False
        serialno = ""
        while serialno ≡ "":
            print ""
            sn = raw_input("Please enter the Serial Number of the SSPA :")
            serialno = str(sn).strip().replace(" ","_")

        values['sn']    = "'%s'" % serialno
        values['uname'] = "'%s'" % self.user

        setStyle( 'bold', 'white' )
        print "\nInitializing %s Test Porcedures..." % \
              self.dict_tests[ testType ]
        setStyle( 'default' )

        # Initialize devices
        self.spectest.initDevices()

        # Overpulse with 3ms pulse
        overpulse = self.conductOverPulseTest()
        values [ 'pulsewidth' ]       = "'%s'" % string.join(overpulse[0], ",")
        values [ 'overpulse_passed' ] = "'%s'" % str(¬ bool(overpulse[1]))
        if bool(overpulse[1]) ≡ True: # Returns fail code as 1 if fails
            testFailFlag = True

        # Droop
        (droop, droop_passed) = self.conductDroopTest()
        values [ 'droop_initpower'  ] = "'%s'" % droop[0]
        values [ 'droop_finalpower' ] = "'%s'" % droop[1]
        values [ 'droop_passed' ] = "'%s'" % droop_passed
        if droop_passed ≡ False:
            testFailFlag = True

        # Efficiency at 430, 440, 450
        (currents, voltages, powers, failflag) = self.conductEfficiencyTest()
        for i in [430,440,450]: # index 0,1,2 given by i /10 − 43
            values [ "current_%s" % i ] = "'%s'" % currents [i/10 − 43]
            values [ "voltage_%s" % i ] = "'%s'" % voltages [i/10 − 43]
            values [ "power_%s"   % i ] = "'%s'" % powers   [i/10 − 43]

        testFailFlag = failflag
        sys.stdout.write ( "Efficiency Test after burnin ...\t" )
         if ( failflag ≡ False ):
            # Passed
            setStyle('bold', 'green' )
            sys.stdout.write("[ PASSED ]")
```

```
                setStyle('default')
            else:
                # Failed
                setStyle('bold', 'red' )
                sys.stdout.write("[ FAILED ]")
                setStyle('default')

        # Power Correct
        powercorrect = self.conductPowerCorrectTest()
        values [ 'power_8_5' ] =  powercorrect[0][0]
        values [ 'power_11_5'] =  powercorrect[0][1]
        values [ 'powercorrect_passed' ] = "'%s'" % \
                                           str(¬ bool(powercorrect[1]))
        if bool(powercorrect[1]) ≡ True:
            testFailFlag = True

        # Open and Mismatch
        variousloads_passed = self.conductVariousLoadsTest()
        values [ 'open_passed'     ] = "'%s'" % \
                                    str(bool(variousloads_passed[0]))
        values [ 'mismatch_passed' ] = "'%s'" % \
                                         str(bool(variousloads_passed[1]))
        if bool(variousloads_passed[0]) ≡ False ∨ \
               bool(variousloads_passed[1]) ≡ False:
            testFailFlag = True

        # Save Data
        # ----------------------------------------
        self.__saveResults(values, testType)
        # ----------------------------------------

        # ========================================
        # End of Procedure
        print "\n"
        if testFailFlag ≡ True:
            setStyle('bold', 'red')
            print 35 * '-'
            print " %s Failed !!!" % self.dict_tests[ testType ]
            print 35 * '-'
        else:
            setStyle('bold', 'green')
            print 35 * '-'
            print " %s Completed !!!" % self.dict_tests[ testType ]
            print 35 * '-'
        setStyle('default')
    # ==================================================================



    ############################################################
    ## Data Saving Routines
    ############################################################

    def __saveResults(self, results, testType):
        tablename = {self.qualification_test  : "dvt_qualification",
                     self.pretest_benchmark   : "dvt_pretest_benchmark",
                     self.posttest_benchmark  : "dvt_posttest_benchmark"}
        names  = [ ]
        values = [ ]
        for fieldname, value in results.items():
            names.append( "%s" % fieldname )
            values.append( "%s" % value )

        names_str = string.join(names, ',')
        values_str = string.join(values, ',')

        db = Database.Database()
        db.storeDVTReadings(names_str, values_str, tablename[testType])
```



```
    # *******************************************************************
    # End of Private Functions Block
    # *******************************************************************
```

```
#! /usr/bin/env python
# -*- python -*-

from Tkinter import *
import Tkinter as Tk
import Controller


#################################################
##   Manual Control Functions
#################################################


def setLoadOne(event):
    selectRFandGateOff()
    controller.setLoad(controller.load_50_ohms)
    print "load switched to one"

def setLoadTwo(event):
    selectRFandGateOff()
    controller.setLoad(controller.load_6_1_mismatch)
    print "load switched to two"

def setLoadFive(event):
    selectRFandGateOff()
    controller.setLoad(controller.load_IQ)
    print "load switched to five"

def setLoadFour(event):
    selectRFandGateOff()
    controller.setLoad(controller.load_open)
    print "load switched to four"

def setLoadThree(event):
    selectRFandGateOff()
    controller.setLoad(controller.load_3_1_mismatch)
    print "load switched to three"

def setRFandGateOff(event):
    controller.setTR(0)
    print "Both Off"

def setGateOn(event):
    controller.setTR(1)
    print "Gate Only"

def setRFandGateOn(event):
    controller.setRF(1)
    print "RF and Gate On"

def selectRFandGateOff():
    SELF.frame2_RFandGateOff.select()

def exitWindow(event=None):
    setRFandGateOff(None)
    setLoadOne(None)
    #root1.iconify()
    root2.destroy()


class manualControlsInterface:
    def __init__(self, master): #, main1, timeVar, loadVar, master=None):
        global root2
        global SELF
        global controller

        global load
        global timevar
```



```
        SELF = self
        root2 = master
        controller = Controller.Controller()
        timevar = StringVar()
        load = StringVar()

        root2.protocol("WM_DELETE_WINDOW", exitWindow)

        frame1 = Frame(root2, width="325", height="215",
                       relief="groove", borderwidth="2")
        frame1.place(in_=root2, x=10, y=10)

        frame2 = Frame(root2, width="325", height="215",
                       relief="groove", borderwidth="2")
        frame2.place(in_=root2, x=340, y=10)

        frame3 = Frame(root2, width="655", height="35",
                       relief="groove", borderwidth="2")
        frame3.place(in_=root2, x=10, y=235)

        self.frame2_timercardHeading = Label (frame2,
                                              text="Gating Line Settings",
                                              font="Helvetica 14 bold")
        self.frame2_timercardHeading.place(in_= frame2,x=70,y=10)


        self.frame2_RFandGateOff = Radiobutton (frame2,
                                                text="RF and Gate OFF",
                                                variable=timevar, value=1,
                                                cursor="hand2")
        self.frame2_RFandGateOff.place(in_=frame2,x=70,y=80)
        self.frame2_RFandGateOff.bind("<Button-1>", func=setRFandGateOff)
        self.frame2_RFandGateOff.select()
        setRFandGateOn(None)

        self.frame2_GateOn = Radiobutton (frame2, text="Gate ON",
                                          variable=timevar, value=2,
                                          cursor="hand2")
        self.frame2_GateOn.place(in_=frame2,x=70,y=110)
        self.frame2_GateOn.bind("<Button-1>", func=setGateOn)

        self.frame2_RFandGateOn = Radiobutton (frame2, text="RF and Gate ON",
                                               variable=timevar, value=3,
                                               cursor="hand2")
        self.frame2_RFandGateOn.place(in_=frame2,x=70,y=140)
        self.frame2_RFandGateOn.bind("<Button-1>", func=setRFandGateOn)


        self.frame1_switchHeading = Label (frame1, text="Load Switch Settings",
                                           font="Helvetica 14 bold")
        self.frame1_switchHeading.place(in_=frame1,x=40,y=10)

        self.frame1_loadOne = Radiobutton(frame1, text="50 Ohm", variable=load,
                                          value=1, cursor="hand2")
        self.frame1_loadOne.place(in_=frame1,x=50,y=60)
        self.frame1_loadOne.bind("<Button-1>", func=setLoadOne)
        self.frame1_loadOne.select()
        setLoadOne(None)

        self.frame1_loadTwo = Radiobutton(frame1, text="6:1 Mismatch",
                                          variable=load, value=2,
                                          cursor="hand2")
        self.frame1_loadTwo.place(in_=frame1,x=50,y=90)
        self.frame1_loadTwo.bind("<Button-1>", func=setLoadTwo)

        self.frame1_loadThree = Radiobutton(frame1, text="3:1 Mismatch",
                                            variable=load, value=3,
                                            cursor="hand2")
```

```
        self.frame1_loadThree.place(in_=frame1,x=50,y=120)
        self.frame1_loadThree.bind("<Button-1>", func=setLoadThree)

        self.frame1_loadFour = Radiobutton(frame1, text="Open", variable=load,
                                    value=4, cursor="hand2")
        self.frame1_loadFour.place(in_=frame1,x=50,y=150)
        self.frame1_loadFour.bind("<Button-1>", func=setLoadFour)

        self.frame1_loadFive = Radiobutton(frame1, text="IQ Detector",
                                    variable=load, value=5,
                                    cursor="hand2")
        self.frame1_loadFive.place(in_=frame1,x=50,y=180)
        self.frame1_loadFive.bind("<Button-1>", func=setLoadFive)

        self.frame3_backButton = Button(frame3, text="Quit", cursor="hand2")
        self.frame3_backButton.place(in_=frame3, x=575, y=0)
        self.frame3_backButton.bind("<Button-1>", func=exitWindow)


if __name__ == "__main__":
    root = Tk.Tk()
    root.resizable(0,0)
    root.title('Welcome to the Automated Test Suite (ATS)')

    # Center the window in the the display screen
    w , h  = 675, 275
    ws, hs = root.winfo_screenwidth(), root.winfo_screenheight()
    x , y  = (ws/2) - (w/2), (hs/2) - (h/2)

    root.geometry('%dx%d+%d+%d' % (w, h, x, y))
    w = manualControlsInterface (root)
    root.mainloop()
```

```
#! /usr/bin/env python

import Controller
import PowerMeter
import SignalGen
import Database

import math
import time
import string
import sys
import os

from TestException import *

offset1_ref = 2.3  # signal generator dBm
offset1_tol = 0.5  # plus/minus 0.5 dB

offset2_ref = 20   # input power dBm
offset2_tol = 1    # plus/minus 1 dB

offset3_ref = 59   # output power
offset3_tol = 1    # plus/minus 1 dB


class OffsetCalibration:
    def __init__(self):
        try:
            # Resetting offsets values in the offsets.ini file
            self.__writeOffsets (0,0,0)

            print "\nInitializing Devices..."
            self.powermeter = PowerMeter.PowerMeter( True )
            # True to allow offsets.ini not found condition

            # Zeroing takes time, so the function has time.sleep(3)
            self.powermeter.zeroPowerHeads()

            self.siggen = SignalGen.SignalGen( True )
            # True to allow offsets.ini not found condition
            self.controller = Controller.Controller()
        except TestException:
            raise

    def destructor(self):
        try:
            del self.powermeter
            del self.siggen
            del self.controller
        except:
            pass

    # ******************************************************************
    #
    #   Public Functions Block
    #
    # ******************************************************************
    def CalibrateOffset(self):
        # print "\n\nWelcome to the Offset Calibration Wizard."
        # print "If you have an SSPA connected, please disconnect it !!!"
        inp = "n"
        while ¬ ( inp ≡ "y" ∨ inp ≡ "q" ):
            print "\nStep 1: Connect 'Amp Input' to 'CABLE B'"
            print "\tusing the N−Type to SMA adapter provided..."
            inp = string.lower(raw_input("Did you do this? [y/q]: "))
            if inp ≡ "q":
                raise TestException (TestException.process_abort_offsetcalib)

        print "\nTurning on RF, Please wait ...\n"
```



```
        self.controller.setRFHigh()     # Sets pulse mod to high, i.e., on

        # initialize out of bounds to ensure measurement and adjustment
        power = 999
        self.siggen.setAmplitude(10)
        offset1 = 0
        self.siggen.setRFOn()
        power = self.powermeter.getMeasOutput( offsetcalibration = True )

        print "Power reading : %s dBm (without offset compensation)" % power
        target_power_at_sspa_input = 10
        offset1 = target_power_at_sspa_input − power
        print "Calculated offset for Signal generator: %s dB" % offset1

        # Sanity check for offset 1
        if offset1 < (offset1_ref − offset1_tol) ∨ \
           offset1 > (offset1_ref + offset1_tol):
            print "Signal generator offset:"
            print "\tExpected : %s, plus/minus %s dB \t Calculated : %s dB" % \
                  (offset1_ref, offset1_tol, offset1)
            self.__saveResults( offset1)
            raise TestException (TestException.calib_offsetCalibfailed)

        self.siggen.setAmplitude(target_power_at_sspa_input + offset1)

        power = self.powermeter.getMeasOutput( True )
        print "Power reading : %s dBm  (with offset compensation)" % (power)

        chAReading = self.powermeter.getMeasInput( offsetcalibration = True )
        print "\nCorresponding reading in Channel A is %s dBm" % chAReading
        offset2 = target_power_at_sspa_input − chAReading
        print "Calculated Offset for Channel A is %s dB" % offset2

        # Sanity check for offset 2
        if offset2 < (offset2_ref − offset2_tol) ∨ \
           offset2 > (offset2_ref + offset2_tol):
            print "Input Power offset:"
            print "\tExpected : %s, plus/minus %s dB \t Calculated : %s dB" % \
                  (offset2_ref, offset2_tol, offset2)
            self.__saveResults( offset1, offset2)
            raise TestException (TestException.calib_offsetCalibfailed)

        self.siggen.setRFOff()

        self.siggen.setAmplitude(17)    # dBm
        self.siggen.setRFOn()
        fullpower = self.powermeter.getMeasOutput(1)
        self.siggen.setRFOff()

        inp = "n"
        while ¬ ( inp ≡ "y" ∨ inp ≡ "q" ):
            print "\nStep 2: Now connect Cable B back to Channel B."

            inp = string.lower(raw_input("Did you do this? [y/q]: "))
            if inp ≡ "q":
                raise TestException (TestException.process_abort_offsetcalib)

        while True:
            inp = "n"
            while ¬ ( inp ≡ "y" ∨ inp ≡ "q" ):
                print "\nStep 3: Connect 'Amp Input' to 'Amp Output'"
                print "\tusing the N−Type to SMA adapter provided."
                inp = string.lower(raw_input("Did you do this? [y/q]: "))
                if inp ≡ "q":
                    raise TestException \
                          (TestException.process_abort_offsetcalib)
            self.siggen.setRFOn()
            time.sleep( 2 )
```

```
        chBReading =  self.powermeter.getMeasOutput(1)
        print "Corresponding reading in Channel B is %s dBm" % chBReading
        offset3 = (fullpower) − chBReading
        print "Offset for Channel B is %s dB" % offset3

        # Sanity check for offset 3
        if offset3 < (offset3_ref − offset3_tol) ∨ \
               offset3 > (offset3_ref + offset3_tol):
            print "Output Power offset:"
            print "\tExpected: %s, plus/minus %s dB \t Calculated: %s dB" \
                  % (offset3_ref, offset3_tol, offset3)
            inp = ""
            while ( inp ≠ "y" ∧ inp ≠ "n"):
                inp = raw_input("Do you want to redo this step? [y/n]")
                inp = string.lower(str(inp))
            if inp ≡ "y":
                continue
            elif inp ≡ "n":
                self.__saveResults( offset1, offset2, offset3 )
                raise TestException (TestException.calib_offsetCalibfailed)
        break  # Break While if it passes successfully

    self.__writeOffsets(offset1, offset2, offset3)
    self.__saveResults(offset1, offset2, offset3);
    self.siggen.setRFOff()
    self.controller.setRFLow()

    print "\nOffset Calibration Complete!"
    return 1


# *******************************************************************
#
#   Private Functions Block
#
# *******************************************************************
def __writeOffsets(self,siggen, input, output):
    #Writes the offsets to offsets.ini
    import pytz
    import datetime
    UTC     = pytz.timezone('UTC')
    mytz    = pytz.timezone('America/Los_Angeles')
    my_time = datetime.datetime.utcnow().replace(tzinfo = UTC)

    f = open( os.environ[ 'HOME' ] + '/Code/offsets.ini', 'w')
    f.write("This file contains the offset due to losses and attn in dB.")
    f.write("\nInput Offset  : %s" % input  )
    f.write("\nOutput Offset : %s" % output )
    f.write("\nSig Gen Offset: %s" % siggen )
    f.write("\nDate and Time Stamp : %s" % my_time.astimezone(mytz))
    f.close()

def __saveResults(self, offset_1, offset_2 = 'NULL', offset_3 ='NULL'):
    offsets = [ offset_1, offset_2, offset_3 ]
    names   = [ ]
    values  = [ ]
    cnt = 1
    for i in offsets:
        names.append ( "offset_%s" % cnt )
        values.append( "%s" % i)
        cnt += 1

    names_str = string.join(names, ',')
    values_str = string.join(values, ',')

    db = Database.Database()
    db.storeOffsetSettings (names_str, values_str)
```

```
#! /usr/bin/env python

import Controller
import PowerMeter
import PowerSupply
import SignalGen
import TempSensor
import Database

import time
import string
import sys

from TestException import *
from Utilities import *

class OperationalTest:
    def __init__(self, uName):
        try:
            print "\nInitializing Devices..."

            self.powersupply = PowerSupply.PowerSupply()
            self.powermeter = PowerMeter.PowerMeter()

            self.siggen = SignalGen.SignalGen()

            self.sensor = TempSensor.TempSensor()

            # Make sure this is initialized last
            self.controller = Controller.Controller()

            self.user = uName
        except Exception:
            raise

    # *********************************************************************
    #
    #  Public functions
    #
    # *********************************************************************
    def destructor(self): # Issues with using the default __del__()
        try:
            del self.sensor
            del self.controller
            del self.powersupply
            del self.siggen
        except:
            pass

    def runOperationalTest (self):
        values = {   "sn"            : "",
                     "uname"         : "",
                     "label"         : "",
                     "current"       : "",
                     "power_in"      : "",
                     "power_out"     : "",
                     "mins"          : "",
                     "temp"          : "",
                     "tempflag"      : "",
                     "vswrflag"      : ""
                 }  # Values dictionary


        serialno = ""
        while serialno ≡ "":
            print ""
            sn = raw_input("Please enter the Serial Number of the amplifier :")
            serialno = str(sn).strip().replace(" ","_")
```



```
        label = ""
        while label ≡ "":
            print ""
            label = str(raw_input("Please enter a label for this test run :"))
            label = label.strip().replace(" ","_")


        values['sn']    = "'%s'" % serialno
        values['uname'] = "'%s'" % self.user
        values['label'] = "'%s'" % label


        how_many_minutes = int(raw_input("\nHow many minutes to run ? :"))

        setStyle( 'bold', 'white' )

        print "\nInitializing Environmental Test Porcedures..."
        setStyle( 'default' )

        self.controller.setTR(0)
        self.siggen.setRFOff()          #From signal generator

        self.powersupply.setPowerOff()
        self.powersupply.setVolt(32)
        self.powersupply.setCurr(1)

        self.controller.setLoad(self.controller.load_50_ohms)

        # Setting address to normal working conditions
        self.controller.setAddr(0)

        self.powersupply.setPowerOn()

        current = self.powersupply.getCurr()
        print "Current measurement of ", current, "Amps"

        print "Turning on Power Supply..."
        self.powersupply.setPowerOn()

        current = self.powersupply.getCurr()
        print "Initial current of ", current, "Amps"


        if (current > 0.5):
            print "\nExcess initial current drawn... Test Cannot proceed ...\n"
            self.__saveCalibrationResults(values, 0,
                                          TestException.calib_initialCurrFailed)
            raise TestException(TestException.calib_initialCurrFailed)
        elif (current < 0):
            print "\nNo SSPA Connected... Test Cannot proceed ... \n"


        # Set Current to 5A
        print "Self test passed... Setting current to 5 Amps...\n"
        self.powersupply.setPowerOff()
        self.powersupply.setVolt(32)
        self.powersupply.setCurr(5)
        self.powersupply.setPowerOn()


        print "Starting TR only ..."
        # Start TR pulse (NO RF!!) and check current
        # This start only the TR gate pulse, the RF pulse remains zero.
        self.controller.setTR(1) # only TR running at default dutycycle
        current = self.powersupply.getCurr()
        print "Current measurement of " + current + \
              "Amps with only TR running..."

        if (current > 0.5):
```

```
            print "\nToo much current drawn when turning on TR only..." + \
                  "Test Cannot proceed ...\n"
            return
            self.__saveCalibrationResults(values, \
                                         0, TestException.calib_gatePulseFailed)
            raise TestException(TestException.calib_gatePulseFailed)

        print "Waiting for RF to turn on"
        time.sleep(2)
        # Start RF signal
        self.siggen.setRFOn()

        # Start RF Input and TR gating
        print "Turning RF gate on...\n"
        self.controller.setRF(1)# RF and TR running at default values
        time.sleep(5)           # Time delay before starting to measure current

        minutes = 0

        while True:
            sys.stdout.write( "\nAcquring Data ... \t\t" )
            sys.stdout.flush()
            current  = self.powersupply.getCurr()
            powerin  = self.powermeter.getMeasInput()
            powerout = self.powermeter.getMeasOutput()

            values['current']  = ("%s" % current)
            values['power_in'] = ("%s" % powerin)
            values['power_out']= ("%s" % powerout)
            values['mins']     = minutes
            values['temp']     = self.sensor.getTemperature()
            values['tempflag'] = ("'%s'" % self.controller.getTemp_Flag())
            values['vswrflag'] = ("'%s'" % self.controller.getVSWR_Flag())

            sys.stdout.write( "\nSaving Data ...\n" )
            sys.stdout.flush()
            print "Power in :%s, Power out :%s, Current :%s" % \
                   (powerin, powerout, current)

            # Database save call
            self.__saveOvenTestResults(values)

            # Check for break condition
            if minutes >= how_many_minutes:
                break

            # Go back to the loop
            seconds = 0
            while seconds < 60:
                str_time = str(minutes) + ' minutes and ' + str(seconds) + \
                           ' seconds...'
                sys.stdout.write( "\rWaiting:%s" % str_time )
                sys.stdout.flush()
                time.sleep(1)
                seconds += 1
            minutes += 1

        # ========================================
        # End of Oven Test Procedure
        print ""
        setStyle('bold', 'green')
        print 35 * '-'
        print "Oven Test Completed !!!"
        print 35 * '-'
        setStyle('default')
        # ========================================


    # *********************************************************************
```



```
    #
    #  Private functions
    #
    # *********************************************************************
    def __saveOvenTestResults(self, results, teststatus=1, failcode='NULL'):
        # By default the test passes and the fail code is 'NULL'

        names  = [ ]
        values = [ ]
        for fieldname, value in results.items():
            names.append( "%s" % fieldname )
            values.append( "%s" % value )

        names_str = string.join(names, ',')
        values_str = string.join(values, ',')

        db = Database.Database()
        db.storeOvenTestReadings(names_str, values_str)

if __name__ == '__main__':
    OvenTest("kaushal").OvenTest()
```

```
#! /usr/bin/env python

# PowerMeter Class is the direct connection between the main computer and
# the Agilent Power Meter.
# This is the class that should be used to interface with the power meter
# This class implements various functions of the power meter using the SCPI
# command set.

from visa import *
from TestException import *
from Utilities import *

import sys
import time
import os

import OffsetCalibration

class PowerMeter:
    "Controls power meter settings for channel A & B"

    GPIB_ADDR = 14

    def __init__(self, offsets_ini_not_found_allow = False):
        try:
            sys.stdout.write(" Initializing Power Meter...\t\t")
            sys.stdout.flush()
            self.device = instrument("GPIB::%s" % self.GPIB_ADDR,
                                    values_format = single | big_endian )
            try:
                self.device.write("*CLS")     # Clear registers
                if self.device.ask("*IDN?")≡"":
                    raise TestException(TestException.device_error_PowerMeter)
            except Exception:
                raise TestException(TestException.device_error_PowerMeter)
            try:
                # Initialize some of the settings of the power meter
                # ------------------------------------------------
                self.device.write("*CLS")     # Clear registers
                self.device.write("*RST")     # Reset
                self.setFreq( 440e6 )
                self.__setTraceUnits()
                self.__setCaptureRate( "DOUBLE" )
                self.__setMeasurementSetting( "PEAK", "CONT", "EXT" )
                self.__setTriggerDelay(100e-6)
            except Exception:
                raise TestException(TestException.device_error_PowerMeter)

            if offsets_ini_not_found_allow ≡ False:
                # offsets_ini_not_fount_allow is False by default
                # When called from the PowerMeter Offset calibration routine
                # we don't have to check for the presence of the file.
                try:
                    self.inputoffset = self.__getOffsetInput()
                    self.outputoffset = self.__getOffsetOutput()

                    # Do a sanity check on the offset values
                    # using the range defined in the OffsetCalibration
                    offset2_ref = OffsetCalibration.offset2_ref
                    offset2_tol = OffsetCalibration.offset2_tol

                    offset3_ref = OffsetCalibration.offset3_ref
                    offset3_tol = OffsetCalibration.offset3_tol

                    if self.inputoffset < (offset2_ref − offset2_tol) ∨ \
                           self.inputoffset > (offset2_ref + offset2_tol) ∨ \
                           self.outputoffset < (offset3_ref − offset3_tol) ∨ \
                           self.outputoffset > (offset3_ref + offset3_tol) :
                        raise TestException( TestException.invalid_offsets )
```



```
                        self.__setGain( self.inputoffset, self.outputoffset)
                    except IOError, err:
                        print err
                        raise TestException(TestException.offsets_ini_not_found)
                else:
                    self.inputoffset  = 0
                    self.outputoffset = 0

            except TestException, e:
                logger.Error( e )
                raise



    def getMeasInput(self, offsetcalibration = False ):
        # Get the peak power measurement from Channel 1
        # CALC1 implies input  (Channel A)
        # ----------------------------------------
        if ¬ offsetcalibration:
            self.__setMeasurementSetting( "PEAK", "CONT", "EXT" )
            return float(self.device.ask("MEAS1?")) #+ self.inputoffset
        else:
            self.__setMeasurementSetting( "AVER", "CONT", "IMM" )
            value = float(self.device.ask("FETCH1?"))
            return value

    def getMeasOutput(self, offsetcalibration = False):
        # Get the peak power measurement from Channel 2
        # CALC2 implies output (Channel B)
        # ----------------------------------------
        if ¬ offsetcalibration:
            time.sleep(3)
            self.__setMeasurementSetting( "PEAK", "CONT", "EXT" )
            return float(self.device.ask("MEAS2?")) #+ self.outputoffset
        else:
            self.__setMeasurementSetting( "AVER", "CONT", "IMM" )
            value = float(self.device.ask("FETCH2?"))
            return value

    def getTraceData(self, timelength = .02, triggerdelay = 0):
        # Get the trace data on channel B
        # Pass the length of time you want to capture as time
        # By default, captures only 1 pulse (20ms)

        self.device.write("INIT1:CONT 1")
        self.device.write("INIT2:CONT 0")
        self.device.write("TRIG:SEQ1:SOUR IMM")
        self.device.write("TRIG:SEQ2:SOUR EXT")
        self.__setTriggerDelay( triggerdelay )
        self.device.write("TRAC2:STAT 1")
        self.device.write("SENS2:TRAC:TIME %s" % timelength )
        self.device.write("INIT2:IMM")


        timeout = 15
        while timeout > 0:
            sys.stdout.write( "\rPlease wait for %2s seconds to fetch " + \
                              "the trace ..." % timeout)
            sys.stdout.flush()
            time.sleep(1)
            timeout −= 1

        sys.stdout.write( "\r" + 50*" " + "\r" )
        sys.stdout.flush()

        # Medium resolution decimates the data to 1000 points
        self.device.write("TRAC2:DATA? MRES")
```

```
        result = self.device.read_values()

        # Reset back
        self.device.write("INIT1:CONT 1")
        self.device.write("INIT2:CONT 1")
        self.device.write("TRIG:SEQ1:SOUR EXT")
        self.device.write("TRIG:SEQ2:SOUR EXT")
        self.__setTriggerDelay( 100e−6 )

        result_offset_comp = []

        for i in result:
            result_offset_comp.append( i )


        return result_offset_comp

    def zeroPowerHeads(self):
        self.device.write("CAL1:ZERO:NORM:AUTO ONCE")
        time.sleep(3)
        self.device.write("CAL2:ZERO:NORM:AUTO ONCE")
        time.sleep(3)

    def setFreq(self, freq = 440e6 ):
        # set the frequency to 440 MHz BY DEFAULT
        self.device.write("SENS1:FREQ %sHz" % freq)
        self.device.write("SENS2:FREQ %sHz" % freq)


    # *******************************************************
    #
    # Private functions
    #
    # *******************************************************
    def __setGain(self, gainA, gainB):
        self.device.write( "SENS1:CORR:GAIN2 %s" % gainA )
        self.device.write( "SENS2:CORR:GAIN2 %s" % gainB )

    def __setCaptureRate(self, mode = "DOUBLE"):
        self.device.write("SENS1:MRAT %s" % mode)
        self.device.write("SENS2:MRAT %s" % mode)

    def __setMeasurementSetting(self, pow="PEAK", mode="CONT", trigger ="EXT")
:
        # mode is acquisition mode and takes in "CONT", "SING" or "FREE"
        # trigger is triggering source and takes in "EXT" or "IMM"
        import string
        mode    = string.upper(mode)
        trigger = string.upper(trigger)
        pow     = string.upper(pow)

        if mode ≡ "CONT" ∨ mode ≡"FREE":
            # continuous trigger mode with external or imm trigger
            self.device.write("INIT1:CONT 1")
            # continuous trigger mode with external or imm trigger
            self.device.write("INIT2:CONT 1")
        elif mode ≡ "SING":
            # single trigger run mode with internal trigger
            self.device.write("INIT1:CONT 0")
            # single trigger run mode with internal trigger
            self.device.write("INIT2:CONT 0")

        self.__setPowMeasurement(pow)
        self.__setTrigger(trigger)

    def __setTriggerDelay(self, delay=100e−6):
        self.device.write( "TRIG:SEQ:DEL %s" % delay )

    def __setTraceUnits(self):
```



```
        # Sets the trace function units on channel A and B
        self.device.write("TRAC1:UNIT DBM")
        self.device.write("TRAC2:UNIT DBM")

    def __enableTrace(self):
        # Enable trace capture for channel B (output)
        self.device.write("TRAC2:STAT 1")

    def __setPowMeasurement(self, type="PEAK"):
        # Setting for peak power or average power measurement
        import string
        type = string.upper(type)
        if type ≠ "PEAK" ∧ type ≠ "AVER":
            print "Invalid option"
            return
        self.device.write("CALC1:FEED \"POW:%s\"" % type)
        self.device.write("CALC2:FEED \"POW:%s\"" % type)

    def __setTrigger(self, trigger="EXT"):
        # Configures trigger system to respond to
        # immediate or external trigger for both channels
        self.device.write("TRIG:SEQ1:SOUR %s" % trigger)
        self.device.write("TRIG:SEQ2:SOUR %s" % trigger)

    def __waitTrigger(self):
        # Places channel 1 & 2 in wait for trigger state
        self.device.write("INIT1:IMM")
        self.device.write("INIT2:IMM")


    def __getOffsetInput(self):
        # Gets dB loss offset for input stage
        f = open( os.environ[ ’HOME’ ] + "/Code/offsets.ini")
        f.readline()   # Bypass the first line
        values = f.readline().split(":")
        return float(values[1])

    def __getOffsetOutput(self):
        # Gets dB loss offset for output stage
        f = open( os.environ[ ’HOME’ ] + ’/Code/offsets.ini’)
        f.readline() # By pass first 2 lines
        f.readline()
        values = f.readline().split(":")
        return float(values[1])
```

```python
#! /usr/bin/env python

# Power Supply Class is the direct connection between the main computer and
# the Agilent Power Supply.
# This is the class that should be used to interface with the power supply
# This class implements various functions of the power meter using the SCPI
# command set.

import socket
import sys
import datetime
import time

from TestException import *
from Utilities import *

class PowerSupply:
    """
  Controls power supply settings for channel 1
  (Functions: SetCurr, SetVolt, GetCurr, GetVolt, On, Off, GetOnOff
  """

    IP_ADDR   = "192.168.0.2"
    SOCKET_NO = 5025

    def __init__(self):
        # Connect to the power supply via ethernet on mfg. default port 5025
        self.socket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        self.socket.connect((self.IP_ADDR, self.SOCKET_NO))
        self.setPowerOff()

    def __del__(self):
        try:
           self.setPowerOff()
           del self.socket
        except Exception:
            raise


    def setCurr(self,val):
        # Sets the current limit designted by val in Amps
        # val takes in a real number between 0 and 5.1
        self.socket.send('CURR '+str(val)+',(@1)\n')

    def getVoltageSetpoint(self):
        self.socket.send('VOLT? (@1)\n')
        return float(self.socket.recv(100))

    def setVolt(self,val):
        # Sets the voltage limit designated by val in Volts
        # val takes in a real number between 0 and 61.2
        self.socket.send('VOLT '+str(val)+',(@1)\n')

    def getCurr(self):
        # Measures the current draw from the supply in Amps
        self.socket.send('*OPC?\n')     # Asks if the reading is stable
        self.socket.recv(100)           # We think blocks until above is yes
        self.socket.send('MEAS:CURR? (@1)\n')
        return float(self.socket.recv(100))

    def getVoltageReading(self):
        # Measures the output voltage in Volts
        self.socket.send('MEAS:VOLT? (@1)\n')
        return float(self.socket.recv(100))


    def setPowerOn(self):
        # Enable output and let the caps charge
        self.socket.send('OUTP ON, (@1)\n')
```



```python
        # Wait until the output voltage has reached what it has been set to
        # Typical value is 32V

        # Time delay to wait for Power Supply to be ready
        t1 = datetime.datetime.utcnow()

        set = self.getVoltageSetpoint()
        time.sleep( 0.25 )          # S
        meas = self.getVoltageReading()
        diff = abs( meas - set )
        limit = 0.1                     # V
        had_to_loop = False
        while diff > limit:
            msg = "VoltageSetpoint: %4.1f V, Reading: %4.1f V, " + \
                  "Diff = %4.1f V > %.1f V" %  ( set, meas, diff, limit )

            time.sleep( 0.25 )          # S
            sys.stdout.write( "\r %s" % msg )
            sys.stdout.flush()
            t2 = datetime.datetime.utcnow()
            if (t2 - t1) > datetime.timedelta( seconds = 10 ):
                print "\nSomething's wrong with the power supply...."
                self.setPowerOff()
                raise TestException(TestException.device_error_PowerSupply)

            set = self.getVoltageSetpoint()
            meas = self.getVoltageReading()
            diff = abs( meas - set )
            had_to_loop = True

        if had_to_loop:
            msg = "VoltageSetpoint: %4.1f V, Reading: %4.1f V, " + \
                  "Diff = %4.1f V > %.1f V" %  ( set, meas, diff, limit )
            sys.stdout.write( "\r %s\n" % msg )
            sys.stdout.flush()


    def setPowerOff(self):
        # Disable output
        self.socket.send('OUTP OFF, (@1)\n')

    def getPowerStatus(self):
        # Get Power Status
        self.socket.send('OUTP? (@1)\n')
        return float(self.socket.recv(100))
```

```python
#! /usr/bin/env python

# SignalGen Class is the direct connection between the main computer and
# the Agilent Signal Generator.
# This is the class that should be used to interface with the signal generator
# This class implements functionality of turning RF power on and off from the
# signal generator.

import socket
import sys
import time
import os

from TestException import *
from Utilities import *

class SignalGen:
    """
   Controls the Signal Generator
   """

    IP_ADDR   = "192.168.0.3"
    SOCKET_NO = 5025

    def __init__( self, offsets_ini_not_found_allow = False ):
        if offsets_ini_not_found_allow ≡ False:
            # offsets_ini_not_fount_allow is False by default
            # When called from the PowerMeter Offset calibration routine
            # we don't have to check for the presence of the file.
            try:
                self.siggenoffset = self.__getOffsetOutput()
            except IOError:
                raise TestException(TestException.offsets_ini_not_found)
        else:
            self.siggenoffset = 0

        # Connect to the signal generator via ethernet on mfg. default port 5025
        self.socket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        self.socket.connect((self.IP_ADDR, self.SOCKET_NO))
        self.setRFOff()
        self.setAmplitude(10)
        self.setFreq( 440e6 )


    def __del__(self):
        try:
            self.setRFOff()
            del self.socket
        except Exception:
            raise


    def setRFOff(self):
        #disable RF output from signal generator
        self.socket.send('OUTP OFF\n')
        time.sleep(2)

    def setRFOn(self):
        #enable RF output from signal generator
        time.sleep(2)
        self.socket.send('OUTP ON\n')

    def setAmplitude(self,val):
        #Sets the power (amplitude) designated by val in dBm
        #val takes in a real number between −110 and 18
        val += self.siggenoffset
        self.socket.send('POW '+str(val)+' dBm\n')

    def setFreq(self,val):
```



```python
        #Sets the frequency designated by val in Hz
        #val takes in a real number between 250e3 to 1e9
        self.socket.send('FREQ '+str(val)+' Hz\n')

    def __getOffsetOutput(self):
        # Gets dB loss offset for output stage
        f = open( os.environ[ 'HOME' ] + '/Code/offsets.ini')
        f.readline() # By pass first 3 lines
        f.readline()
        f.readline()
        values = f.readline().split(":")
        return float(values[1])
```

```
#! /usr/bin/env python

import Controller
import PowerMeter
import PowerSupply
import SignalGen

import Database

import time
import string
import sys
import math

from TestException import *
from Utilities import *

warmup_period = 3 # S

# Fail reasons
fail_overpulse    = 1
fail_droop        = 2
fail_power_430    = 3
fail_power_440    = 4
fail_power_450    = 5
fail_powercorrect = 6
fail_open         = 7
fail_mismatch     = 8

failreasons = {fail_overpulse    : "Over Pulse Test Failed",
               fail_droop        : "Droop Test Failed",
               fail_power_430    : "Power Efficiency at 430 Failed",
               fail_power_440    : "Power Efficiency at 430 Failed",
               fail_power_450    : "Power Efficiency at 430 Failed",
               fail_powercorrect : "Power Correct Test Failed",
               fail_open         : "Open Circuit at Load Failed",
               fail_mismatch     : "VSWR Mismatch Failed"
              }

###################################################################
##
## Specifications Tests include both Pre−Burnin and Post−Burinin
##
###################################################################
class SpecTests:
    def __init__(self, username):
        try:
            print "\nInitializing Devices ..."
            self.powersupply = PowerSupply.PowerSupply()
            self.powermeter = PowerMeter.PowerMeter()
            self.siggen = SignalGen.SignalGen()
            self.controller = Controller.Controller()

            self.user = username
        except Exception:
            raise


    def destructor(self): # Issues with using the default __del__()
        del self.controller
        del self.powersupply
        del self.siggen


    # *******************************************************************
    #
    # Start of  "Public Functions" Block
    #
    # *******************************************************************
```



```
    # ===================================================================
        """
    Pre Burnin Test

    1. OverPulse Test
    2. Droop Test
    3. Power Efficiency Test
    4. Power Correct Test
    5. Open Load Test
    6. Mismatch Load Test
    """
    def runPreBurninTest(self, serialno = ""):
        values = {   "sn"                  : " ",
                     "uname"               : " ",

                     "pulsewidth"          : " ",
                     "overpulse_passed"    : " ",

                     "droop_initpower"     : " ",
                     "droop_finalpower"    : " ",
                     "droop_passed"        : " ",

                     "current_430"         : " ",
                     "voltage_430"         : " ",
                     "power_430"           : " ",

                     "current_450"         : " ",
                     "voltage_450"         : " ",
                     "power_450"           : " ",

                     "current_440"         : " ",
                     "voltage_440"         : " ",
                     "power_440"           : " ",

                     "power_8_5"           : " ",
                     "power_11_5"          : " ",
                     "powercorrect_passed" : " ",

                     "open_passed"         : " ",
                     "mismatch_passed"     : " ",

                     "test_passed"         : " ",
                     "fail_reason"         : " "
                  }  # Values dictionary

        testFailFlag = False
        testFailCode = []

        while serialno ≡ "":
            print ""
            sn = raw_input("Please enter the Serial Number of the SSPA :")
            serialno = str(sn).strip().replace(" ","_")

        values['sn']    = "'%s'" % serialno
        values['uname'] = "'%s'" % self.user

        print "\nInitializing Pre Burnin Test Porcedures..."

        # Initialize devices
        self.initDevices()

        # Overpulse with 3ms pulse
        overpulse = self.conductOverPulseTest()
        values [ 'pulsewidth' ]       = "'%s'" % string.join(overpulse[0], ",")
        values [ 'overpulse_passed' ] = "'%s'" % str(¬ bool(overpulse[1]))
        if bool(overpulse[1]) ≡ True: # Returns fail code as 1 if fails
            testFailFlag = True
            testFailCode.append (fail_overpulse)
```

```
        # Droop
        (initpower, finalpower, passed) = self.conductDroopTest()
        values [ 'droop_initpower'  ] = "'%s'" % initpower
        values [ 'droop_finalpower' ] = "'%s'" % finalpower
        values [ 'droop_passed' ] = "'%s'" % passed
        if droop_passed ≡ False:
            testFailFlag = True
            testFailCodea.append(fail_droop)

        # Efficiency at 430, 440, 450
        (currents, voltages, powers, failflag) = self.conductEfficiencyTest()
        for i in [430,440,450]: # indexex 0,1,2 (430, 440, 450)
            values [ "current_%s" % i ] = "'%s'" % currents [i/10 − 43]
            values [ "voltage_%s" % i ] = "'%s'" % voltages [i/10 − 43]
            values [ "power_%s"   % i ] = "'%s'" % powers   [i/10 − 43]

        testFailFlag = bool(failflag) # returns the fail code and 0 if passed
        sys.stdout.write ( "Efficiency Test before burnin ...\t" )
        if ( testFailFlag ≡ False ):
            # PASSED
            setStyle('bold', 'green' )
            sys.stdout.write("[ PASSED ]")
            setStyle('default')
        else:
            # Failed
            setStyle('bold', 'red' )
            sys.stdout.write("[ FAILED ]")
            setStyle('default')
            testFailCode.append(failflag)

        # Power Correct
        powercorrect = self.conductPowerCorrectTest()
        values [ 'power_8_5'  ] =  powercorrect[0][0]
        values [ 'power_11_5' ] =  powercorrect[0][1]
        values [ 'powercorrect_passed' ] = "'%s'" % \
                                   str(¬ bool(powercorrect[1]))
        if bool(powercorrect[1]) ≡ True:
            testFailFlag = True
            testFailCode.append(fail_powercorrect)

        # Open and Mismatch
        variousloads_passed = self.conductVariousLoadsTest()
        values [ 'open_passed'     ] = "'%s'" % \
                                   str(bool(variousloads_passed[0]))
        values [ 'mismatch_passed' ] = "'%s'" % \
                                   str(bool(variousloads_passed[1]))

        if bool(variousloads_passed[0]) ≡ False:
            testFailFlag = True
            testFailCode.append(fail_open)

        if bool(variousloads_passed[1]) ≡ False:
            testFailFlag = True
            testFailCode.append(fail_mismatch)

        values [ 'test_passed' ] = "'%s'" % str(¬(testFailFlag))
        vals_fails = []
        for i in testFailCode:
           vals_fails.append("'%s'" % failreasons[i])
        values [ 'fail_reason' ] = string.join (vals_fails , ',')
        # Save Data
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        self.__savePreBurninResults(values)
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−

        # End of PreBurinin Procedure
        print "\n"
        if testFailFlag ≡ True:
```



```
            setStyle('bold', 'red')
            print 35 * '−'
            print " PreBurnin Test Failed !!!"
            print 35 * '−'
        else:
            setStyle('bold', 'green')
            print 35 * '−'
            print " PreBurnin Test Completed !!!"
            print 35 * '−'
        setStyle('default')

    # ====================================================================



    # ====================================================================
        """
    Post Burnin Test

    1. OverPulse Test
    2. Droop Test
    3. Power Efficiency Test
    4. Power Correct Test
    5. Open Load Test
    6. Mismatch Load Test
    """
    def runPostBurninTest(self, serialno = "" ):
        values = {   "sn"                  : " ",
                     "uname"               : " ",

                     "pulsewidth"          : " ",
                     "overpulse_passed"    : " ",

                     "droop_initpower"     : " ",
                     "droop_finalpower"    : " ",
                     "droop_passed"        : " ",

                     "current_430"         : " ",
                     "voltage_430"         : " ",
                     "power_430"           : " ",

                     "current_450"         : " ",
                     "voltage_450"         : " ",
                     "power_450"           : " ",

                     "current_440"         : " ",
                     "voltage_440"         : " ",
                     "power_440"           : " ",

                     "power_8_5"           : " ",
                     "power_11_5"          : " ",
                     "powercorrect_passed" : " ",

                     "open_passed"         : " ",
                     "mismatch_passed"     : " ",

                     "test_passed"         : " ",
                     "fail_reason"         : " "
                 }  # Values dictionary

        testFailFlag = False
        testFailCode = []
        while serialno ≡ "":
            print ""
            sn = raw_input("Please enter the Serial Number of the SSPA :")
            serialno = sn.strip().replace(" ","_")

        values['sn']    = "'%s'" % serialno
```

```
        values['uname'] = "'%s'" % self.user

        print "\nInitializing Post Burnin Test Porcedures..."


        # Initialize devices
        self.initDevices()

        # Overpulse with 3ms pulse
        overpulse = self.conductOverPulseTest()
        values [ 'pulsewidth' ]        = "'%s'" % string.join(overpulse[0], ",")
        values [ 'overpulse_passed' ] = "'%s'" % str(¬ bool(overpulse[1]))
        if bool(overpulse[1]) ≡ True: # Returns fail code as 1 if fails
            testFailFlag = True
            testFailCode.append (fail_overpulse)

        # Droop
        (initpower, finalpower, passed) = self.conductDroopTest()
        values [ 'droop_initpower'  ] = "'%s'" % initpower
        values [ 'droop_finalpower' ] = "'%s'" % finalpower
        values [ 'droop_passed' ] = "'%s'" % passed
        if droop_passed ≡ False:
            testFailFlag = True
            testFailCodea.append(fail_droop)

        # Efficiency at 430, 440, 450
        (currents, voltages, powers, failflag) = self.conductEfficiencyTest()
        for i in [430,440,450]: # indexex 0,1,2 (430, 440, 450)
            values [ "current_%s" % i ] = "'%s'" % currents [i/10 - 43]
            values [ "voltage_%s" % i ] = "'%s'" % voltages [i/10 - 43]
            values [ "power_%s"   % i ] = "'%s'" % powers   [i/10 - 43]

        testFailFlag = bool(failflag) # returns the fail code and 0 if passed
        sys.stdout.write ( "Efficiency Test after burnin ...\t" )
        if ( testFailFlag ≡ False ):
            # PASSED
            setStyle('bold', 'green' )
            sys.stdout.write("[ PASSED ]")
            setStyle('default')
        else:
            # Failed
            setStyle('bold', 'red' )
            sys.stdout.write("[ FAILED ]")
            setStyle('default')
            testFailCode.append(failflag)

        # Power Correct
        powercorrect = self.conductPowerCorrectTest()
        values [ 'power_8_5'  ] =  powercorrect[0][0]
        values [ 'power_11_5' ] =  powercorrect[0][1]
        values [ 'powercorrect_passed' ] = "'%s'" % \
                                            str(¬ bool(powercorrect[1]))
        if bool(powercorrect[1]) ≡ True:
            testFailFlag = True
            testFailCode.append(fail_powercorrect)

        # Open and Mismatch
        variousloads_passed = self.conductVariousLoadsTest()
        values [ 'open_passed'     ] = "'%s'" % \
                                       str(bool(variousloads_passed[0]))
        values [ 'mismatch_passed' ] = "'%s'" % \
                                       str(bool(variousloads_passed[1]))

        if bool(variousloads_passed[0]) ≡ False:
            testFailFlag = True
            testFailCode.append(fail_open)

        if bool(variousloads_passed[1]) ≡ False:
            testFailFlag = True
```



```
            testFailCode.append(fail_mismatch)

        values [ 'test_passed' ] = "'%s'" % str(¬(testFailFlag))
        vals_fails = []
        for i in testFailCode:
            vals_fails.append("'%s'" % failreasons[i])
        values [ 'fail_reason' ] = string.join (vals_fails , ',')

        # Save Data
        # -------------------------------------------
        self.__savePostBurninResults(values)
        # -------------------------------------------

        # End of PostBurinin Procedure
        print "\n"
        if testFailFlag ≡ True:
            setStyle('bold', 'red')
            print 35 * '-'
            print " PostBurnin Test Failed !!!"
            print 35 * '-'
        else:
            setStyle('bold', 'green')
            print 35 * '-'
            print " PostBurnin Test Completed !!!"
            print 35 * '-'
        setStyle('default')

    # ======================================================================



    def initDevices (self):
        # -----------------------------------------------------
        # Setup Power Supply with 32 V and 5 A
        # We will not be turning off the power supply in the
        # middle of sequence of tests
        # -----------------------------------------------------
        self.powersupply.setPowerOff()
        self.powersupply.setCurr(5)
        self.powersupply.setVolt(32)
        self.powersupply.setPowerOn()


    def conductOverPulseTest (self):
        # --------------------------------------------
        # Conducts Overpulse test
        # --------------------------------------------
        print  "\nConducting Overpulse test ... "
        overpulse = self.__OverPulseTest()
        sys.stdout.write( "Overpulse test ... \t\t\t" )
        if overpulse[1] ≡ 1:                # Fail bit
            setStyle('bold', 'red' )
            sys.stdout.write("[ FAILED ]")
            setStyle('default')
        else:
            setStyle('bold', 'green' )
            sys.stdout.write("[ PASSED ]")
            setStyle('default')
        print ""
        return overpulse


    def conductDroopTest (self):
        # --------------------------------------------
        # Conducts Droop test
        # --------------------------------------------
        droop_max = 0.1                   # 10%
        sys.stdout.write( "\nConducting Droop test ... < %s\n" % droop_max )
```

```
        initpower, finalpower = self.__DroopTest()   # dBm

        power_init_mW  = 10 ** initpower/ 10.0
        power_final_mW = 10 ** finalpower / 10.0

        sys.stdout.write( "Droop test ... \t\t\t\t" )
        if power_final_mW > ((1 − droop_max) * power_init_mW) :
            droop_passed = 't'
            setStyle('bold', 'green' )
            sys.stdout.write("[ PASSED ]")
            setStyle('default')
        else:
            droop_passed = 'f'
            setStyle('bold', 'red' )
            sys.stdout.write("[ FAILED ]")
            setStyle('default')

            print "\n  Power at the beginning of pulse is %s mW (%s dBm)" % \
                  (power_init_mW, initpower)
            print "  Power at the end of pulse is %s mW (%s dBm)" % \
                  (power_final_mW, finalpower)
        print ""
        return (initpower, finalpower, droop_passed)


    def conductEfficiencyTest (self):
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        # Conducts Efficiency test at
        # 430, 450 and 440 MHz
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        currents = []
        voltages = []
        powers   = []

        print "\nConducting Efficiency test ... "
        # 430 MHz
        current, voltage, power = self.__EfficiencyTest( 430e6 )
        print "  At 430 MHz"
        print "\tCurrent : %.3f A, Voltage : %.3f V, Power : %.3f dBm"\
              % (current, voltage, power)
        print "\tEfficiency : %.1f %%" % \
                ((10**(power/10))/10000/(current * voltage)*100)

        currents.append(current)
        voltages.append(voltage)
        powers.append(power)

        # 440 MHz
        current, voltage, power = self.__EfficiencyTest( 440e6 )
        print "  At 440 MHz"
        print "\tCurrent : %.3f A, Voltage : %.3f V, Power : %.3f dBm"\
              % (current, voltage, power)
        print "\tEfficiency : %.1f %%" % \
                ((10**(power/10))/10000/(current * voltage)*100)

        currents.append(current)
        voltages.append(voltage)
        powers.append(power)

        # 450 MHz
        current, voltage, power = self.__EfficiencyTest( 450e6 )
        print "  At 450 MHz"
        print "\tCurrent : %.3f A, Voltage : %.3f V, Power : %.3f dBm"\
              % (current, voltage, power)
        print "\tEfficiency : %.1f %%" % \
                ((10**(power/10))/10000/(current * voltage)*100)

        currents.append(current)
        voltages.append(voltage)
```



```
        powers.append(power)

        efficiency = 38 # % percentage
        # the divide 10 is to convert peak power to average power
        # Note the power is converted into Watts
        eff_0 = (10**(powers[0]/10)) / 10000 / (currents[0] * voltages[0])* 100
        eff_1 = (10**(powers[1]/10)) / 10000 / (currents[1] * voltages[1])* 100
        eff_2 = (10**(powers[2]/10)) / 10000 / (currents[2] * voltages[2])* 100

        if (eff_0 ≥ efficiency ∧ eff_1 ≥ efficiency ∧ eff_2 ≥ efficiency):
            # PASSED
            failflag = 0
        else:
            # Failed
            if (eff_0 < efficiency):
                failflag =  fail_power_430
            elif (eff_1 < efficiency):
                failflag =  fail_power_440
            elif (eff_2 < efficiency):
                failflag = fail_power_450

        return (currents, voltages, powers, failflag)


    def conductPowerCorrectTest (self):
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        # Powercorrect test
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        print ( "\nConducting PowerCorrect test ... " )
        powercorrect = self.__PowerCorrectTest()
        sys.stdout.write( "Powercorrect test... \t\t\t" )
        if powercorrect[1] ≡ 1: #Fail bit
            setStyle('bold', 'red' )
            sys.stdout.write("[ FAILED ]\n")
            setStyle('default')
        else:
            setStyle('bold', 'green' )
            sys.stdout.write("[ PASSED ]\n")
            setStyle('default')

        return powercorrect

    def conductVariousLoadsTest (self):
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        # Open and 3:1 Mismatch test
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        print "\nConducting Open and 3:1 VSWR Mismatch test ... "

        # Gets a list [open, vswr] passed status
        variousloads_passed = self.__VariousLoadsTest()
        return variousloads_passed



    # *******************************************************************
    #
    # Start of Private Functions Block
    #
    # *******************************************************************

    def __OverPulseTest(self):
        """
Check for the output pulse−limiting
behavior of the SSPA
"""
        # −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
        # This test supplies 3ms pulses at 25Hz to
        # the SSPA to test the excessive pulse
```

```
        # shutoff capability of the SSPA.
        # ------------------------------------------
        traceLength = 0.100      # seconds
        period      = 40e-3      # seconds
        pw          = 3e-3       # 3ms pulse
        outputPulseLength = []

        # Turn off Signal Gen and Gating
        self.siggen.setRFOff()
        self.controller.setTR(0)

        # Settings
        self.controller.setAddr(0)
        self.controller.setLoad(self.controller.load_50_ohms)

        # Turn on Signal Generator
        self.siggen.setFreq(440e6)
        self.siggen.setAmplitude(10)
        self.siggen.setRFOn()

        # Conduct Test
        self.controller.setRF(1, period, pw)  # start the rf
        time.sleep( warmup_period )
        try:
            #get trace data traceLength in seconds
            traceData = self.powermeter.getTraceData(traceLength)
        except Exception:
            sys.stdout.write( "\rFetching trace\t\t\t\t" )
            setStyle('bold', 'red')
            print "[ FAILED ]"
            setStyle('default')
            raise
        else:
            sys.stdout.write( "\rFetching trace\t\t\t\t" )
            setStyle('bold', 'green')
            print "[ OK ]"
            setStyle('default')


        failstate = 0    #initial state = pass
        i = 0
        index = 0                    #pulse index
        while i < len(traceData) - 5: #checks every data point (except the
                                      # last few to avoid false failure)
            count = 0     #initial measured output pulse width is 0
            while traceData[i + count] > 45:#count how long the output pulse is
                count += 1

            if count ≠ 0 :
                #convert number of samples to time
                outputPulseLength.append(str(count*(traceLength/1000)))
                if float(outputPulseLength[index]) > 2.5e-3:
                    #fail SSPA if output pulse width too long
                    failstate = 1
                    print "Pulse length over 2.5 ms => %s" % \
                          outputPulseLength[index]
                index += 1 #check next pulse
            i += count + 1

        # Turn off RF Gating
        self.controller.setTR(0)
        # Turn off Signal Generator
        self.siggen.setRFOff()

        return [outputPulseLength, failstate]


    def __PowerCorrectTest(self):
        """
```



```
        Check for the correctneess of the power
        """
            # This test verifies that the SSPA can compensate for
            # variable input powers
            # The input power varies by 10% and the output power
            # should remain at or above 57dBm

            # Turn Signal Gen and Gating
            self.siggen.setRFOff()
            self.controller.setTR(0)

            # Turn on Signal Generator
            self.siggen.setFreq(440e6)
            self.siggen.setAmplitude(10)
            self.siggen.setRFOn()

            # Conduct Test
            self.controller.setRF(1)     #start the rf
            time.sleep( warmup_period )

            measured = []

            fail = 0
            for k in range(0, 3, 2):
                # Equivalent C statement 'for (k=0 ; k < 3 ; k+=2)'
                power_input = 8.5 + (k*1.5)
                self.siggen.setAmplitude( power_input )
                self.controller.setRF(1)
                print " Setting input power to %s dBm..." % power_input
                time.sleep( warmup_period )
                power_output = self.powermeter.getMeasOutput()
                print " Output Power read is %s dBm" % power_output
                measured.append ( power_output )
                self.controller.setRF(0)
                if power_output < 56.8:
                    fail = 1
                time.sleep(.3)


            # Turn off Gating
            self.controller.setTR(0)

            # Turn off Signal Generator
            self.siggen.setRFOff()

            # Return Result in form of
            # [[power at 8.5dBm, power at 10dBm, power at 11.5dBm], fail?]
            result = [measured, fail]
            return result



    def __DroopTest(self):
            """
        Checks for the power droop of the output pulse
        """
            # This test supplies 2ms pulses at 50Hz (40ms cycle) to the SSPA
            # to test the SSPA's Ouput Power Droop
            traceLength = 0.0025     # seconds
            period      = 20e-3      # seconds
            pw          = 2e-3       # 2ms pulse
            droop = []

            # Turn off Signal Gen and Gating
            self.siggen.setRFOff()
            self.controller.setTR(0)

            # Settings
            self.controller.setAddr(0)
```

```
        self.controller.setLoad(self.controller.load_50_ohms)

        # Turn on Signal Generator
        self.siggen.setFreq(440e6)
        self.siggen.setAmplitude(10)
        self.siggen.setRFOn()

        # Conduct Test
        self.controller.setRF(1, period, pw)  # start the rf
        time.sleep( warmup_period )

        # Get trace data for 2.5 ms
        traceData = self.powermeter.getTraceData(traceLength, 100e-6)

        # Turn off RF Gating
        self.controller.setTR(0)

        # Turn off Signal Generator
        self.siggen.setRFOff()

        # Now we need to filter out only the pulse as we will be grabbing
        # values outside the pulse as well
        filteredData = []
        for i in traceData:
            if i > 50:
                filteredData.append ( i )

        value_max = max( filteredData )
        value_min = min( filteredData )
        return [ value_max, value_min ]




    def __EfficiencyTest(self, freq):
        # This test supplies RF signal at the given freq to the SSPA
        # to test the SSPA's Ouput Power efficiency

        # Turn off Signal Gen and Gating
        self.siggen.setRFOff()
        self.controller.setTR(0)
        self.powermeter.setFreq( freq)

        # Settings
        self.controller.setAddr(0)
        self.controller.setLoad(self.controller.load_50_ohms)

        # Turn on Signal Generator
        self.siggen.setFreq( freq )   # Changes the freq
        self.siggen.setAmplitude(10)
        self.siggen.setRFOn()

             # Turn on RF Gating signal
        self.controller.setRF(1)

        time.sleep( warmup_period )

        current = self.powersupply.getCurr()
        voltage = self.powersupply.getVoltageReading()
        power   = self.powermeter.getMeasOutput()

        # Turn off RF Gating
        self.controller.setTR(0)

        # Turn off Signal Generator
        self.siggen.setRFOff()

        # Reset powermeter to read 440 MHz
```



```
        self.powermeter.setFreq( 440e6 )

        return [current, voltage, power]


    def __VariousLoadsTest(self):
        """
    This test supplies RF signal the SSPA with the ouput hooked to
    various loads and checks if the amplifier shuts off

    Returns a python list with the <test>_passed status for each of
    open and mismatch
    """
        # Turn off and Signal Gen and Gating
        self.siggen.setRFOff()
        self.controller.setTR(0)

        # Settings
        self.controller.setAddr(0)


        # Turn on Signal Generator
        self.siggen.setAmplitude(10)
        self.siggen.setRFOn()


        # Load :: Open
        # -------------------------------------------------
        # Cold switching done in the setLoad() method
        print "Performing test with ..."

        sys.stdout.write( " OPEN circuit at the load ...\t\t" )
        sys.stdout.flush()
        self.controller.setLoad( self.controller.load_open )
        self.controller.setRF( 1 )
        time.sleep( warmup_period )
        current = self.powersupply.getCurr()
        # If the amplifier shuts off it should be drawing less than an amp
        # Cannot use power measurement as power meter crashes
        if current > 1:
            # If current is greater than 1 A, try to get the power.
            open_passed = False
            setStyle( 'bold' , 'red' )
            print "[ Failed ]"
            setStyle( 'default')
            power   = self.powermeter.getMeasOutput()
            print "  Power found to be %s dBm" % power

        else:
            open_passed = True
            setStyle( 'bold' , 'green' )
            print "[ PASSED ]"
            setStyle( 'default')


        # Load :: VSWR Mismatch 3:1
        # -------------------------------------------------
        # Cold switching done in the setLoad() method
        sys.stdout.write( " 3:1 mismatch at the load ...\t\t" )
        sys.stdout.flush()

        # Need to change it to 3:1 mismatch once we get the cable
        self.controller.setLoad( self.controller.load_3_1_mismatch )
        self.controller.setRF( 1 )
        time.sleep( warmup_period )

        vswr_flag = self.controller.getVSWR_Flag()

        if vswr_flag == 1:
```

```
            vswr_passed = False
            setStyle( 'bold' , 'red' )
            print "[ Failed ]"
            setStyle( 'default')
        else:
            vswr_passed = True
            setStyle( 'bold' , 'green' )
            print "[ PASSED ]"
            setStyle( 'default')

        # Turn off RF Gating
        self.controller.setTR(0)

        # Turn off Signal Generator
        self.siggen.setRFOff()

        return [ open_passed, vswr_passed]



    ############################################################
    ## Data Saving Routines
    ############################################################
    def __savePreBurninResults(self, results):
        """
Formats the Pre Burnin data for the database adapter
"""
        names  = [ ]
        values = [ ]
        for fieldname, value in results.items():
            names.append( "%s" % fieldname )
            values.append( "%s" % value )

        names_str = string.join(names, ',')
        values_str = string.join(values, ',')
        db = Database.Database()
        db.storePreBurninReadings(names_str, values_str)


    def __savePostBurninResults(self, results):
        """
Formats the Post Burnin data for the database adapter
"""
        names  = [ ]
        values = [ ]
        for fieldname, value in results.items():
            names.append( "%s" % fieldname )
            values.append( "%s" % value )

        names_str = string.join(names, ',')
        values_str = string.join(values, ',')
        db = Database.Database()
        db.storePostBurninReadings(names_str, values_str)


    # ******************************************************************
    # End of Private Functions Block
    # ******************************************************************
```

```
#!/usr/bin/env python

import Calibration
import SpecTests
import OvenTest
import OffsetCalibration

import string
import os
import sys
import time

from TestException import *
from Utilities import *

class SSPA_Test:
    def __init__(self):
        os.system('reset')
        self.WelcomeScreen()

    def WelcomeScreen(self):
        os.system('clear')
        setStyle('bold', 'default')
        print 60 * "="
        print 5*" " , "Welcome to the AMISR SSPA Automated Test Suite"
        print 60 * "="
        setStyle('default')


    def Login(self):
        print ""
        print "Please login below (avoid spaces) ... "
        LoginName = ""
        while LoginName ≡ "":
            try:
                LoginName = str(raw_input("Username : "))
                LoginName = LoginName.strip().replace(" ","_")
            except KeyboardInterrupt:
                print "\n"
                setStyle('default')
                sys.exit(1)
        self.UserName = LoginName


    def run (self):
        while True:
            self.Login()
            self.WelcomeScreen()
            while ¬ (self.UserName ≡ ""):
                print ""
                print "0. Log Off", self.UserName
                print "1. Calibration"
                print "2. Pre  Burn−in Test"
                print "3. Post Burn−in Test"
                print "4. Power Meter Offset Calibration"
                print "Q. Quit\n"

                inp = ""
                while inp ≡ "":
                    try:
                        inp = raw_input("\rEnter our choice : ")
                        inp = string.lower( str(inp) )
                        inp = inp.strip()
                    except KeyboardInterrupt:
                        setStyle( 'bold', 'red' )
                        print "\n\nForced Termination By the User ... \n"
                        setStyle( 'default' )
                        return
```



```
                if (inp ≡ "q"):
                    return
                elif (inp ≡ "0"):
                    self.UserName = ""
                    break
                proc = None
                try:     # Try ... Finally block
                    try: # Try ... Except block
                        if (inp ≡ "1"):
                            serialno = −1
                            proc = Calibration.Calibration(self.UserName)
                            serialno =  proc.runCalibration()
                            if serialno ≠ −1 ∨ serialno is (¬ None):
                                # calibration successful if serialno <> −1
                                # returned value is the the SSPA SN
                                print "\n"
                                finaltest = ""
                                while (finaltest ≠ "n" ∧ finaltest ≠ "y"):
                                    ans=raw_input("Do you want to proceed " + \
                                                  "with the pre−burnin test?"+\
                                                  "[y/n]:")
                                    finaltest = str(ans).strip()
                                    finaltest = string.lower(finaltest)
                                    if finaltest ≡ "y":
                                        proc = SpecTests.SpecTests\
                                               ( self.UserName )
                                        proc.runPreBurninTest(serialno)
                        elif (inp ≡ "2"):
                            proc = SpecTests.SpecTests(self.UserName)
                            proc.runPreBurninTest()
                        elif ( inp ≡ "3" ):
                            proc =  SpecTests.SpecTests(self.UserName)
                            proc.runPostBurninTest()
                        elif (inp ≡ "4"):
                            proc = OffsetCalibration.OffsetCalibration()
                            proc.CalibrateOffset()
                    except KeyboardInterrupt:
                        setStyle( 'bold', 'red' )
                        print "\n\nProcess Terminated By User ... \n"
                        setStyle( 'default' )
                    except TestException, err:
                        setStyle('bold', 'red')
                        print "\n", 65 * "−"
                        msg = err.__str__().split("\n")
                        for _msg in msg:
                            print ' ' + _msg
                        print 65 * "−"
                        setStyle( 'default' )
                        print "\n"
                finally:
                    # Delete the object so that it calls its destructor
                    # to restore settings to default
                    try:
                        proc.destructor()
                        del proc
                    except:
                        pass

if  __name__ ≡ "__main__":
    SSPA_Test().run()
    print "\nPlease wait while the system shuts down... \n\n"
```

```
#!/usr/bin/env python

import sys
import re
import time
import string
import urllib2
import datetime
import pytz

from Utilities import *
from TestException import *


class TempSensor:
    """
   TempSensor does a HTTP GET on a URL to capture a string of temperatures
   from a probe located at Toolik Alaska, and then stores the results
   in a database through the supporting Database class
   """

    sensor = "192.168.0.4"

    def __init__( self ):
        """
   """

    def getTemperature( self ):
        sensor_reading = self.__getSensaTronicTemps( self.sensor )
        return sensor_reading


    def __getSensaTronicTemps( self, sensor ):
        """
   Return a dict[ probe_name ] = probe_value
   The probe_values are assumed to be in F.

   An unconnected sensor port will report −99.9.  It is worth
   reporting these in case a wire comes loose, however if we have
   a 16 port sensor with only 2 ports in use then it is foolish
   to report the other 14 ports all the time.  So we need someway
   of determining of a port is actually in use.

   We count on the configuration of the sensor for this.  The
   default probe name is 'probeN'.  If we find a default name
   then we assume that the port is not in use and don't bother
   with it's −99.9 reading.  As a check to this we will logg a
   warning to any actual value found on the port with a default
   name.

   """
        probe_re = re.compile( "Probe \d{1,2}" )

        # SensaTronic's embedded HTTP server offers the page "temps"
        # to get the current readings.
        url = "http://%s/temp" % sensor

        try:
            fid = urllib2.urlopen( url )
        except urllib2.HTTPError, e:
            # Errors such as 404, Not Found
            msg = "HTTPError: %s" % e
            print msg
            return None
        except urllib2.URLError, e:
            # Errors in the format of the URL or a timeout
            msg = "URLError: %s" % e
            print msg
            return None
```



```
        data = fid.read()
        fid.close()

        # "SwitchRoom|reading0|EngineRoom|reading1|probe2|reading2"
        fields = data.split( '|' )

        # Make sure we have an even number of fields, name|reading pairs
        n_fields = len( fields )
        if n_fields % 2 ≠ 0:
            msg = "Odd number of fields in \"%s\"" % data
            print msg
            return None

        # Our dict to return
        sensor_readings = {}

        # Separate the probes
        n_probes = n_fields / 2
        for i in range( n_probes ):
            probe_name = fields[ i * 2 ]
            probe_reading_str = fields[ i * 2 + 1 ]

            if probe_re.match( probe_name ):
                # Default probe name so we assume not in use
                # But should also have no legitimate value.
                if probe_reading_str ≠ "−99.9":
                    probe_reading = float( probe_reading_str )     # deg F
                    probe_reading = (probe_reading − 32) * 5 / 9.0 # deg C
                    return probe_reading

                    msg = "Actual reading (%s) on un−named probe %s" % \
                          ( probe_reading_str, probe_name )
                    print msg
            else:
                sensor_readings[ probe_name ] = probe_reading

        return −99.9


if __name__ ≡ "__main__":
    print TempSensor().getTemperature()
```

```
"""
Class that handles the TestResults (The Calibration process and the actual test) along with the Handling of various exce
ptions.
"""

class TestException (Exception):
    device_error_PowerSupply = 100 # Cannot handshake with the Power Supply
    device_error_PowerMeter  = 101 # Cannot handshake with the Power Meter
    device_error_DAQCard     = 102 # Cannot handshake with the DAQ
    device_error_SignalGen   = 103 # Cannot handshake with the Signal Generator
    device_error_SSPA_Power  = 104 # Cannot handshake with the SSPA

    calib_initialCurrFailed  = 200 # Initial current above 0.5 A during Cal
    calib_gatePulseFailed    = 201 # Current is above 0.5A with only gate pulse
    calib_normalCurrFailed   = 202 # Current is out of range
    calib_driverCurrFailed   = 203 # Current out of bounds Pot 1 (Driver Bias)
    calib_outputCurrFailed   = 204 # Current out of bounds Pot 2 (Output Bias)
    calib_outputPowerFailed  = 205 # Power out of bounds   Pot 3 (Power Level)
    calib_phaseFailed        = 206 # Phase out of bounds   Pot 4 (Phase)
    calib_vswrFailed         = 207 # VSWR out of bounds    Pot 5 (VSWR)

    calib_offsetCalibfailed  = 208 # Power Meter Offset Calibration failed

    offsets_ini_not_found    = 300 # Offsets.init not found

    process_abort_calib      = 500 # Abort Calibration Process
    process_abort_offsetcalib= 501 # Abort Offset Calibration Process

    invalid_data_type        = 700 # Invalid data type
    invalid_offsets          = 701 # Invalid offset values in offsets.ini


    # Key:Value pair for device errors and corresponding strings
    eStr ={device_error_PowerSupply : \
           "Cannot establish connection to the Power Supply.\n" + \
           "Please check the connections and the power is turned on.",
           device_error_PowerMeter  : \
           "Cannot establish connection to the Power Meter.\n" + \
           "Please check the connections and the power turned on.",
           device_error_SignalGen   : \
           "Cannot establish connection to the Signal Generator.\n" + \
           "Please check the connections and the power turned on.",
           device_error_DAQCard     : \
           "Driver issue with DAQ Card." + \
           "Please contact the administrator.",
           device_error_SSPA_Power  : \
           "Cannot establish connection to the SSPA.\n" + \
           "Please check the power connections.",

           calib_initialCurrFailed  : \
           "Initial current during calibration is above 0.5A",
           calib_gatePulseFailed    : \
           "Current exceeds 0.5A with only gate pulse turned on",
           calib_normalCurrFailed   : \
           "Current drawn from the power supply out of bounds",
           calib_driverCurrFailed   : \
           "Current out of bounds while setting Address 1 (Driver Bias)",
           calib_outputCurrFailed   : \
           "Current out of bounds while setting Address 2 (Output Bias)",
           calib_outputPowerFailed  : \
           "Power out of bounds while setting Address 4 (Power Level)",
           calib_phaseFailed        : \
           "Phase out of bounds while setting Address 5 (Phase)",
           calib_vswrFailed         : \
           "Pots out of bounds while setting Address 6 (VSWR)",

           calib_offsetCalibfailed  : \
           "Offset Calibration failed.\nPlease check the connections, & \n" +\
           "Run the Offset Calibration test again.",
```



```
           offsets_ini_not_found    : \
           "Offsets.ini file not found. \n" + \
           "Please run the Power Meter Offset Calibration Procedure.",

           process_abort_calib      : "Aborting Calibration Process ...",
           process_abort_offsetcalib: "Aborting Offset Calibration Process...",

           invalid_data_type        : "Invalid parameter trapped",
           invalid_offsets          : \
           "Invalid values for offsets found in offsets.ini file.\n" + \
           "Please Re-Calibrate the Offsets before proceeding."
         }


    def __init__(self, value):
        self.errno = value

    def __str__(self):
        try:
            return str(self.eStr[self.errno])
        except:
            return "Unexpected and unhandled error. %s" % self.errno
```

```
import sys

"""
This utility enables us to print colors and styles in the
terminal window without having to use the curses for
programming
"""
__styles = {'default'    :    "\033[0m",
            'bold'       :    "\033[1m",
            'underline'  :    "\033[4m",
            'blink'      :    "\033[5m",
            'reverse'    :    "\033[7m",
            'concealed'  :    "\033[8m" }

__colors = {'black'      :    "\033[30m",
            'red'        :    "\033[31m",
            'green'      :    "\033[32m",
            'yellow'     :    "\033[33m",
            'blue'       :    "\033[34m",
            'magenta'    :    "\033[35m",
            'cyan'       :    "\033[36m",
            'white'      :    "\033[37m",

            'on_black'   :    "\033[40m",
            'on_red'     :    "\033[41m",
            'on_green'   :    "\033[42m",
            'on_yellow'  :    "\033[43m",
            'on_blue'    :    "\033[44m",
            'on_magenta' :    "\033[45m",
            'on_cyan'    :    "\033[46m",
            'on_white'   :    "\033[47m" }

def setColor(color):
    sys.stdout.write ( __colors[color] )

def setStyle(style, color=None):
    if style ≡ 'default':
        sys.stdout.write ( __styles[style] )
    else:
        if ¬ (color ≡ 'default'):
            sys.stdout.write ( __colors[color] )
        sys.stdout.write ( __styles[style] )
```

```c
#include <stdlib.h>
#include <stdio.h>
#include <NIDAQmx.h>
#include <math.h>
#include <string.h>

#define DAQmxErrChk(functionCall) if( DAQmxFailed(error=(functionCall)) ) \
    goto Error; else


float64 * acquireData(int samples_per_channel, float pulse_width, int *length);
int     writetofile(float64 *data, int size);
int     loadCounter(int start, int rf, double ipp, double pw);
uInt8   * readDigital(uInt8 *data);
int     writeDigital(int port, char lines[], char values[]);


/* Python Wrapper */
/* Written by Kaushal Shrestha */
/* January 31, 2007 */
// ===================================================================

#include "Python.h"

PyObject *Convert_Big_Array(PyObject *pylist,double array[],int start,int end)
{
    int i = 0, j;
    int length = end - start;
    pylist  = PyList_New( length );

    for (i=0, j=start; i < length;j++, i++) {
        PyList_SetItem(pylist, i, PyFloat_FromDouble(array[j]));
        //printf("%f \n",array[i]);
    }
    return pylist;
}


PyObject *py_acquireData(PyObject *self, PyObject *args) {

    int      samples_per_channel = 1000;
    float    pulsewidth = 0.02*3;
    float64  *data;
    int      length;
    PyObject *pylist1, *pylist2, *pylist3;

    if (¬PyArg_ParseTuple(args,"if", &samples_per_channel, &pulsewidth )) {
        printf("Restoring to default");
        if (¬PyArg_ParseTuple(args,"" )) {
            return Py_BuildValue("d",-1);
        }
    }

    //printf("%d %f",samples_per_channel,pulsewidth);
    data = acquireData(samples_per_channel, pulsewidth, &length);
    pylist1 = Convert_Big_Array( pylist1, data, 0, length/3 );
    pylist2 = Convert_Big_Array( pylist2, data, length / 3, length * 2/3 );
    pylist3 = Convert_Big_Array( pylist3, data, length*2/3, length );
    return Py_BuildValue( "[OOO]", pylist1, pylist2, pylist3 );
}

PyObject *py_loadTimers  (PyObject *self, PyObject *args) {
    int   trrf      = 0; // 0 is only TR 1 is both TR and RF
    float period    = 0;
    float pw = 0; // Duty cycle in percentage

    if (¬PyArg_ParseTuple(args,"iff", &trrf, &period, &pw)) {
        return Py_BuildValue("i",-1);
    }
```



```c
    loadCounter(1, trrf, period, pw);
    return Py_BuildValue("i",1);
}

PyObject *py_stopTimers  (PyObject *self, PyObject *args) {
    if (¬PyArg_ParseTuple(args,"")) {
        return Py_BuildValue("i",-1);
    }
    loadCounter(0,0,0,0);
    return Py_BuildValue("d",1);
}

PyObject *py_readDigital  (PyObject *self, PyObject *args) {
    uInt8 *value;
    if (¬PyArg_ParseTuple(args,"")) {
        return Py_BuildValue("i",-1);
    }
    value = readDigital(value);
    return Py_BuildValue("ii", value[0], value[1]);
}

PyObject *py_writeDigital  (PyObject *self, PyObject *args) {
    int  port;
    char *lines;
    char *values;
    if (¬PyArg_ParseTuple( args,
                           "iss", /* int, string, string */
                           &port, &lines, &values)) {
        return Py_BuildValue("i",-1);
    }
    return Py_BuildValue( "i",  /* return an int */
                          writeDigital(port, lines, values));
}

static PyMethodDef DAQ_methods[] = {
    {"acquireData",  py_acquireData,  METH_VARARGS},
    {"loadTimers",   py_loadTimers,   METH_VARARGS},
    {"stopTimers",   py_stopTimers,   METH_VARARGS},
    {"readDigital",  py_readDigital,  METH_VARARGS},
    {"writeDigital", py_writeDigital, METH_VARARGS},
    {NULL, NULL} // Sentinel
};


void initDAQ(){
    PyObject *m = Py_InitModule("DAQ",DAQ_methods);
}

// ===================================================================




float64 *acquireData( int samples_per_channel,
                      float pulse_width,
                      int *length ) {
    int No_of_Channels = 3;
    int Post_Trigger_Samples_Per_Channel = 20; /* min is 2 */
    int samples = No_of_Channels * samples_per_channel;
                 //total number of samples including
    int BuffSize=samples + No_of_Channels *  Post_Trigger_Samples_Per_Channel;
    float       samplingrate   = BuffSize / pulse_width;

    // Check if the samplingrate exceed 250KSamples/sec, the limit of the DAQ
    if (samplingrate * No_of_Channels > 250000) {
        samplingrate = 250000 / No_of_Channels;
        BuffSize     = ceil(samplingrate * pulse_width);
    }
```

```
    int32       error=0;
    TaskHandle  taskHandle=0;
    int32       read;
    float64     *data;
    char        *errBuff;
    int         i;
    int         posttriggersamples;

    data    = (double *) calloc(BuffSize, sizeof(double));
    errBuff = (char   *) calloc(BuffSize, sizeof(char));


    /*********************************************/
    // DAQmx Configure Code
    /*********************************************/
    DAQmxErrChk (DAQmxCreateTask("Task_DAQ",&taskHandle));

    // ai0: I of I/Q detector in differential mode
    // ai0(+), pin 68 & ai8(-), pin 34
    DAQmxErrChk (DAQmxCreateAIVoltageChan(taskHandle,"Dev1/ai0","",
                                          DAQmx_Val_Diff,-5.0, 5.0,
                                          DAQmx_Val_Volts,NULL));
                                    // ai0 and ai8 used for differential input

    if (No_of_Channels > 1) {
        // ai1: Q of I/Q detector in differential mode
        // ai1(+), pin 33 & ai9(-), pin 66
        DAQmxErrChk (DAQmxCreateAIVoltageChan(taskHandle,"Dev1/ai1","",
                                              DAQmx_Val_Diff, -5.0, 5.2,
                                              DAQmx_Val_Volts,NULL));
                                    // ai1 and ai9 used for differential input
    }

    if (No_of_Channels > 2) {
        // ai2: RF pulse, used to get offset to zero for I&Q
        //    referenced, single-ended
        // ai2, pin 65
        DAQmxErrChk (DAQmxCreateAIVoltageChan(taskHandle,"Dev1/ai2","",
                                              DAQmx_Val_RSE, -0.1,5.2,
                                              DAQmx_Val_Volts,NULL));
                                              // ai2 used for capturing gate
    }

    DAQmxErrChk (DAQmxCfgSampClkTiming( taskHandle,
                                        "", /* use default clock */
                                        samplingrate,
                                        DAQmx_Val_Rising,
                                        DAQmx_Val_FiniteSamps,
                                        BuffSize / No_of_Channels));


    /* RF Pulse Modulation is pin #11 */
    /* Can not use digial port 1, line #0, because using pin 11 */
    DAQmxErrChk (DAQmxCfgDigEdgeStartTrig( taskHandle,
                                           "/Dev1/PFI0", /* RF Pulse Mod  */
                                           DAQmx_Val_Rising));

    posttriggersamples = (BuffSize / No_of_Channels);
    posttriggersamples -= Post_Trigger_Samples_Per_Channel)
    DAQmxErrChk (DAQmxCfgDigEdgeRefTrig( taskHandle,
                                         "/Dev1/PFI0",
                                         DAQmx_Val_Falling,
                                         posttriggersamples));


    /*********************************************/
    // DAQmx Start Code
    /*********************************************/
    DAQmxErrChk (DAQmxStartTask(taskHandle));
```



```
    /*********************************************/
    // DAQmx Read Code
    /*********************************************/

    // 5 seconds timeout
    DAQmxErrChk (DAQmxReadAnalogF64( taskHandle,
                                     BuffSize / No_of_Channels,
                                     5.0,
                                     0,
                                     data,
                                     BuffSize,
                                     &read,
                                     NULL) );

Error:
    if( DAQmxFailed(error) )
        DAQmxGetExtendedErrorInfo(errBuff,2048);
    if( taskHandle≠0 ) {
        /*********************************************/
        // DAQmx Stop Code
        /*********************************************/
        DAQmxStopTask(taskHandle);
        DAQmxClearTask(taskHandle);
    }
    if( DAQmxFailed(error) ) {
        printf("DAQmx Error: %s\n",errBuff);

        BuffSize = 200;
        data    = (double *) calloc(BuffSize, sizeof(double));
        for (i = 0 ; i < BuffSize ; i++) {
            *(data+i) = (rand() % 10);
        }
    }
    *length = BuffSize;
    return data;
}


uInt8 *readDigital(uInt8 *data){
    int32       error=0;
    TaskHandle  taskHandle=0;
    //uInt8       data[100];
    char        errBuff[2048]={'\0'};
    int32       read, bytesPerSamp;

    /*********************************************/
    // DAQmx Configure Code
    /*********************************************/
    data = (uInt8 *) calloc(100, sizeof(uInt8));

    DAQmxErrChk (DAQmxCreateTask("",&taskHandle));
    DAQmxErrChk (DAQmxCreateDIChan(taskHandle,"Dev1/port1/line1:2","",
                                   DAQmx_Val_ChanForAllLines));

    /*********************************************/
    // DAQmx Start Code
    /*********************************************/
    DAQmxErrChk (DAQmxStartTask(taskHandle));

    /*********************************************/
    // DAQmx Read Code
    /*********************************************/
    DAQmxErrChk (DAQmxReadDigitalLines(taskHandle,1,10.0,
                                       DAQmx_Val_GroupByChannel,data,
                                       100,&read,&bytesPerSamp,NULL));
 Error:
    if( DAQmxFailed(error) )
        DAQmxGetExtendedErrorInfo(errBuff,2048);
```

```
    if( taskHandle≠0 ) {
        /*********************************************/
        // DAQmx Stop Code
        /*********************************************/
        DAQmxStopTask(taskHandle);
        DAQmxClearTask(taskHandle);
    }
    if( DAQmxFailed(error) )
        printf("DAQmx Error: %s\n",errBuff);

    return data;
}


int writeDigital(int port, char lines[], char values[]) {
    int         error=0;

    /* See the note below about keeping the port in force when a task
       handle is cleared.
    */
    TaskHandle  taskHandle = 0;
    char        errBuff[2048]={'\0'};
    uInt8       *data;
    int         i;

    //                     012345678901234567
    char        line[] = {"Dev1/portN/line0:7"};

    line[9] = port + 48;        /* convert int to ascii */
    line[15]= lines[0];
    line[17]= lines[strlen(lines)-1];
    data = (uInt8 *) calloc (strlen(values), sizeof(uInt8));

    for (i = 0 ; i < strlen(values) ; i++) {
        data[i] = values[i] - 48; /* convert from ascii to int */
    }

    /*********************************************/
    // DAQmx Configure Code
    /*********************************************/
    DAQmxErrChk (DAQmxCreateTask("",&taskHandle));
    DAQmxErrChk (DAQmxCreateDOChan( taskHandle,
                                    line,
                                    "", /* default clock */
                                    DAQmx_Val_ChanForAllLines ));

    /*********************************************/
    // DAQmx Start Code
    /*********************************************/
    DAQmxErrChk (DAQmxStartTask(taskHandle));

    /*********************************************/
    // DAQmx Write Code
    /*********************************************/
    DAQmxErrChk (DAQmxWriteDigitalLines( taskHandle,
                                         1, 1, 10.0,
                                         DAQmx_Val_GroupByChannel,
                                         data, NULL, NULL));
  Error:
    if( DAQmxFailed(error) )
        DAQmxGetExtendedErrorInfo(errBuff,2048);
    if( taskHandle≠0 ) {
        /*********************************************/
        // DAQmx Stop CodeDAQmxErrChk (
        /*********************************************/
        /* Digital functions remain in force even when the task is cleared.
           This is not so for timer tasks.  See also loadCounter.
        */
        DAQmxStopTask(taskHandle);
```



```
        DAQmxClearTask(taskHandle);
    }

    if( DAQmxFailed(error) )
        printf("DAQmx Error: %s\n",errBuff);
    return 1;
}


int loadCounter(int start, int rf, double ipp, double pw) {
    double   delay = 1.0 / 1000000; // 1us delay
    double   dutycycle1 = pw / ipp;
    double   dutycycle2 = (pw + 2 * delay) / ipp;  // duty cycle for TR
    double   freq       = 1.0 / ipp;
    int      error=0;

    /* Most of the routines use local's for TaskHandle, but the timers
     * require static handles that are not destroyed upon function returns
     */
    static TaskHandle  taskHandle1=0, taskHandle2 = 0;

    char     errBuff[2048]={'\0'};

    /*********************************************/
    // DAQmx Configure Code
    /*********************************************/

    if( taskHandle1 ≠0 ) {
        /*********************************************/
        // DAQmx Stop Code
        /*********************************************/
        DAQmxStopTask(taskHandle1);
        DAQmxClearTask(taskHandle1);
        taskHandle1 = 0;
    }

    if( taskHandle2 ≠0 ) {
        /*********************************************/
        // DAQmx Stop Code
        /*********************************************/
        DAQmxStopTask(taskHandle2);
        DAQmxClearTask(taskHandle2);
        taskHandle2 = 0;
    }

    if ( start ≡ 0 ) {
        return 0;
    }

    if (rf ≡ 1) {
        DAQmxErrChk (DAQmxCreateTask("Counter_1",&taskHandle1));
    }

    DAQmxErrChk (DAQmxCreateTask("Counter_2",&taskHandle2));


    // Counter 0 is RF
    // Counter 1 is TR
    if (rf ≡ 1) {
        DAQmxErrChk (DAQmxCreateCOPulseChanFreq(taskHandle1,"Dev1/ctr0","",
                                                DAQmx_Val_Hz,DAQmx_Val_Low,
                                                delay, freq, dutycycle1));
    }
    DAQmxErrChk (DAQmxCreateCOPulseChanFreq(taskHandle2,"Dev1/ctr1","",
                                            DAQmx_Val_Hz,DAQmx_Val_Low, 0.00,
                                            freq, dutycycle2));



    // Trigger Counter 0 on rising edge of 1
```

```
    if (rf ≡ 1) {
        DAQmxErrChk (DAQmxCfgDigEdgeStartTrig(taskHandle1, "/Dev1/PFI9",
                                              DAQmx_Val_Rising));
        DAQmxErrChk(DAQmxCfgImplicitTiming(taskHandle1,DAQmx_Val_ContSamps,10));
    }
    DAQmxErrChk (DAQmxCfgImplicitTiming(taskHandle2,DAQmx_Val_ContSamps,10));

    // DAQmxErrChk (DAQmxRegisterDoneEvent(taskHandle,0,DoneCallback,NULL));

    /*********************************************/
    // DAQmx Start Code
    /*********************************************/
    // Start counter 1 first (because this is what is waiting for trigger)
    DAQmxErrChk (DAQmxStartTask(taskHandle2));

    if (rf ≡ 1) {
      // Start counter 0 now   (this triggers the counter 1)
      DAQmxErrChk (DAQmxStartTask(taskHandle1));
    }

  Error:
    if( DAQmxFailed(error) ) {
        DAQmxGetExtendedErrorInfo(errBuff,2048);
        DAQmxStopTask(taskHandle1);
        DAQmxClearTask(taskHandle1);
        DAQmxStopTask(taskHandle2);
        DAQmxClearTask(taskHandle2);
        printf("DAQmx Error: %s\n",errBuff);
    }
    return 0;
}

// ============================================================
```

Appendix E

Distribution Board Component Data Sheets

Table of Contents

1. 2N7002: N-Channel Enhancement Mode Field Effect Transistor

Fairchild Semiconductor

N-Channel Enhancement Mode

Field Effect Transistor

2N7002

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter	Conditions	Type	Min	Typ	Max	Units
OFF CHARACTERISTICS							
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS} = 0 V, I_D = 10 µA	All	60			V
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 48 V, V_{GS} = 0 V	2N7000			1	µA
		T_J=125°C				1	mA
		V_{DS} = 60 V, V_{GS} = 0 V	2N7002 NDS7002A			1	µA
		T_J=125°C				0.5	mA
I_{GSSF}	Gate - Body Leakage, Forward	V_{GS} = 15 V, V_{DS} = 0 V	2N7000			10	nA
		V_{GS} = 20 V, V_{DS} = 0 V	2N7002 NDS7002A			100	nA
I_{GSSR}	Gate - Body Leakage, Reverse	V_{GS} = -15 V, V_{DS} = 0 V	2N7000			-10	nA
		V_{GS} = -20 V, V_{DS} = 0 V	2N7002 NDS7002A			-100	nA
ON CHARACTERISTICS (Note 1)							
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS}, I_D = 1 mA	2N7000	0.8	2.1	3	V
		V_{DS} = V_{GS}, I_D = 250 µA	2N7002 NDS7002A	1	2.1	2.5	
$R_{DS(ON)}$	Static Drain-Source On-Resistance	V_{GS} = 10 V, I_D = 500 mA	2N7000		1.2	5	Ω
		T_J =125°C			1.9	9	
		V_{GS} = 4.5 V, I_D = 75 mA			1.8	5.3	
		V_{GS} = 10 V, I_D = 500 mA	2N7002		1.2	7.5	
		T_J =100°C			1.7	13.5	
		V_{GS} = 5.0 V, I_D = 50 mA			1.7	7.5	
		T_J =100C			2.4	13.5	
		V_{GS} = 10 V, I_D = 500 mA	NDS7002A		1.2	2	
		T_J =125°C			2	3.5	
		V_{GS} = 5.0 V, I_D = 50 mA			1.7	3	
		T_J =125°C			2.8	5	
$V_{DS(ON)}$	Drain-Source On-Voltage	V_{GS} = 10 V, I_D = 500 mA	2N7000		0.6	2.5	V
		V_{GS} = 4.5 V, I_D = 75 mA			0.14	0.4	
		V_{GS} = 10 V, I_D = 500mA	2N7002		0.6	3.75	
		V_{GS} = 5.0 V, I_D = 50 mA			0.09	1.5	
		V_{GS} = 10 V, I_D = 500mA	NDS7002A		0.6	1	
		V_{GS} = 5.0 V, I_D = 50 mA			0.09	0.15	

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter	Conditions	Type	Min	Typ	Max	Units
ON CHARACTERISTICS Continued (Note 1)							
$I_{D(ON)}$	On-State Drain Current	V_{GS} = 4.5 V, V_{DS} = 10 V	2N7000	75	600		mA
		V_{GS} = 10 V, $V_{DS} \geq$ 2 $V_{DS(on)}$	2N7002	500	2700		
		V_{GS} = 10 V, $V_{DS} \geq$ 2 $V_{DS(on)}$	NDS7002A	500	2700		
g_{FS}	Forward Transconductance	V_{DS} = 10 V, I_D = 200 mA	2N7000	100	320		mS
		$V_{DS} \geq$ 2 $V_{DS(on)}$, I_D = 200 mA	2N7002	80	320		
		$V_{DS} \geq$ 2 $V_{DS(on)}$, I_D = 200 mA	NDS7002A	80	320		
DYNAMIC CHARACTERISTICS							
C_{iss}	Input Capacitance	V_{DS} = 25 V, V_{GS} = 0 V, f = 1.0 MHz	All		20	50	pF
C_{oss}	Output Capacitance		All		11	25	pF
C_{rss}	Reverse Transfer Capacitance		All		4	5	pF
t_{on}	Turn-On Time	V_{DD} = 15 V, R_L = 25 Ω, I_D = 500 mA, V_{GS} = 10 V, R_{GEN} = 25	2N7000			10	ns
		V_{DD} = 30 V, R_L = 150 Ω, I_D = 200 mA, V_{GS} = 10 V, R_{GEN} = 25 Ω	2N700 NDS7002A			20	
t_{off}	Turn-Off Time	V_{DD} = 15 V, R_L = 25 Ω, I_D = 500 mA, V_{GS} = 10 V, R_{GEN} = 25	2N7000			10	ns
		V_{DD} = 30 V, R_L = 150 Ω, I_D = 200 mA, V_{GS} = 10 V, R_{GEN} = 25 Ω	2N700 NDS7002A			20	
DRAIN-SOURCE DIODE CHARACTERISTICS AND MAXIMUM RATINGS							
I_S	Maximum Continuous Drain-Source Diode Forward Current		2N7002			115	mA
			NDS7002A			280	
I_{SM}	Maximum Pulsed Drain-Source Diode Forward Current		2N7002			0.8	A
			NDS7002A			1.5	
V_{SD}	Drain-Source Diode Forward Voltage	V_{GS} = 0 V, I_S = 115 mA (Note 1)	2N7002		0.88	1.5	V
		V_{GS} = 0 V, I_S = 400 mA (Note 1)	NDS7002A		0.88	1.2	

Note:
1. Pulse Test: Pulse Width ≤ 300µs, Duty Cycle ≤ 2.0%.

Typical Electrical Characteristics

2N7000 / 2N7002 / NDS7002A

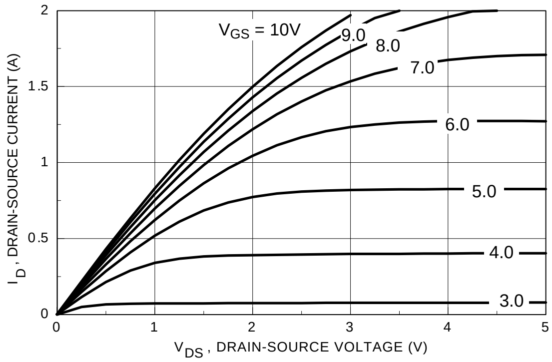

Figure 1. On-Region Characteristics

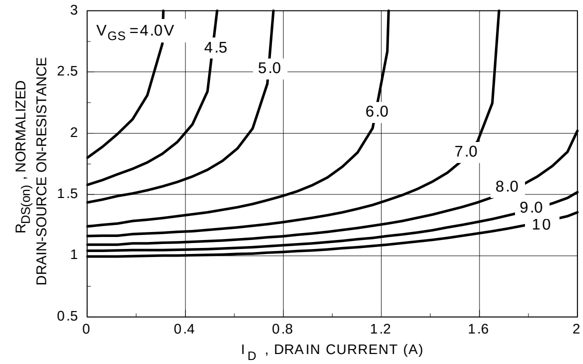

Figure 2. On-Resistance Variation with Gate Voltage and Drain Current

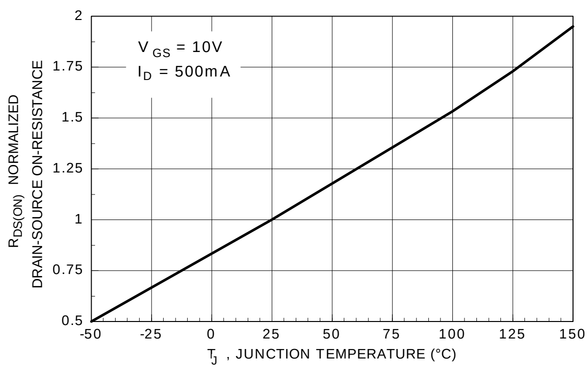

Figure 3. On-Resistance Variation with Temperature

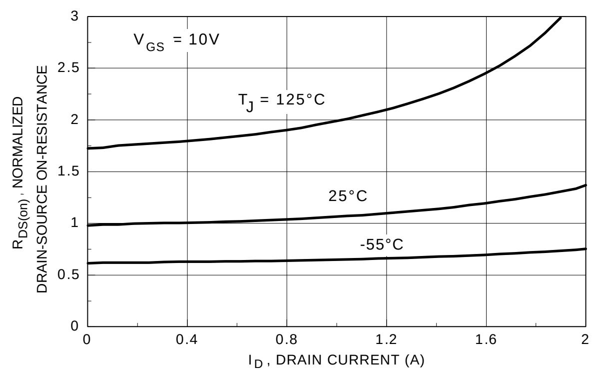

Figure 4. On-Resistance Variation with Drain Current and Temperature

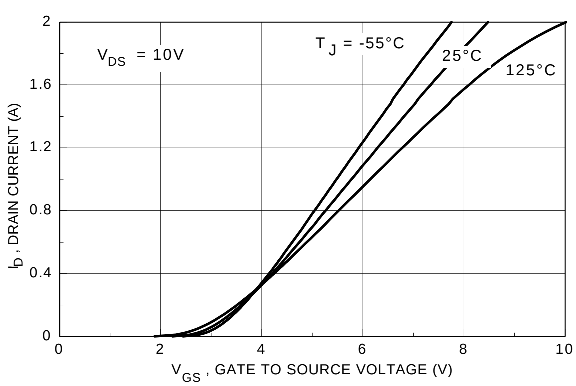

Figure 5. Transfer Characteristics

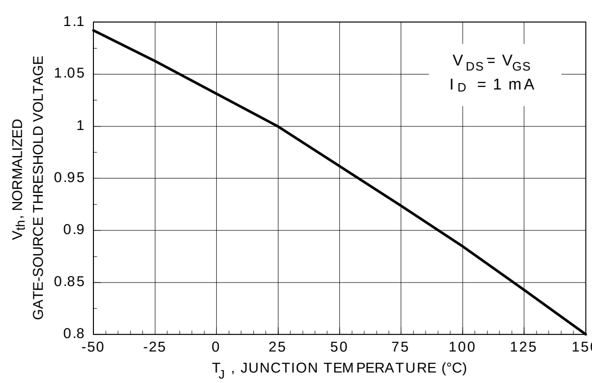

Figure 6. Gate Threshold Variation with Temperature

Typical Electrical Characteristics (continued)

2N7000 / 2N7002 /NDS7002A

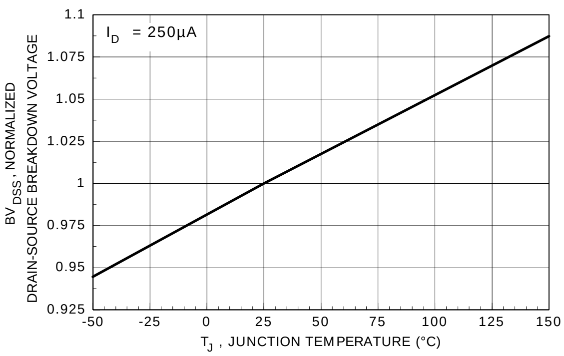

Figure 7. Breakdown Voltage Variation with Temperature

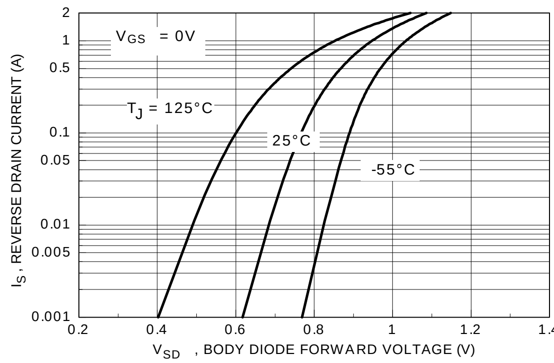

Figure 8. Body Diode Forward Voltage Variation with

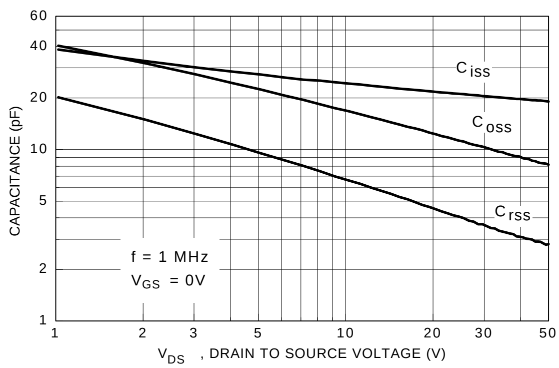

Figure 9. Capacitance Characteristics

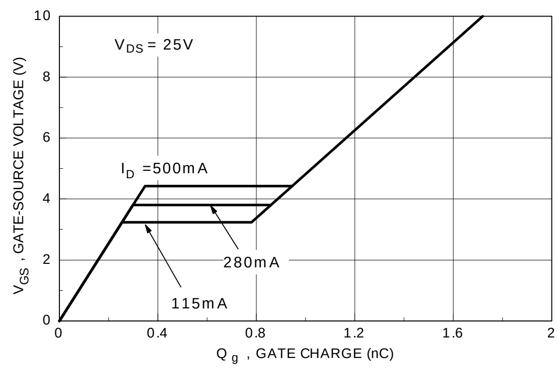

Figure 10. Gate Charge Characteristics

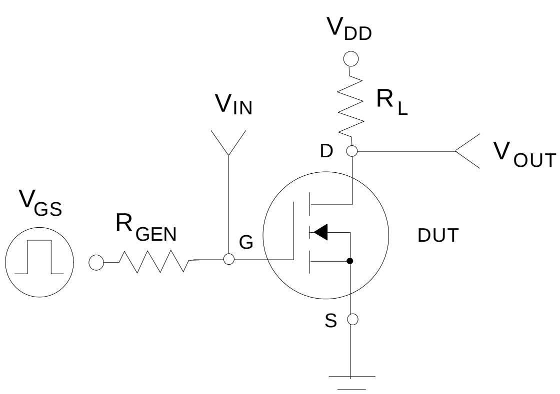

Figure 11.

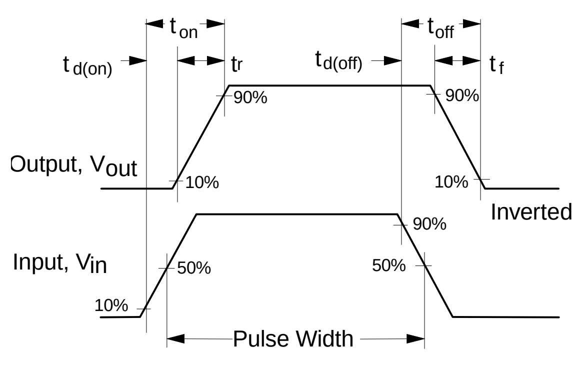

Figure 12. Switching Waveforms

Typical Electrical Characteristics (continued)

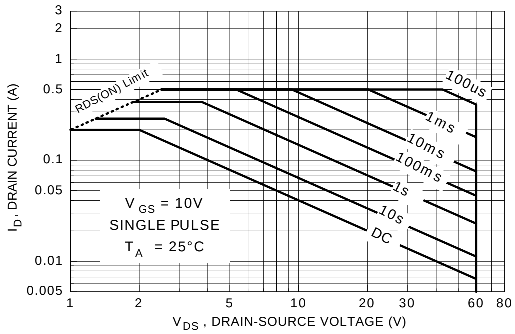

Figure 13. 2N7000 Maximum Safe Operating Area

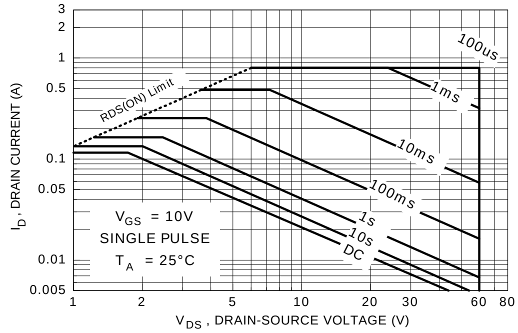

Figure 14. 2N7002 Maximum Safe Operating Area

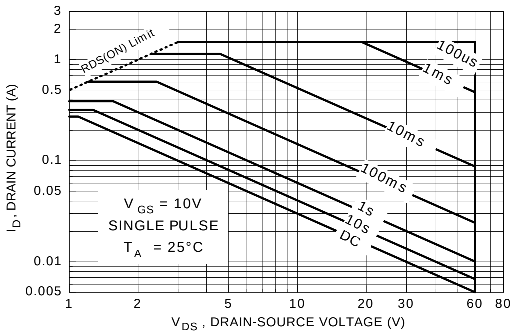

Figure 15. NDS7000A Maximum Safe Operating Area

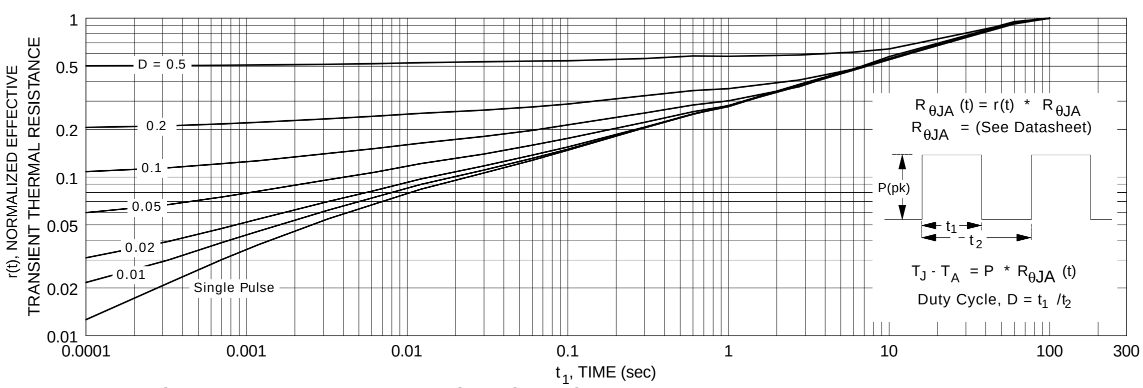

Figure 16. TO-92, 2N7000 Transient Thermal Response Curve

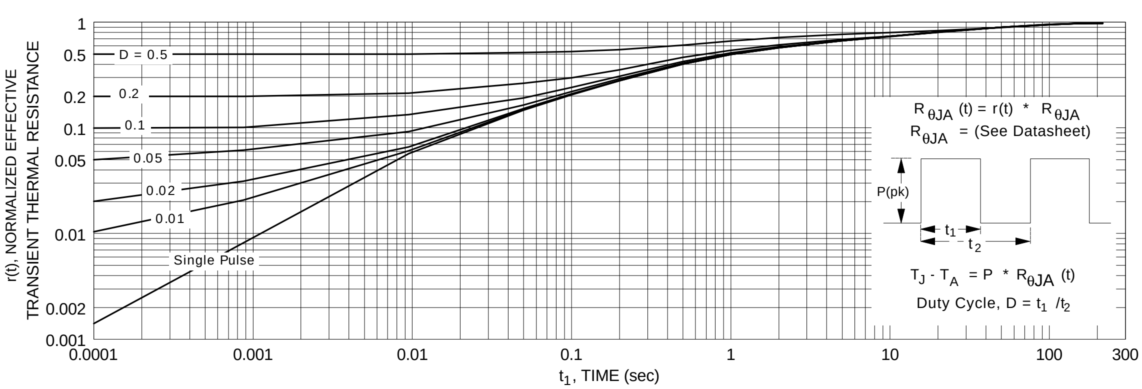

Figure 17. SOT-23, 2N7002 / NDS7002A Transient Thermal Response Curve

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DOME™	ISOPLANAR™	Quiet Series™	
E^2CMOS™	MICROWIRE™	SILENT SWITCHER®	
EnSigna™	OPTOLOGIC™	SMART START™	
FACT™	OPTOPLANAR™	SuperSOT™-3	
FACT Quiet Series™	PACMAN™	SuperSOT™-6	
FAST®	POP™	SuperSOT™-8	

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FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.

Rev. G

November 1995

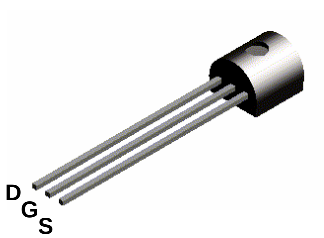
2N7000 / 2N7002 / NDS7002A
N-Channel Enhancement Mode Field Effect Transistor

General Description

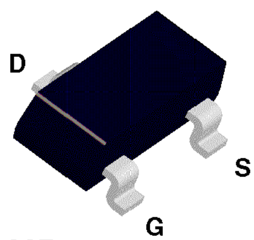
These N-Channel enhancement mode field effect transistors are produced using Fairchild's proprietary, high cell density, DMOS technology. These products have been designed to minimize on-state resistance while provide rugged, reliable, and fast switching performance. They can be used in most applications requiring up to 400mA DC and can deliver pulsed currents up to 2A. These products are particularly suited for low voltage, low current applications such as small servo motor control, power MOSFET gate drivers, and other switching applications.

Features

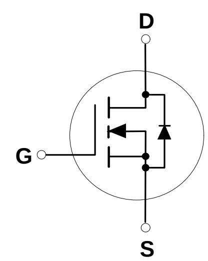
- High density cell design for low $R_{DS(ON)}$.
- Voltage controlled small signal switch.
- Rugged and reliable.
- High saturation current capability.



TO-92
2N7000



SOT-23
(TO-236AB)
2N7002/NDS7002A



Absolute Maximum Ratings
T_A = 25°C unless otherwise noted

Symbol	Parameter	2N7000	2N7002	NDS7002A	Units
V_{DSS}	Drain-Source Voltage		60		V
V_{DGR}	Drain-Gate Voltage ($R_{GS} \leq 1$ MΩ)		60		V
V_{GSS}	Gate-Source Voltage - Continuous		±20		V
	- Non Repetitive (tp < 50µs)		±40		
I_D	Maximum Drain Current - Continuous	200	115	280	mA
	- Pulsed	500	800	1500	
P_D	Maximum Power Dissipation	400	200	300	mW
	Derated above 25°C	3.2	1.6	2.4	mW/°C
T_J,T_{STG}	Operating and Storage Temperature Range	-55 to 150		-65 to 150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16" from Case for 10 Seconds		300		°C
THERMAL CHARACTERISTICS					
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	312.5	625	417	°C/W

2. 74AC74: Dual D-Type Positive Edge Triggered Flip-Flop

Fairchild Semiconductor

Dual D-Type Positive Edge

Triggered Flip-Flop

74AC74

FAIRCHILD SEMICONDUCTOR®

November 1988
Revised February 2005

74AC74 • 74ACT74
Dual D-Type Positive Edge-Triggered Flip-Flop

General Description

The AC/ACT74 is a dual D-type flip-flop with Asynchronous Clear and Set inputs and complementary (Q, $\overline{Q}$) outputs. Information at the input is transferred to the outputs on the positive edge of the clock pulse. Clock triggering occurs at a voltage level of the clock pulse and is not directly related to the transition time of the positive-going pulse. After the Clock Pulse input threshold voltage has been passed, the Data input is locked out and information present will not be transferred to the outputs until the next rising edge of the Clock Pulse input.

Asynchronous Inputs:

LOW input to $\overline{S}_D$ (Set) sets Q to HIGH level

LOW input to $\overline{C}_D$ (Clear) sets Q to LOW level

Clear and Set are independent of clock

Simultaneous LOW on $\overline{C}_D$ and $\overline{S}_D$ makes both Q and $\overline{Q}$ HIGH

Features

- I_{CC} reduced by 50%
- Output source/sink 24 mA
- ACT74 has TTL-compatible inputs

Ordering Code:

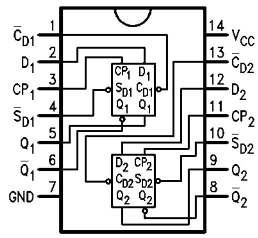
Order Number	Package Number	Package Description
74AC74SC	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
74AC74SC_NL (Note 1)	M14A	Pb-Free 14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
74AC74SJ	M14D	Pb-Free 14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
74AC74MTC	MTC14	14-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide
74AC74MTCX_NL (Note 2)	MTC14	Pb-Free 14-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide
74AC74PC	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300” Wide
74ACT74SC	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
74ACT74SC_NL (Note 1)	M14A	Pb-Free 14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
74ACT74SJ	M14D	Pb-Free 14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
74ACT74SJX_NL (Note 2)	M14D	Pb-Free 14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
74ACT74MTC	MTC14	14-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide
74ACT74PC	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300” Wide

Device also available in Tape and Reel. Specify by appending suffix letter “X” to the ordering code.
Pb-Free package per JECED J-STD-020B.

Note 1: “_NL” indicates lead-free product (per JEDEC J-STD-020B).

Note 2: “_NL” indicates lead-free product (per JEDEC J-STD-020B). Device is available in Tape and Reel only.

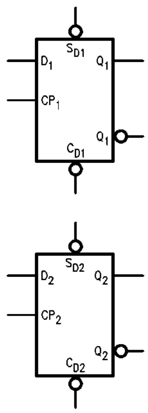
Connection Diagram



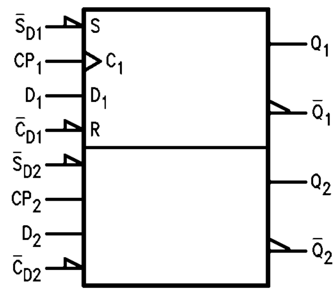
Pin Descriptions

Pin Names	Description
D_1, D_2	Data Inputs
CP_1, CP_2	Clock Pulse Inputs
$\overline{C}_{D1}$, $\overline{C}_{D2}$	Direct Clear Inputs
$\overline{S}_{D1}$, $\overline{S}_{D2}$	Direct Set Inputs
Q_1, $\overline{Q}_1$, Q_2, $\overline{Q}_2$	Outputs

Logic Symbols



IEEE/IEC



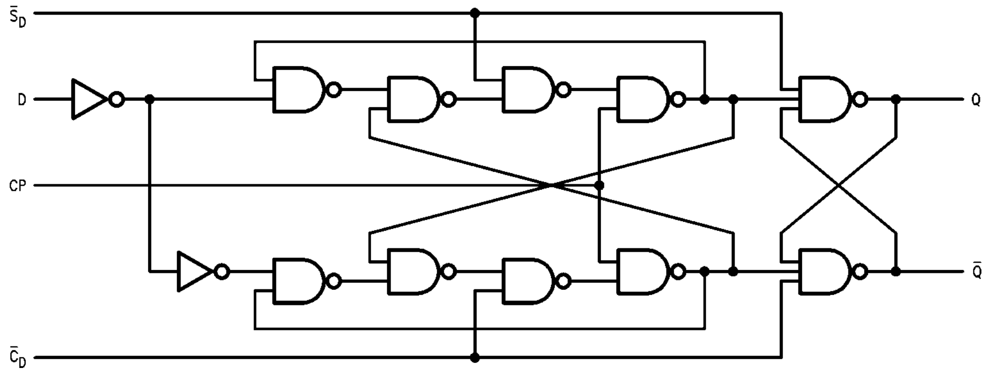
Truth Table

(Each Half)

Inputs				Outputs	
$\overline{S}_D$	$\overline{C}_D$	CP	D	Q	$\overline{Q}$
L	H	X	X	H	L
H	L	X	X	L	H
L	L	X	X	H	H
H	H	⌐	H	H	L
H	H	⌐	L	L	H
H	H	L	X	Q_0	$\overline{Q}_0$

H = HIGH Voltage Level
L = LOW Voltage Level
X = Immaterial
⌐ = LOW-to-HIGH Clock Transition
Q_0 ($\overline{Q}_0$) = Previous Q ($\overline{Q}$) before LOW-to-HIGH Transition of Clock

Logic Diagram



Please note that this diagram is provided only for the understanding of logic operations and should not be used to estimate propagation delays.

Absolute Maximum Ratings (Note 3)

Supply Voltage (V_{CC})	−0.5V to +7.0V
DC Input Diode Current (I_{IK})	
$V_I = -0.5V$	−20 mA
$V_I = V_{CC} + 0.5V$	+20 mA
DC Input Voltage (V_I)	−0.5V to V_{CC} + 0.5V
DC Output Diode Current (I_{OK})	
$V_O = -0.5V$	−20 mA
$V_O = V_{CC} + 0.5V$	+20 mA
DC Output Voltage (V_O)	−0.5V to V_{CC} + 0.5V
DC Output Source or Sink Current (I_O)	±50 mA
DC V_{CC} or Ground Current per Output Pin (I_{CC} or I_{GND})	±50 mA
Storage Temperature (T_{STG})	−65°C to +150°C
Junction Temperature (T_J)	
PDIP	140°C

Recommended Operating Conditions

Supply Voltage (V_{CC})	
AC	2.0V to 6.0V
ACT	4.5V to 5.5V
Input Voltage (V_I)	0V to V_{CC}
Output Voltage (V_O)	0V to V_{CC}
Operating Temperature (T_A)	−40°C to +85°C
Minimum Input Edge Rate ($\Delta V/\Delta t$)	
AC Devices	
V_{IN} from 30% to 70% of V_{CC}	
V_{CC} @ 3.3V, 4.5V, 5.5V	125 mV/ns
Minimum Input Edge Rate ($\Delta V/\Delta t$)	
ACT Devices	
V_{IN} from 0.8V to 2.0V	
V_{CC} @ 4.5V, 5.5V	125 mV/ns

Note 3: Absolute maximum ratings are those values beyond which damage to the device may occur. The databook specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. Fairchild does not recommend operation of FACT™ circuits outside databook specifications.

DC Electrical Characteristics for AC

Symbol	Parameter	V_{CC} (V)	$T_A = +25°C$ Typ	$T_A = +25°C$ Guaranteed Limits	$T_A = -40°C$ to $+85°C$ Guaranteed Limits	Units	Conditions
V_{IH}	Minimum HIGH Level Input Voltage	3.0	1.5	2.1	2.1	V	$V_{OUT} = 0.1V$ or $V_{CC} - 0.1V$
		4.5	2.25	3.15	3.15		
		5.5	2.75	3.85	3.85		
V_{IL}	Maximum LOW Level Input Voltage	3.0	1.5	0.9	0.9	V	$V_{OUT} = 0.1V$ or $V_{CC} - 0.1V$
		4.5	2.25	1.35	1.35		
		5.5	2.75	1.65	1.65		
V_{OH}	Minimum HIGH Level Output Voltage	3.0	2.99	2.9	2.9	V	$I_{OUT} = -50\ \mu A$
		4.5	4.49	4.4	4.4		
		5.5	5.49	5.4	5.4		
						V	$V_{IN} = V_{IL}$ or V_{IH}
		3.0		2.56	2.46		$I_{OH} = -12$ mA
		4.5		3.86	3.76		$I_{OH} = -24$ m
		5.5		4.86	4.76		$I_{OH} = -24$ m (Note 4)
V_{OL}	Maximum LOW Level Output Voltage	3.0	0.002	0.1	0.1	V	$I_{OUT} = 50\ \mu A$
		4.5	0.001	0.1	0.1		
		5.5	0.001	0.1	0.1		
						V	$V_{IN} = V_{IL}$ or V_{IH}
		3.0		0.36	0.44		$I_{OL} = 12$ mA
		4.5		0.36	0.44		$I_{OL} = 24$ mA
		5.5		0.36	0.44		$I_{OL} = 24$ mA (Note 4)
I_{IN} (Note 6)	Maximum Input Leakage Current	5.5		± 0.1	± 1.0	µA	$V_I = V_{CC}$, GND
I_{OLD}	Minimum Dynamic Output Current (Note 5)	5.5			75	mA	$V_{OLD} = 1.65V$ Maximum
I_{OHD}		5.5			−75	mA	$V_{OHD} = 3.85V$ Minimum
I_{CC} (Note 6)	Maximum Quiescent Supply Current	5.5		2.0	20.0	µA	$V_{IN} = V_{CC}$ or GND

Note 4: All outputs loaded; thresholds on input associated with output under test.

Note 5: Maximum test duration 2.0 ms, one output loaded at a time.

Note 6: I_{IN} and I_{CC} @ 3.0V are guaranteed to be less than or equal to the respective limit @ 5.5V V_{CC}.

DC Electrical Characteristics for ACT

Symbol	Parameter	V_{CC} (V)	$T_A = +25°C$ Typ		$T_A = -40°C$ to $+85°C$	Units	Conditions
			Typ	Guaranteed Limits			
V_{IH}	Minimum HIGH Level Input Voltage	4.5 5.5	1.5 1.5	2.0 2.0	2.0 2.0	V	$V_{OUT} = 0.1V$ or $V_{CC} - 0.1V$
V_{IL}	Maximum LOW Level Output Voltage	4.5 5.5	1.5 1.5	0.8 0.8	0.8 0.8	V	$V_{OUT} = 0.1V$ or $V_{CC} - 0.1V$
V_{OH}	Minimum HIGH Level Output Voltage	4.5 5.5	4.49 5.49	4.4 5.4	4.4 5.4	V	$I_{OUT} = -50$ µA
		4.5 5.5		3.86 4.86	3.76 4.76	V	$V_{IN} = V_{IL}$ or V_{IH} $I_{OH} = -24$ mA $I_{OH} = -24$ mA (Note 7)
V_{OL}	Maximum LOW Level Output Voltage	4.5 5.5	0.001 0.001	0.1 0.1	0.1 0.1	V	$I_{OUT} = 50$ µA
		4.5 5.5		0.36 0.36	0.44 0.44	V	$V_{IN} = V_{IL}$ or V_{IH} $I_{OL} = 24$ mA $I_{OL} = 24$ mA (Note 7)
I_{IN}	Maximum Input Leakage Current	5.5		±0.1	±1.0	µA	$V_I = V_{CC}$, GND
I_{CCT}	Maximum I_{CC}/Input	5.5	0.6		1.5	mA	$V_I = V_{CC} - 2.1V$
I_{OLD}	Minimum Dynamic	5.5			75	mA	$V_{OLD} = 1.65V$ Maximum
I_{OHD}	Output Current (Note 8)	5.5			−75	mA	$V_{OHD} = 3.85V$ Minimum
I_{CC}	Maximum Quiescent Supply Current	5.5		2.0	20.0	µA	$V_{IN} = V_{CC}$ or GND

Note 7: All outputs loaded; thresholds on input associated with output under test.

Note 8: Maximum test duration 2.0 ms, one output loaded at a time.

AC Electrical Characteristics for AC

Symbol	Parameter	V_{CC} (V) (Note 9)	$T_A = +25°C$, $C_L = 50$ pF			$T_A = -40°C$ to $+85°C$, $C_L = 50$ pF		Units
			Min	Typ	Max	Min	Max	
f_{MAX}	Maximum Clock Frequency	3.3 5.0	100 140	125 160		95 125		MHz
t_{PLH}	Propagation Delay $\overline{C}_{Dn}$ or $\overline{S}_{Dn}$ to Q_n or $\overline{Q}_n$	3.3 5.0	3.5 2.5	8.0 6.0	12.0 9.0	2.5 2.0	13.0 10.0	ns
t_{PHL}	Propagation Delay $\overline{C}_{Dn}$ or $\overline{S}_{Dn}$ to Q_n or $\overline{Q}_n$	3.3 5.0	4.0 3.0	10.5 8.0	12.0 9.5	3.5 2.5	13.5 10.5	ns
t_{PLH}	Propagation Delay CP_n to Q_n or $\overline{Q}_n$	3.3 5.0	4.5 3.5	8.0 6.0	13.5 10.0	4.0 3.0	16.0 10.5	ns
t_{PHL}	Propagation Delay CP_n to Q_n or $\overline{Q}_n$	3.3 5.0	3.5 2.5	8.0 6.0	14.0 10.0	3.5 2.5	14.5 10.5	ns

Note 9: Voltage Range 3.3 is 3.3V ± 0.3V
Voltage Range 5.0 is 5.0V ± 0.5V

AC Operating Requirements for AC

Symbol	Parameter	V_{CC} (V) (Note 10)	$T_A = +25°C$ $C_L = 50$ pF Typ	$T_A = +25°C$ $C_L = 50$ pF Guaranteed Minimum	$T_A = -40°C$ to $+85°C$ $C_L = 50$ pF Guaranteed Minimum	Units
t_S	Set-up Time, HIGH or LOW	3.3	1.5	4.0	4.5	ns
	D_n to CP_n	5.0	1.0	3.0	3.0	
t_H	Hold Time, HIGH or LOW	3.3	−2.0	0.5	0.5	ns
	D_n to CP_n	5.0	−1.5	0.5	0.5	
t_W	CP_n or $\overline{C}_{Dn}$ or $\overline{S}_{Dn}$	3.3	3.0	5.5	7.0	ns
	Pulse Width	5.0	2.5	4.5	5.0	
t_{rec}	Recovery Time	3.3	−2.5	0	0	ns
	$\overline{C}_{Dn}$ or $\overline{S}_{Dn}$ to CP	5.0	−2.0	0	0	

Note 10: Voltage Range 3.3 is 3.3V ± 0.3V
Voltage Range 5.0 is 5.0V ± 0.5V

AC Electrical Characteristics for ACT

Symbol	Parameter	V_{CC} (V) (Note 11)	$T_A = +25°C$ $C_L = 50$ pF Min	Typ	Max	$T_A = -40°C$ to $+85°C$ $C_L = 50$ pF Min	Max	Units
f_{MAX}	Maximum Clock Frequency	5.0	145	210		125		MHz
t_{PLH}	Propagation Delay $\overline{C}_{Dn}$ or $\overline{S}_{Dn}$ to Q_n or $\overline{Q}_n$	5.0	3.0	5.5	9.5	2.5	10.5	ns
t_{PHL}	Propagation Delay $\overline{C}_{Dn}$ or $\overline{S}_{Dn}$ to Q_n or $\overline{Q}_n$	5.0	3.0	6.0	10.0	3.0	11.5	ns
t_{PLH}	Propagation Delay CP_n to Q_n or $\overline{Q}_n$	5.0	4.0	7.5	11.0	4.0	13.0.	ns
t_{PHL}	Propagation Delay CP_n to Q_n or $\overline{Q}_n$	5.0	3.5	6.0	10.0	3.0	11.5	ns

Note 11: Voltage Range 5.0 is 5.0V ± 0.5V

AC Operating Requirements for ACT

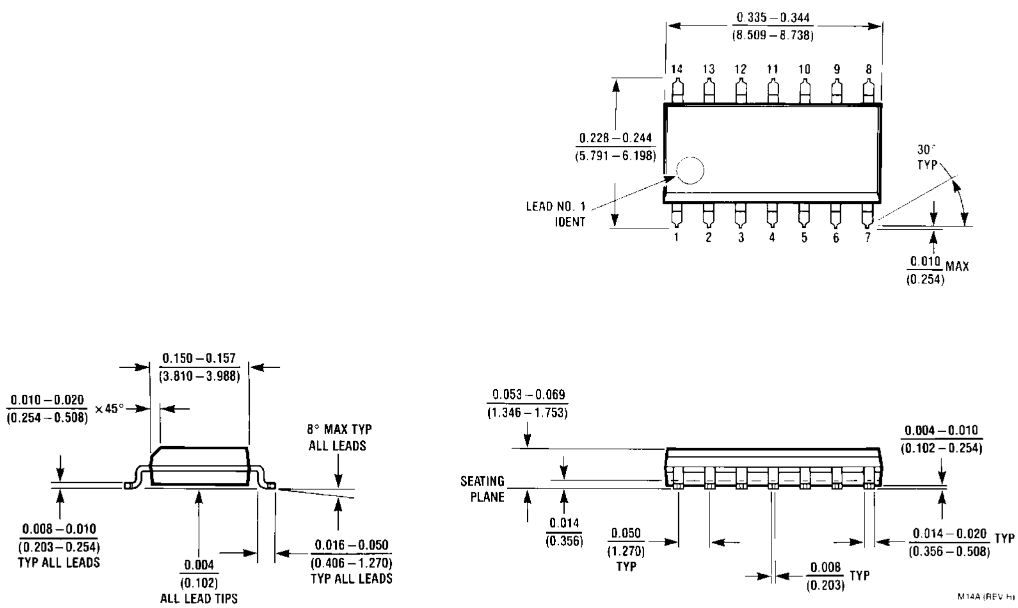
Symbol	Parameter	V_{CC} (V) (Note 12)	$T_A = +25°C$ $C_L = 50$ pF Typ	$T_A = +25°C$ $C_L = 50$ pF Guaranteed Minimum	$T_A = -40°C$ to $+85°C$ $C_L = 50$ pF Guaranteed Minimum	Units
t_S	Set-up Time, HIGH or LOW D_n to CP_n	5.0	1.0	3.0	3.5	ns
t_H	Hold Time, HIGH or LOW D_n to CP_n	5.0	−0.5	1.0	1.0	ns
t_W	CP_n or $\overline{C}_{Dn}$ or $\overline{S}_{Dn}$ Pulse Width	5.0	3.0	5.0	6.0	ns
t_{rec}	Recovery Time $\overline{C}_{Dn}$ or $\overline{S}_{Dn}$ to CP	5.0	−2.5	0	0	ns

Note 12: Voltage Range 5.0 is 5.0V ± 0.5V

Capacitance

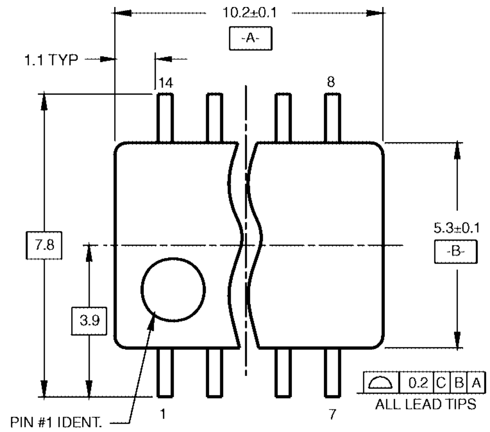
Symbol	Parameter	Typ	Units	Conditions
C_{IN}	Input Capacitance	4.5	pF	V_{CC} = OPEN
C_{PD}	Power Dissipation Capacitance	35.0	pF	$V_{CC} = 5.0V$

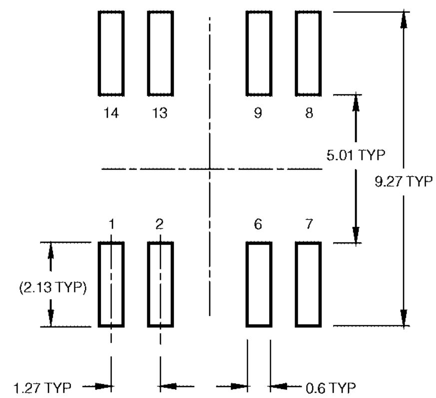
Physical Dimensions inches (millimeters) unless otherwise noted



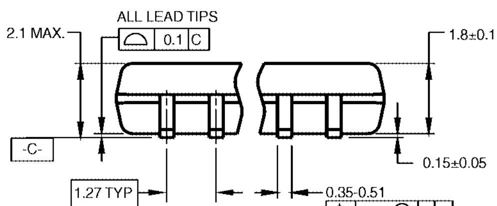
14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
Package Number M14A

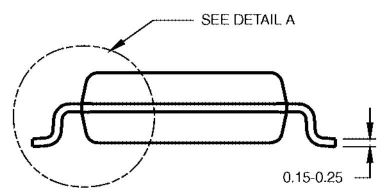
Physical Dimensions inches (millimeters) unless otherwise noted (Continued)





LAND PATTERN RECOMMENDATION





DIMENSIONS ARE IN MILLIMETERS

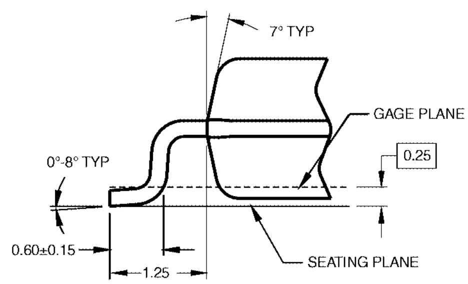
NOTES:

A. CONFORMS TO EIAJ EDR-7320 REGISTRATION, ESTABLISHED IN DECEMBER, 1998.

B. DIMENSIONS ARE IN MILLIMETERS.

C. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS.

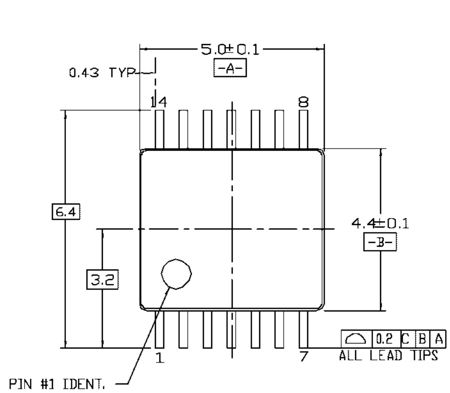
M14DRevB1

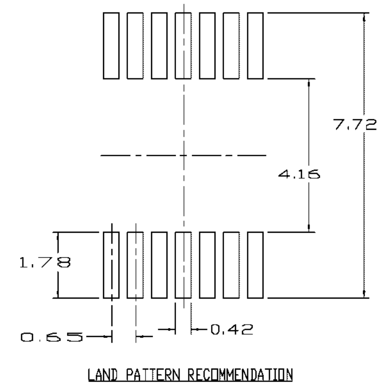


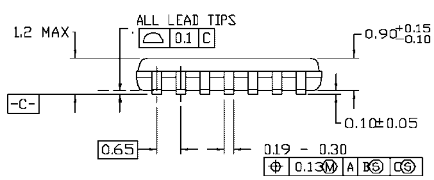
DETAIL A

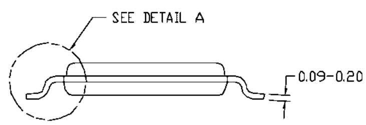
Pb-Free 14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
Package Number M14D

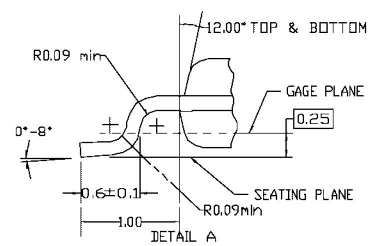
Physical Dimensions inches (millimeters) unless otherwise noted (Continued)











NOTES:

A. CONFORMS TO JEDEC REGISTRATION MO-153, VARIATION AB, REF NOTE 6, DATED 7/93

B. DIMENSIONS ARE IN MILLIMETERS

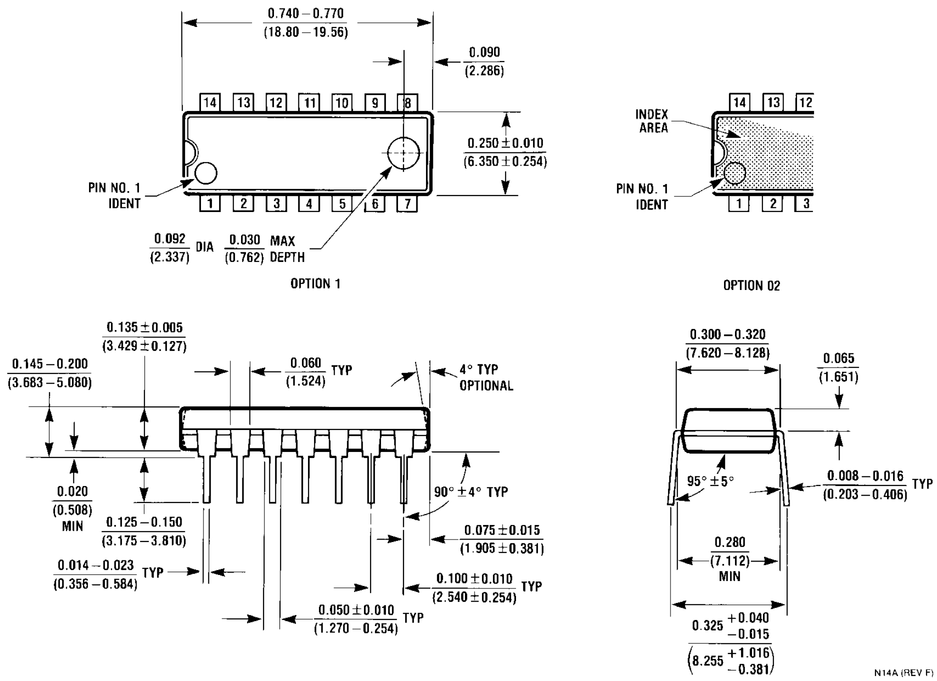
C. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS

D. DIMENSIONING AND TOLERANCES PER ANSI Y14.5M, 1982

MTC14revD

14-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide
Package Number MTC14

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide
Package Number N14A

Fairchild does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and Fairchild reserves the right at any time without notice to change said circuitry and specifications.

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

www.fairchildsemi.com

3. SN74AHCT14: Hex Schmitt-Trigger Inverter

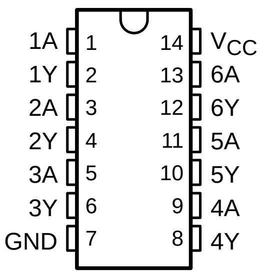
Texas Instruments

Hex Schmitt-Trigger Inverter

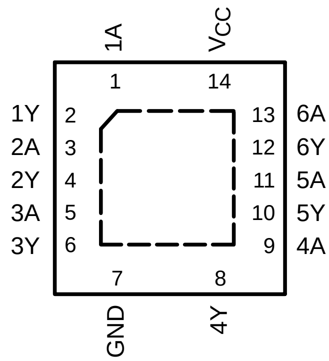
SN74AHCT14

- **Inputs Are TTL-Voltage Compatible**
- **Latch-Up Performance Exceeds 250 mA Per JESD 17**
- **ESD Protection Exceeds JESD 22**
  - **2000-V Human-Body Model (A114-A)**
  - **200-V Machine Model (A115-A)**
  - **1000-V Charged-Device Model (C101)**

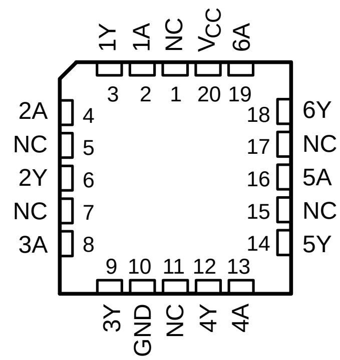
SN54AHCT14 . . . J OR W PACKAGE
SN74AHCT14 . . . D, DB, DGV, N, NS, OR PW PACKAGE
(TOP VIEW)



SN74AHCT14 . . . RGY PACKAGE
(TOP VIEW)



SN54AHCT14 . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

description/ordering information

The ’AHCT14 devices contain six independent inverters. These devices perform the Boolean function $Y = \overline{A}$.

Each circuit functions as an independent inverter, but because of the Schmitt action, the inverters have different input threshold levels for positive-going (V_{T+}) and for negative-going (V_{T-}) signals.

ORDERING INFORMATION

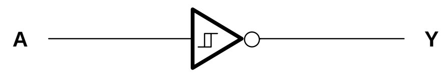
T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	QFN – RGY	Tape and reel	SN74AHCT14RGYR	HB14
	PDIP – N	Tube	SN74AHCT14N	SN74AHCT14N
	SOIC – D	Tube	SN74AHCT14D	AHCT14
		Tape and reel	SN74AHCT14DR	
	SOP – NS	Tape and reel	SN74AHCT14NSR	AHCT14
	SSOP – DB	Tape and reel	SN74AHCT14DBR	HB14
	TSSOP – PW	Tube	SN74AHCT14PW	HB14
		Tape and reel	SN74AHCT14PWR	
	TVSOP – DGV	Tape and reel	SN74AHCT14DGVR	HB14
–55°C to 125°C	CDIP – J	Tube	SNJ54AHCT14J	SNJ54AHCT14J
	CFP – W	Tube	SNJ54AHCT14W	SNJ54AHCT14W
	LCCC – FK	Tube	SNJ54AHCT14FK	SNJ54AHCT14FK

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

FUNCTION TABLE
(each inverter)

INPUT A	OUTPUT Y
H	L
L	H

logic diagram, each inverter (positive logic)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, V_{CC} . . . . –0.5 V to 7 V
Input voltage range, V_I (see Note 1) . . . . –0.5 V to 7 V
Output voltage range, V_O (see Note 1) . . . . –0.5 V to V_{CC} + 0.5 V
Input clamp current, I_{IK} (V_I < 0) . . . . –20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{CC}) . . . . ±20 mA
Continuous output current, I_O (V_O = 0 to V_{CC}) . . . . ±25 mA
Continuous current through V_{CC} or GND . . . . ±50 mA
Package thermal impedance, θ_{JA} (see Note 2): D package . . . . 86°C/W
(see Note 2): DB package . . . . 96°C/W
(see Note 2): DGV package . . . . 127°C/W
(see Note 2): N package . . . . 80°C/W
(see Note 2): NS package . . . . 76°C/W
(see Note 2): PW package . . . . 113°C/W
(see Note 3): RGY package . . . . 47°C/W
Storage temperature range, T_{stg} . . . . –65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. The input and output voltage ratings may be exceeded if the input and output current ratings are observed.
2. The package thermal impedance is calculated in accordance with JESD 51-7.
3. The package thermal impedance is calculated in accordance with JESD 51-5.

recommended operating conditions (see Note 4)

		SN54AHCT14		SN74AHCT14		UNIT
		MIN	MAX	MIN	MAX	
V_{CC}	Supply voltage	4.5	5.5	4.5	5.5	V
V_I	Input voltage	0	5.5	0	5.5	V
V_O	Output voltage	0	V_{CC}	0	V_{CC}	V
I_{OH}	High-level output current		–8		–8	mA
I_{OL}	Low-level output current		8		8	mA
T_A	Operating free-air temperature	–55	125	–40	85	°C

NOTE 4: All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	V_{CC}	T_A = 25°C MIN	TYP	MAX	SN54AHCT14 MIN	MAX	SN74AHCT14 MIN	MAX	UNIT
V_{T+} Positive-going input threshold voltage		4.5 V	0.9		1.9	0.9	1.9	0.9	1.9	V
		5.5 V	1		2.1	1	2.1	1	2.1	
V_{T-} Negative-going input threshold voltage		4.5 V	0.5		1.5	0.5	1.5	0.5	1.5	V
		5.5 V	0.6		1.7	0.6	1.7	0.6	1.7	
ΔV_T Hysteresis ($V_{T+} - V_{T-}$)		4.5 V	0.4		1.4	0.4	1.4	0.4	1.4	V
		5.5 V	0.4		1.5	0.4	1.5	0.4	1.5	
V_{OH}	I_{OH} = –50 μA	4.5 V	4.4	4.5		4.4		4.4		V
	I_{OH} = –8 mA	4.5 V	3.94			3.8		3.8		
V_{OL}	I_{OL} = 50 μA	4.5 V			0.1		0.1		0.1	V
	I_{OL} = 8 mA	4.5 V			0.36		0.44		0.44	
I_I	V_I = 5.5 V or GND	0 V to 5.5 V			±0.1		±1*		±1	μA
I_{CC}	$V_I = V_{CC}$ or GND, I_O = 0	5.5 V			2		20		20	μA
ΔI_{CC}†	One input at 3.4 V, Other inputs at V_{CC} or GND	5.5 V			1.35		1.5		1.5	mA
C_i	$V_I = V_{CC}$ or GND	5 V		2	10				10	pF

* On products compliant to MIL-PRF-38535, this parameter is not production tested at V_{CC} = 0 V.
† This is the increase in supply current for each input at one of the specified TTL voltage levels, rather than 0 V or V_{CC}.

switching characteristics over recommended operating free-air temperature range V_{CC} = 5 V ± 0.5 V (unless otherwise noted) (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	LOAD CAPACITANCE	T_A = 25°C MIN	TYP	MAX	SN54AHCT14 MIN	MAX	SN74AHCT14 MIN	MAX	UNIT
t_{PLH}	A	Y	C_L = 15 pF		4**	7**	1**	8**	1	8	ns
t_{PHL}					4**	7**	1**	8**	1	8	
t_{PLH}	A	Y	C_L = 50 pF		5.5	8	1	9	1	9	ns
t_{PHL}					5.5	8	1	9	1	9	

** On products compliant to MIL-PRF-38535, this parameter is not production tested.

noise characteristics, V_{CC} = 5 V, C_L = 50 pF, T_A = 25°C (see Note 5)

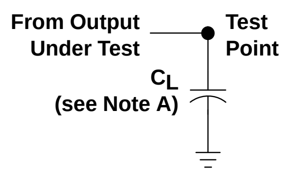
PARAMETER		SN74AHCT14 MIN	TYP	MAX	UNIT
$V_{OL(P)}$	Quiet output, maximum dynamic V_{OL}		0.9		V
$V_{OL(V)}$	Quiet output, minimum dynamic V_{OL}		–0.7		V
$V_{OH(V)}$	Quiet output, minimum dynamic V_{OH}		4.3		V
$V_{IH(D)}$	High-level dynamic input voltage	2.1			V
$V_{IL(D)}$	Low-level dynamic input voltage			0.5	V

NOTE 5: Characteristics are for surface-mount packages only.

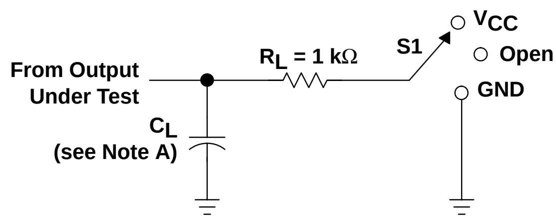
operating characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
C_{pd}	Power dissipation capacitance	No load, f = 1 MHz	12	pF

PARAMETER MEASUREMENT INFORMATION

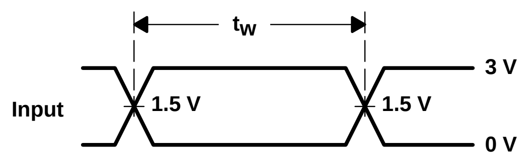


LOAD CIRCUIT FOR
TOTEM-POLE OUTPUTS

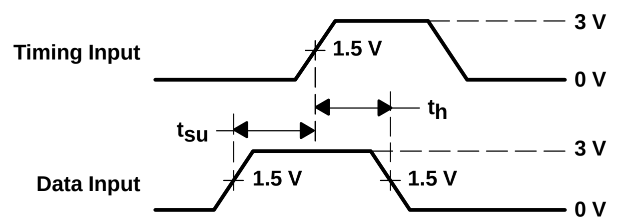


LOAD CIRCUIT FOR
3-STATE AND OPEN-DRAIN OUTPUTS

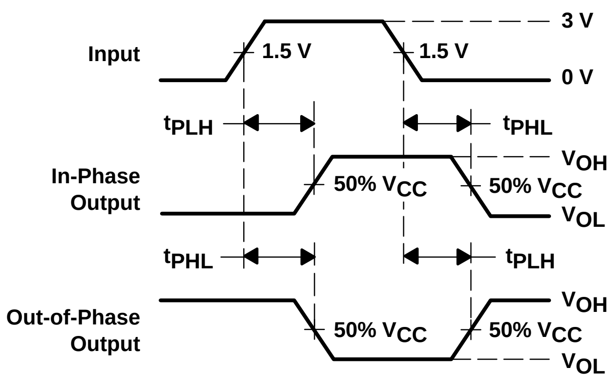
TEST	S1
t_{PLH}/t_{PHL}	Open
t_{PLZ}/t_{PZL}	V_{CC}
t_{PHZ}/t_{PZH}	GND
Open Drain	V_{CC}



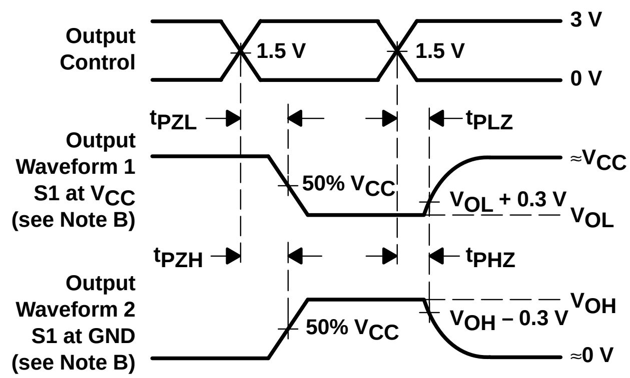
VOLTAGE WAVEFORMS
PULSE DURATION



VOLTAGE WAVEFORMS
SETUP AND HOLD TIMES



VOLTAGE WAVEFORMS
PROPAGATION DELAY TIMES
INVERTING AND NONINVERTING OUTPUTS



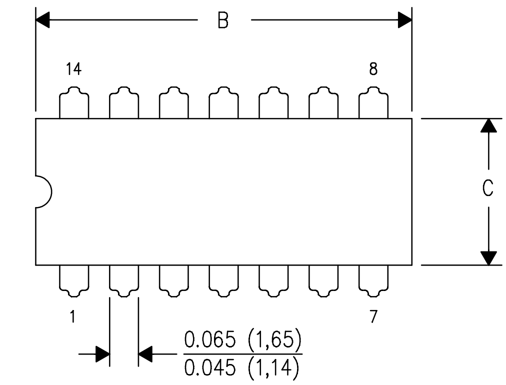
VOLTAGE WAVEFORMS
ENABLE AND DISABLE TIMES
LOW- AND HIGH-LEVEL ENABLING

NOTES: A. C_L includes probe and jig capacitance.
B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.
C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 1 MHz, Z_O = 50 Ω, t_r ≤ 3 ns, t_f ≤ 3 ns.
D. The outputs are measured one at a time with one input transition per measurement.
E. All parameters and waveforms are not applicable to all devices.

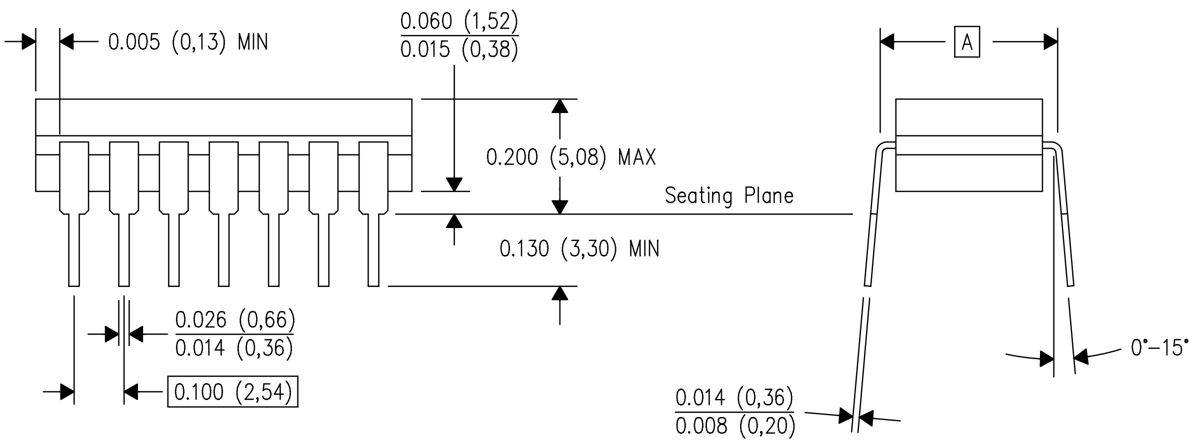
Figure 1. Load Circuit and Voltage Waveforms

J (R−GDIP−T**) CERAMIC DUAL IN−LINE PACKAGE

14 LEADS SHOWN



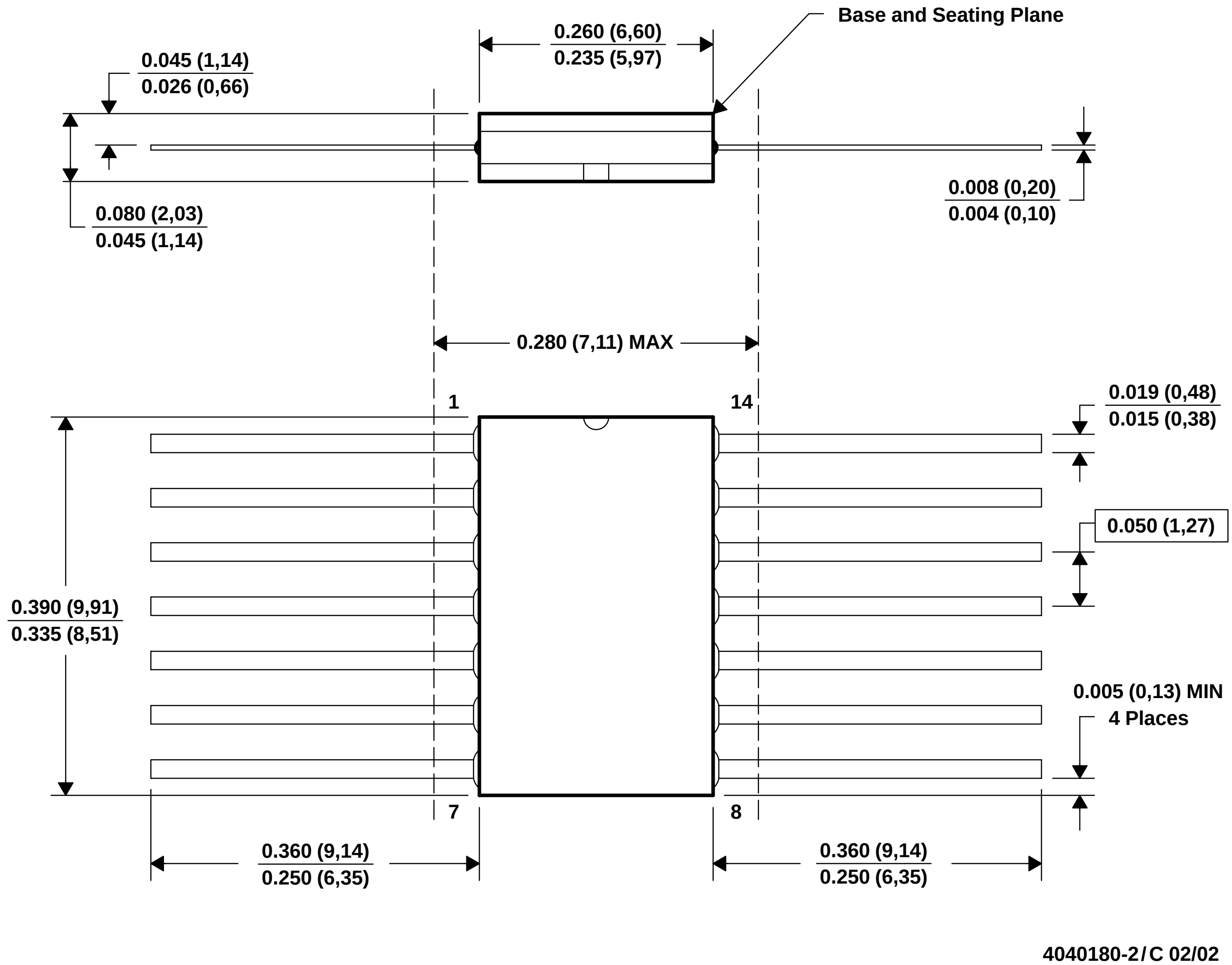
DIM \ PINS **	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	——	——	——	——
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)



4040083/F 03/03

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package is hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL STD 1835 GDIP1−T14, GDIP1−T16, GDIP1−T18 and GDIP1−T20.

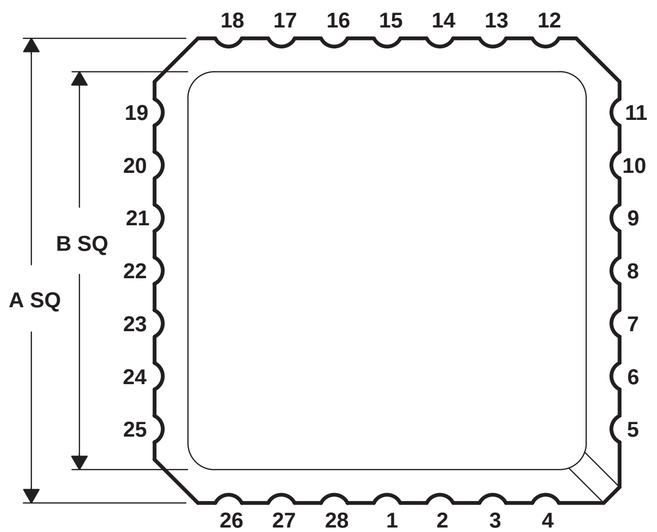
W (R-GDFP-F14) **CERAMIC DUAL FLATPACK**



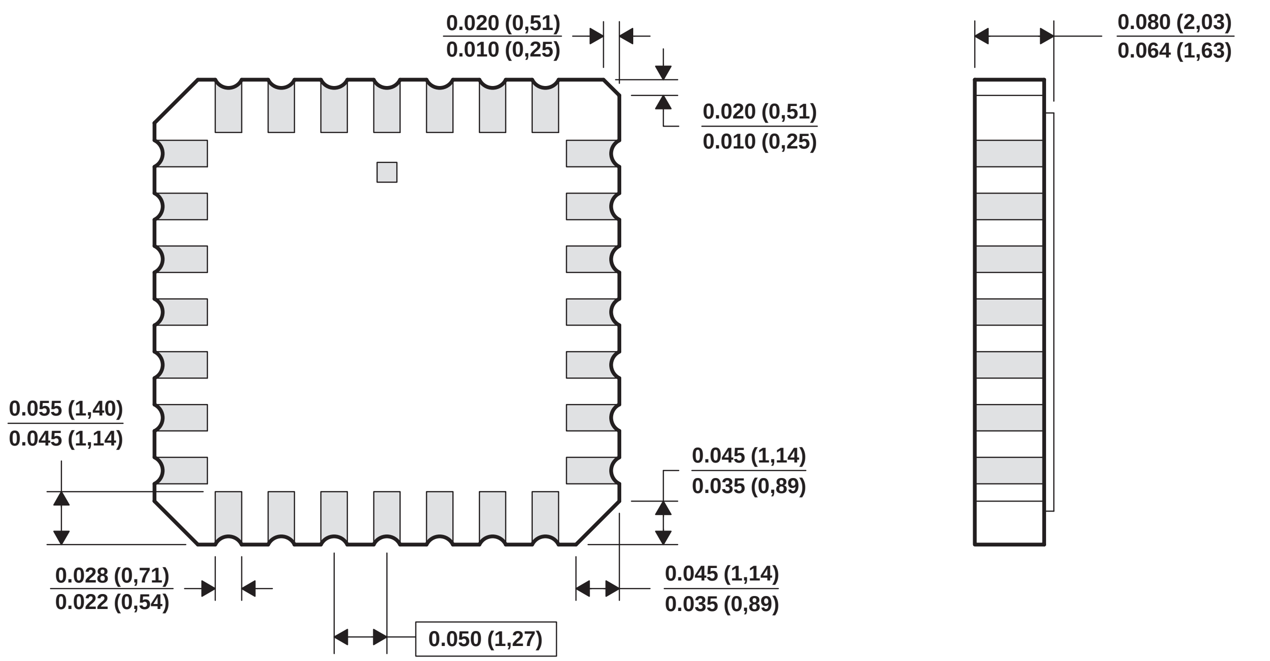
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only.
E. Falls within MIL STD 1835 GDFP1-F14 and JEDEC MO-092AB

FK (S-CQCC-N)** **LEADLESS CERAMIC CHIP CARRIER**

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



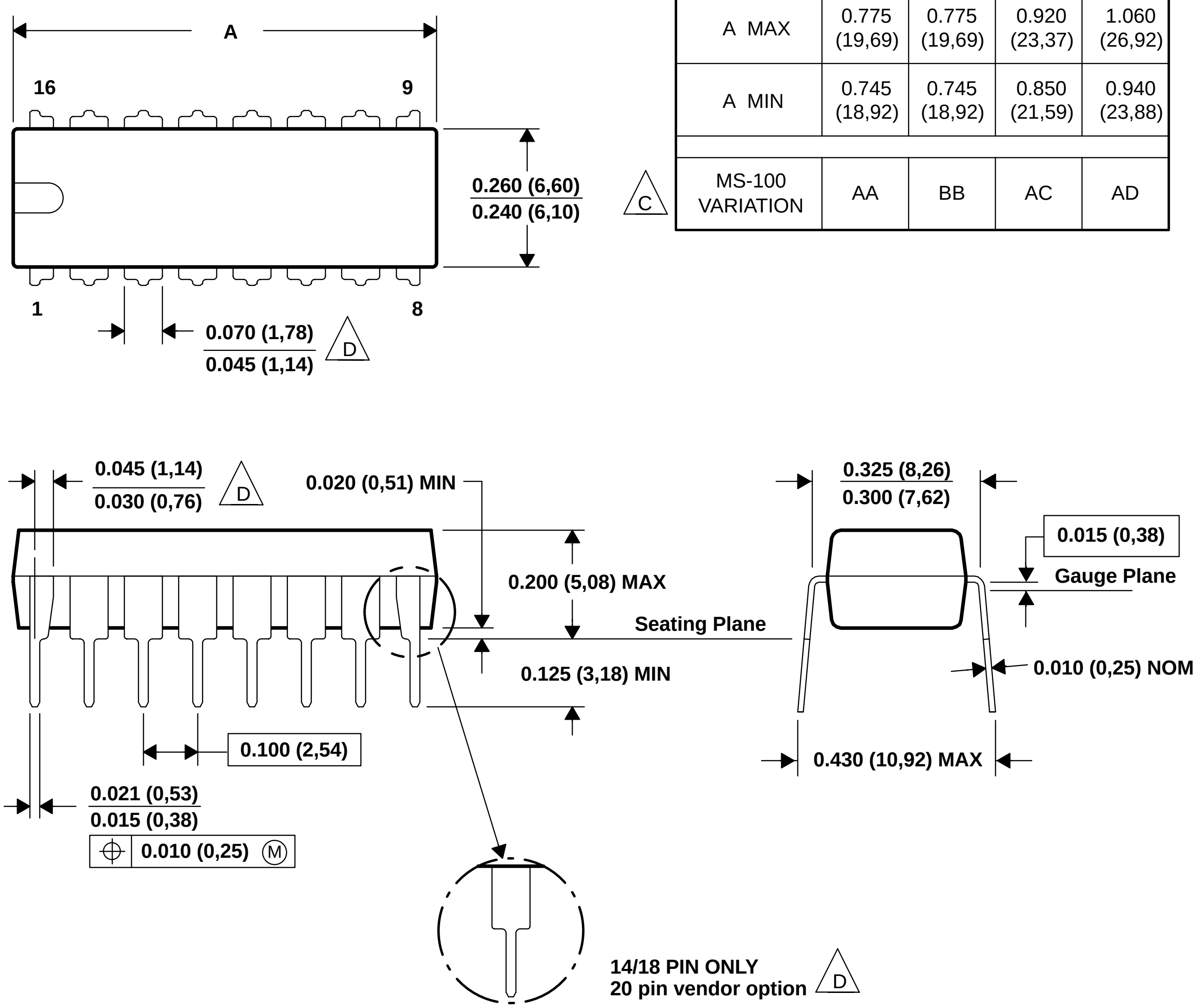
4040140 / D 10/96

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

N (R-PDIP-T)** **PLASTIC DUAL-IN-LINE PACKAGE**

16 PINS SHOWN

DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-100 VARIATION	AA	BB	AC	AD



4040049/E 12/2002

NOTES: A. All linear dimensions are in inches (millimeters).

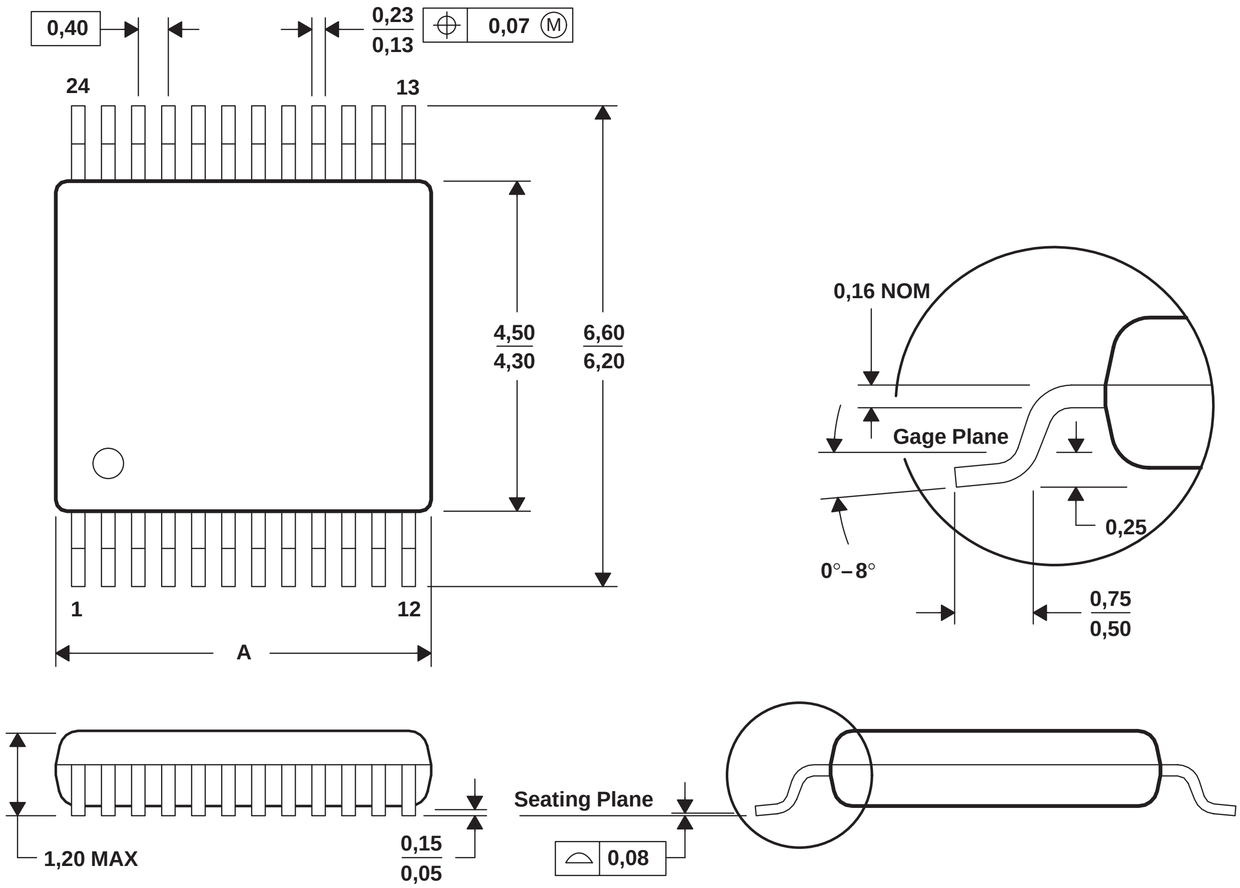
B. This drawing is subject to change without notice.

C. Falls within JEDEC MS-001, except 18 and 20 pin minimum body lrngth (Dim A).

D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

DGV (R-PDSO-G)** **PLASTIC SMALL-OUTLINE**

24 PINS SHOWN

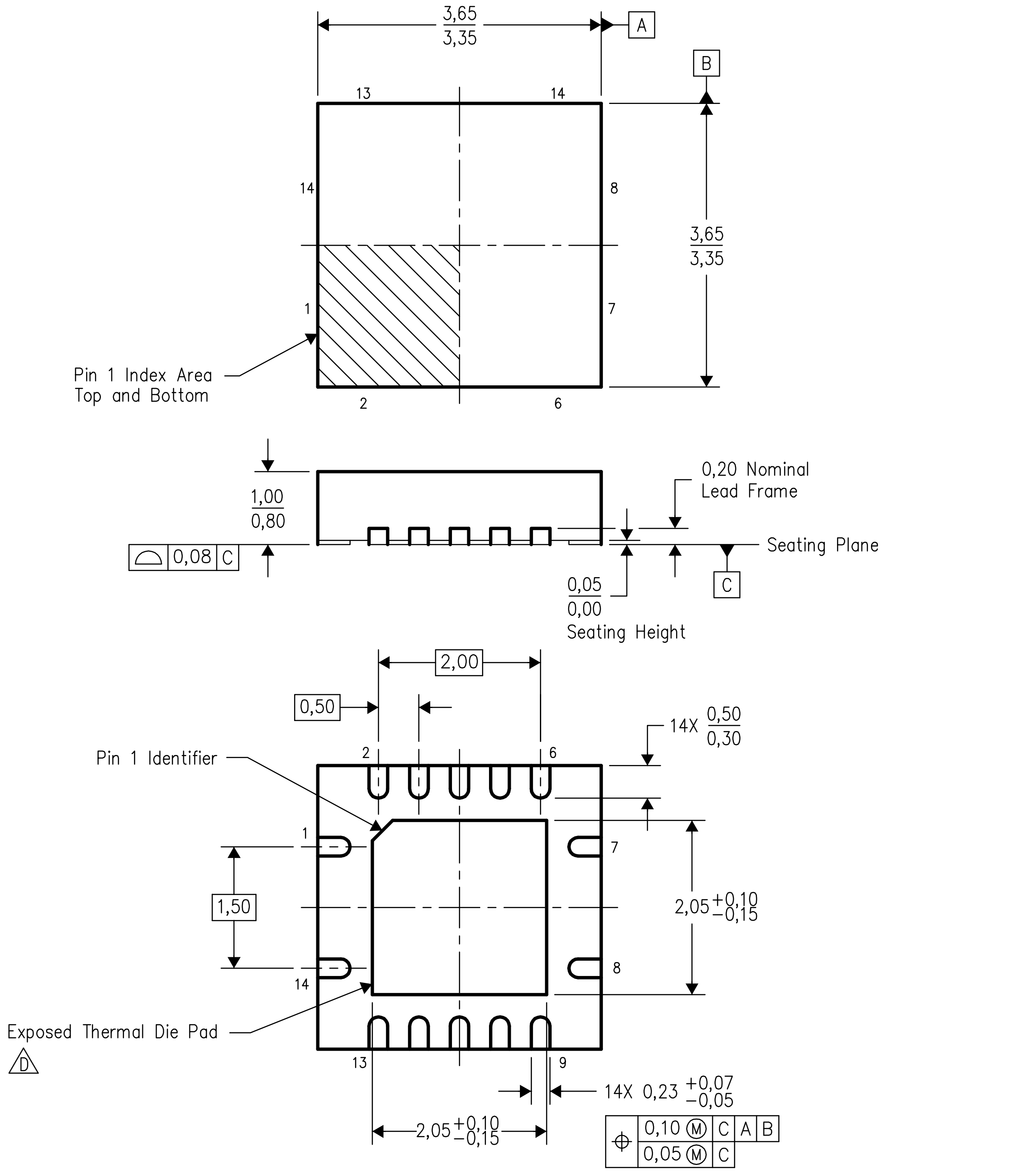


PINS ** / DIM	14	16	20	24	38	48	56
A MAX	3,70	3,70	5,10	5,10	7,90	9,80	11,40
A MIN	3,50	3,50	4,90	4,90	7,70	9,60	11,20

4073251/E 08/00

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15 per side.
D. Falls within JEDEC: 24/48 Pins – MO-153
14/16/20/56 Pins – MO-194

RGY (S–PQFP–N14) PLASTIC QUAD FLATPACK

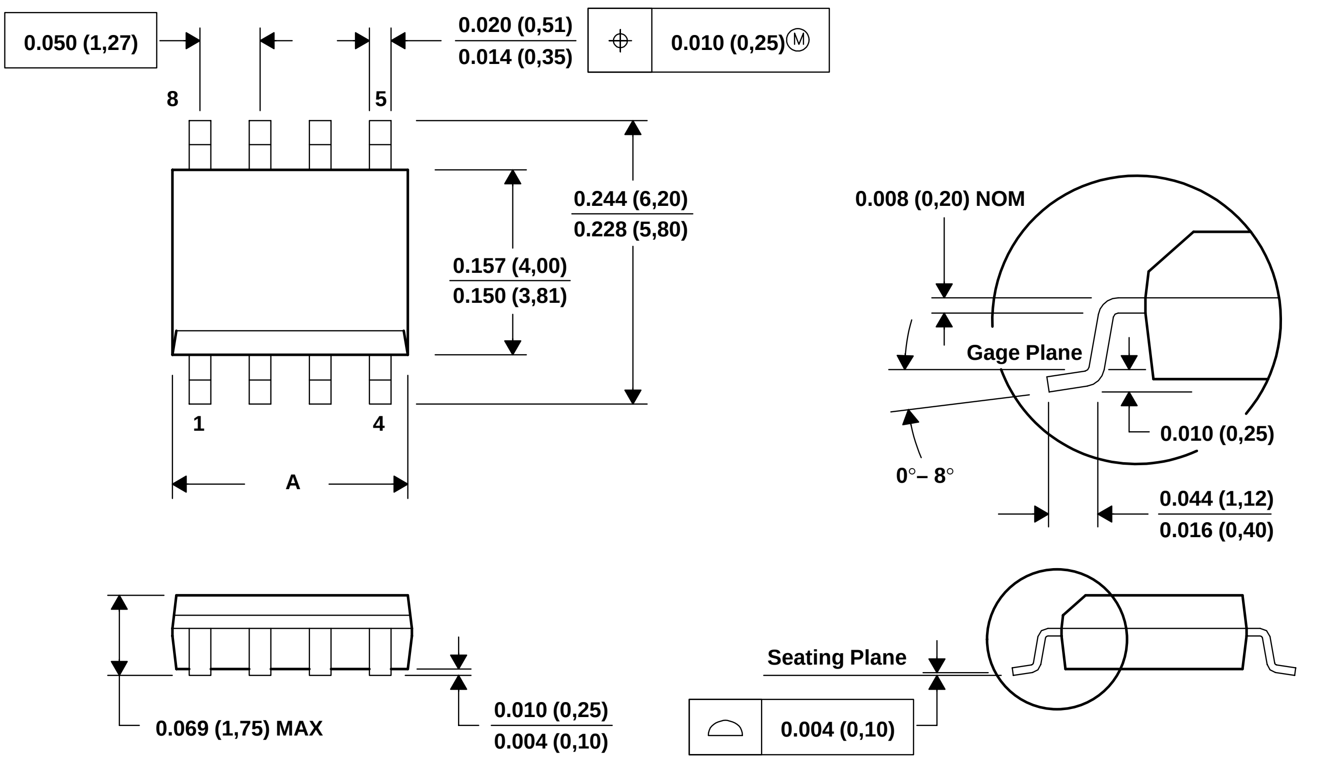


4203539-2/E 05/03

NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. QFN (Quad Flatpack No–Lead) package configuration.
- D. The package thermal performance may be enhanced by bonding the thermal die pad to an external thermal plane. This pad is electrically and thermally connected to the backside of the die and possibly selected ground leads.
- E. Package complies to JEDEC MO–241 variation BA.

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN



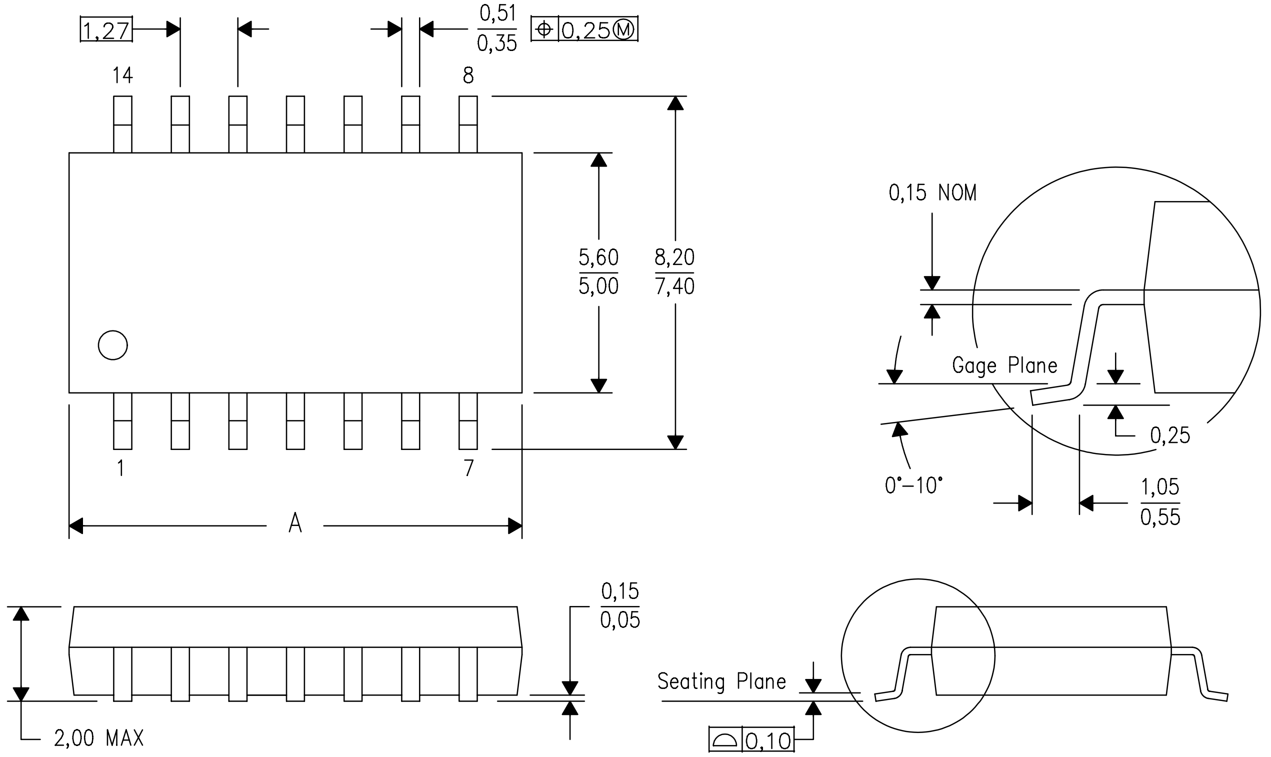
PINS ** / DIM	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



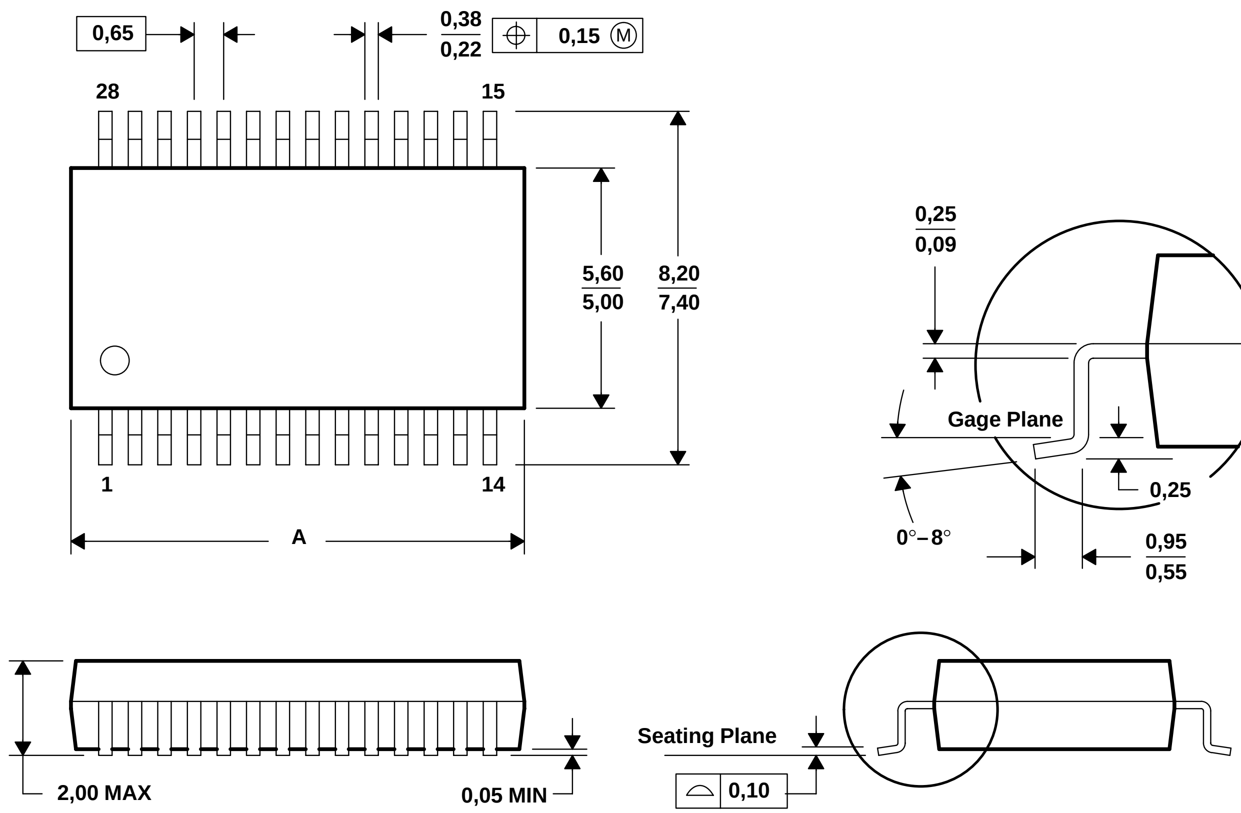
PINS ** / DIM	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

DB (R-PDSO-G)** **PLASTIC SMALL-OUTLINE**

28 PINS SHOWN



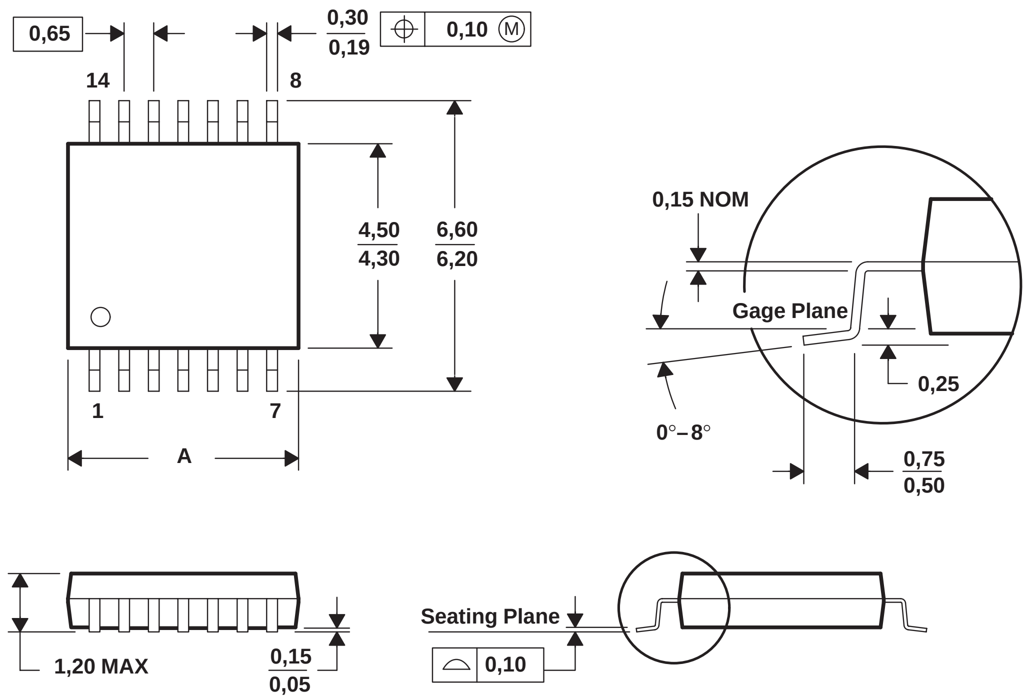
PINS ** / DIM	14	16	20	24	28	30	38
A MAX	6,50	6,50	7,50	8,50	10,50	10,50	12,90
A MIN	5,90	5,90	6,90	7,90	9,90	9,90	12,30

4040065 /E 12/01

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-150

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
- D. Falls within JEDEC MO-153

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4. SN74ALS08: Quadruple 2-Input Positive-AND Gates

Texas Instruments

Quadruple 2-Input Positive-AND Gates

SN74ALS08

SDAS191A – APRIL 1982 – REVISED DECEMBER 1994

- **Package Options Include Plastic Small-Outline (D) Packages, Ceramic Chip Carriers (FK), and Standard Plastic (N) and Ceramic (J) 300-mil DIPs**

description

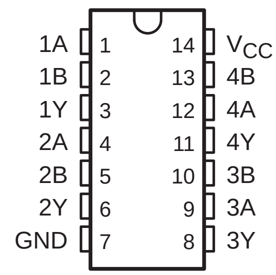
These devices contain four independent 2-input positive-AND gates. They perform the Boolean functions Y = A • B or $Y = \overline{\overline{A} + \overline{B}}$ in positive logic.

The SN54ALS08 and SN54AS08 are characterized for operation over the full military temperature range of –55°C to 125°C. The SN74ALS08 and SN74AS08 are characterized for operation from 0°C to 70°C.

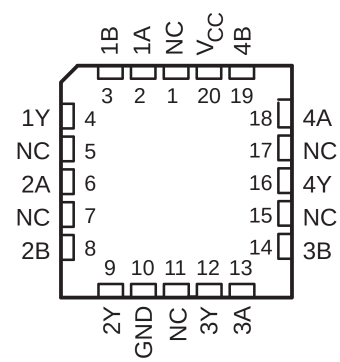
FUNCTION TABLE
(each gate)

INPUTS A	INPUTS B	OUTPUT Y
H	H	H
L	X	L
X	L	L

SN54ALS08, SN54AS08 . . . J PACKAGE
SN74ALS08, SN74AS08 . . . D OR N PACKAGE
(TOP VIEW)

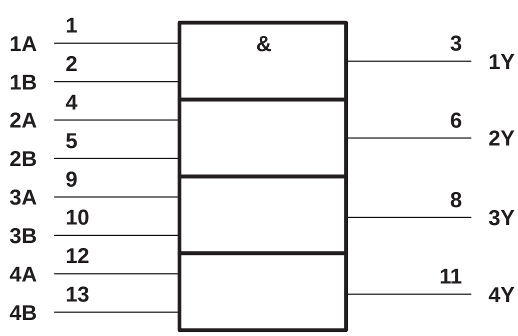


SN54ALS08, SN54AS08 . . . FK PACKAGE
(TOP VIEW)



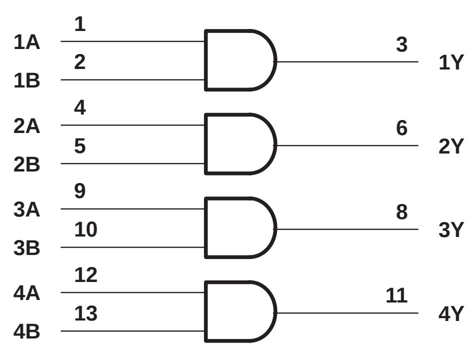
NC – No internal connection

logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.
Pin numbers shown are for the D, J, and N packages.

logic diagram (positive logic)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{CC} . . . . 7 V
Input voltage, V_I . . . . 7 V
Operating free-air temperature range, T_A: SN54ALS08 . . . . –55°C to 125°C
SN74ALS08 . . . . 0°C to 70°C
Storage temperature range . . . . –65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

recommended operating conditions

		SN54ALS08			SN74ALS08			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
V_{CC}	Supply voltage	4.5	5	5.5	4.5	5	5.5	V
V_{IH}	High-level input voltage	2			2			V
V_{IL}	Low-level input voltage			0.8‡			0.8	V
				0.7§				
I_{OH}	High-level output current			–0.4			–0.4	mA
I_{OL}	Low-level output current			4			8	mA
T_A	Operating free-air temperature	–55		125	0		70	°C

‡ Applies over temperature range –55°C to 70°C
§ Applies over temperature range 70°C to 125°C

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS		SN54ALS08			SN74ALS08			UNIT
			MIN	TYP¶	MAX	MIN	TYP¶	MAX	
V_{IK}	V_{CC} = 4.5 V,	I_I = –18 mA			–1.5			–1.5	V
V_{OH}	V_{CC} = 4.5 V to 5.5 V,	I_{OH} = –0.4 mA	V_{CC} –2			V_{CC} –2			V
V_{OL}	V_{CC} = 4.5 V	I_{OL} = 4 mA		0.25	0.4		0.25	0.4	V
		I_{OL} = 8 mA					0.35	0.5	
I_I	V_{CC} = 5.5 V,	V_I = 7 V			0.1			0.1	mA
I_{IH}	V_{CC} = 5.5 V,	V_I = 2.7 V			20			20	μA
I_{IL}	V_{CC} = 5.5 V,	V_I = 0.4 V			–0.1			–0.1	mA
I_O#	V_{CC} = 5.5 V,	V_O = 2.25 V	–20		–112	–30		–112	mA
I_{CCH}	V_{CC} = 5.5 V,	V_I = 4.5 V		1.3	2.4		1.3	2.4	mA
I_{CCL}	V_{CC} = 5.5 V,	V_I = 0		2.2	4		2.2	4	mA

¶ All typical values are at V_{CC} = 5 V, T_A = 25°C.
# The output conditions have been chosen to produce a current that closely approximates one half of the true short-circuit output current, I_{OS}.

switching characteristics (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	V_{CC} = 4.5 V to 5.5 V, C_L = 50 pF, R_L = 500 Ω, T_A = MIN to MAX†				UNIT
			SN54ALS08		SN74ALS08		
			MIN	MAX	MIN	MAX	
t_{PLH}	A or B	Y	2	14	4	14	ns
t_{PHL}			2	12.5	3	10	

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)‡

Supply voltage, V_{CC} . . . . 7 V
Input voltage, V_I . . . . 7 V
Operating free-air temperature range, T_A: SN54AS08 . . . . –55°C to 125°C
SN74AS08 . . . . 0°C to 70°C
Storage temperature range . . . . –65°C to 150°C

‡ Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

recommended operating conditions

		SN54AS08			SN74AS08			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
V_{CC}	Supply voltage	4.5	5	5.5	4.5	5	5.5	V
V_{IH}	High-level input voltage	2			2			V
V_{IL}	Low-level input voltage			0.8			0.8	V
I_{OH}	High-level output current			–2			–2	mA
I_{OL}	Low-level output current			20			20	mA
T_A	Operating free-air temperature	–55		125	0		70	°C

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS		SN54AS08			SN74AS08			UNIT
			MIN	TYP§	MAX	MIN	TYP§	MAX	
V_{IK}	V_{CC} = 4.5 V,	I_I = –18 mA			–1.2			–1.2	V
V_{OH}	V_{CC} = 4.5 V to 5.5 V,	I_{OH} = –2 mA	V_{CC} –2			V_{CC} –2			V
V_{OL}	V_{CC} = 4.5 V,	I_{OL} = 20 mA		0.35	0.5		0.35	0.5	V
I_I	V_{CC} = 5.5 V,	V_I = 7 V			0.1			0.1	mA
I_{IH}	V_{CC} = 5.5 V,	V_I = 2.7 V			20			20	µA
I_{IL}	V_{CC} = 5.5 V,	V_I = 0.4 V			–0.5			–0.5	mA
I_O¶	V_{CC} = 5.5 V,	V_O = 2.25 V	–30		–112	–30		–112	mA
I_{CCH}	V_{CC} = 5.5 V,	V_I = 4.5 V		5.8	9.3		5.8	9.3	mA
I_{CCL}	V_{CC} = 5.5 V,	V_I = 0		14.9	24		14.9	24	mA

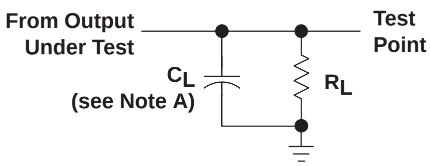
§ All typical values are at V_{CC} = 5 V, T_A = 25°C.
¶ The output conditions have been chosen to produce a current that closely approximates one half of the true short-circuit output current, I_{OS}.

switching characteristics (see Figure 1)

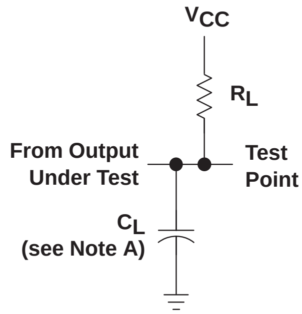
PARAMETER	FROM (INPUT)	TO (OUTPUT)	V_{CC} = 4.5 V to 5.5 V, C_L = 50 pF, R_L = 500 Ω, T_A = MIN to MAX†				UNIT
			SN54AS08		SN74AS08		
			MIN	MAX	MIN	MAX	
t_{PLH}	A or B	Y	1	6.5	1	5.5	ns
t_{PHL}			1	6.5	1	5.5	

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

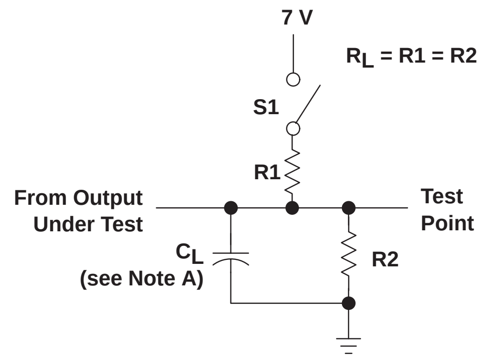
PARAMETER MEASUREMENT INFORMATION
SERIES 54ALS/74ALS AND 54AS/74AS DEVICES



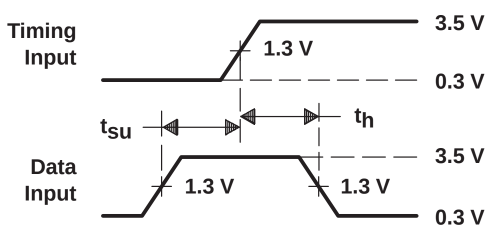
LOAD CIRCUIT FOR
BI-STATE
TOTEM-POLE OUTPUTS



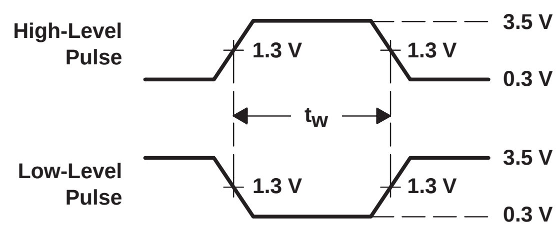
LOAD CIRCUIT
FOR OPEN-COLLECTOR OUTPUTS



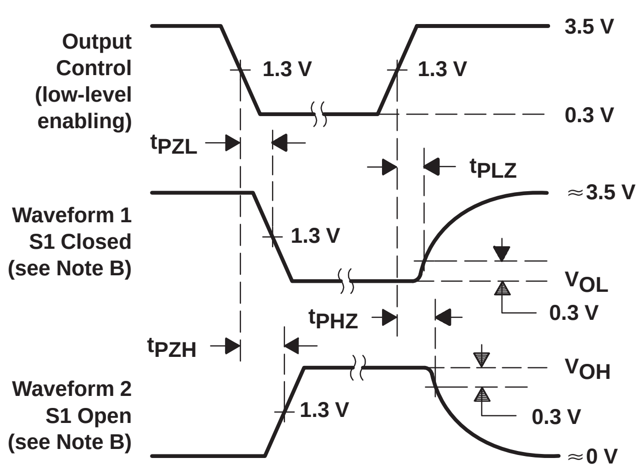
LOAD CIRCUIT
FOR 3-STATE OUTPUTS



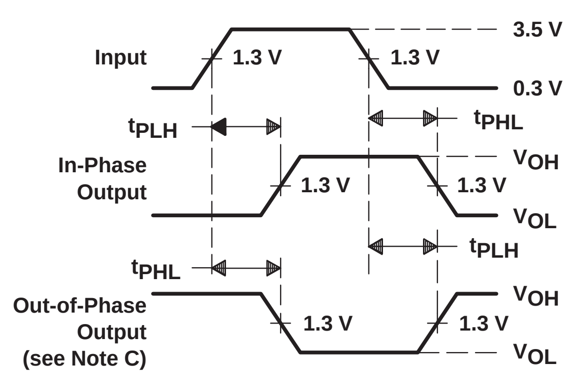
VOLTAGE WAVEFORMS
SETUP AND HOLD TIMES



VOLTAGE WAVEFORMS
PULSE DURATIONS



VOLTAGE WAVEFORMS
ENABLE AND DISABLE TIMES, 3-STATE OUTPUTS



VOLTAGE WAVEFORMS
PROPAGATION DELAY TIMES

NOTES: A. C_L includes probe and jig capacitance.
B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.
C. When measuring propagation delay items of 3-state outputs, switch S1 is open.
D. All input pulses have the following characteristics: PRR ≤ 1 MHz, $t_r = t_f = 2$ ns, duty cycle = 50%.
E. The outputs are measured one at a time with one transition per measurement.

Figure 1. Load Circuits and Voltage Waveforms

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
5962-86842012A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type
5962-8684201CA	ACTIVE	CDIP	J	14	1	TBD	A42 SNPB	N / A for Pkg Type
5962-8684201DA	ACTIVE	CFP	W	14	1	TBD	A42	N / A for Pkg Type
JM38510/37401B2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type
JM38510/37401BCA	ACTIVE	CDIP	J	14	1	TBD	A42 SNPB	N / A for Pkg Type
SN54ALS08J	ACTIVE	CDIP	J	14	1	TBD	A42 SNPB	N / A for Pkg Type
SN54AS08J	ACTIVE	CDIP	J	14	1	TBD	A42 SNPB	N / A for Pkg Type
SN74ALS08D	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74ALS08DE4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74ALS08DG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74ALS08DR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74ALS08DRE4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74ALS08DRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74ALS08N	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
SN74ALS08N3	OBSOLETE	PDIP	N	14		TBD	Call TI	Call TI
SN74ALS08NE4	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
SN74ALS08NSR	ACTIVE	SO	NS	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74ALS08NSRE4	ACTIVE	SO	NS	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74AS08D	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74AS08DE4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74AS08DR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74AS08DRE4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74AS08N	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
SN74AS08N3	OBSOLETE	PDIP	N	14		TBD	Call TI	Call TI
SN74AS08NE4	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
SN74AS08NSR	ACTIVE	SO	NS	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SN74AS08NSRE4	ACTIVE	SO	NS	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
SNJ54ALS08FK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type
SNJ54ALS08J	ACTIVE	CDIP	J	14	1	TBD	A42 SNPB	N / A for Pkg Type

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
SNJ54ALS08W	ACTIVE	CFP	W	14	1	TBD	A42	N / A for Pkg Type
SNJ54AS08FK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type
SNJ54AS08J	ACTIVE	CDIP	J	14	1	TBD	A42 SNPB	N / A for Pkg Type
SNJ54AS08W	ACTIVE	CFP	W	14	1	TBD	A42	N / A for Pkg Type

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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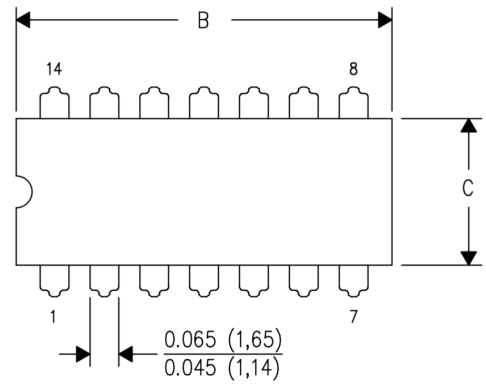
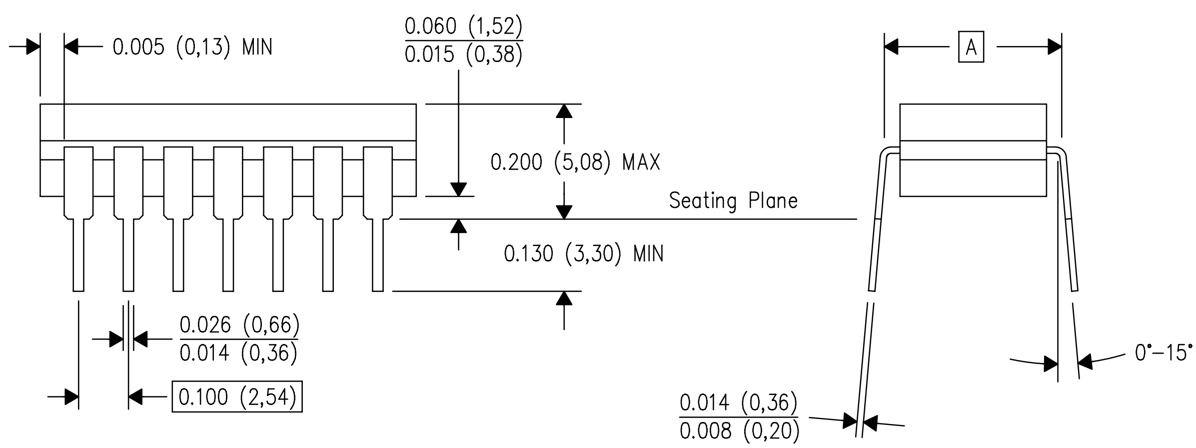
J (R–GDIP–T**) CERAMIC DUAL IN–LINE PACKAGE

14 LEADS SHOWN



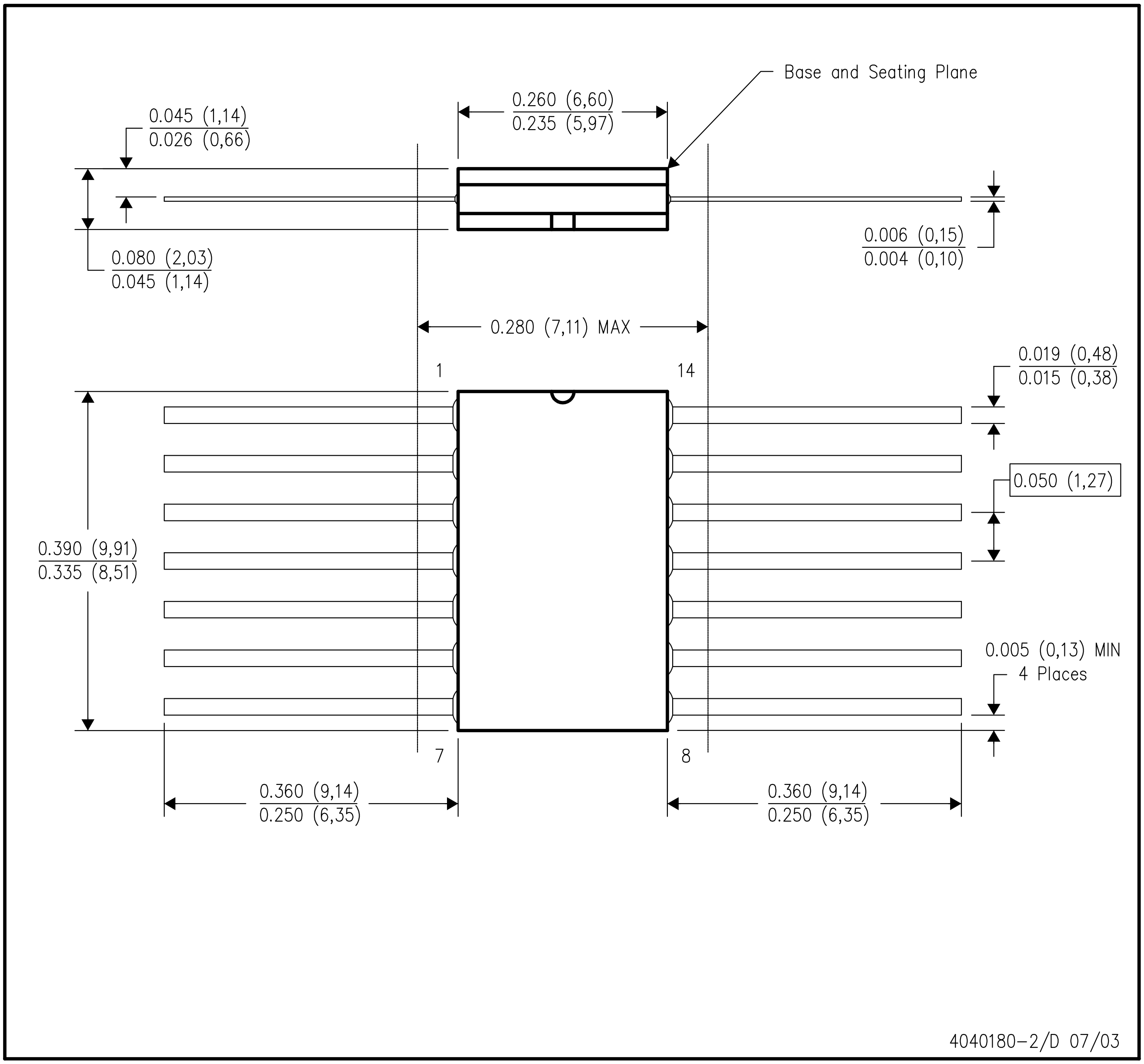
PINS ** / DIM	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	——	——	——	——
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)



4040083/F 03/03

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package is hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL STD 1835 GDIP1–T14, GDIP1–T16, GDIP1–T18 and GDIP1–T20.

W (R-GDFP-F14) CERAMIC DUAL FLATPACK

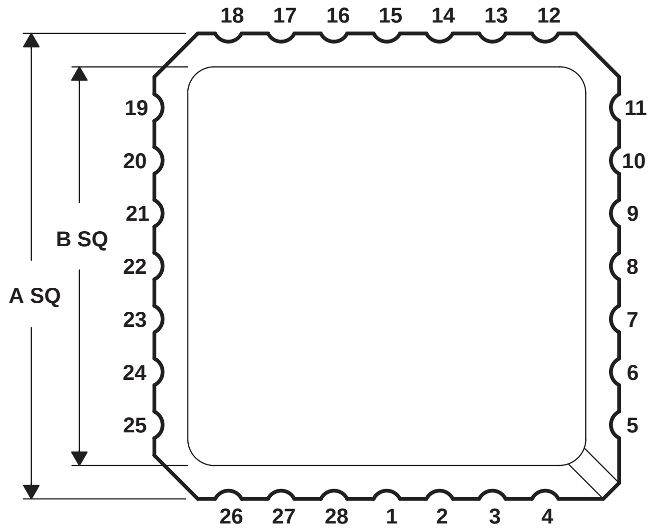


NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only.
- E. Falls within MIL STD 1835 GDFP1-F14 and JEDEC MO-092AB

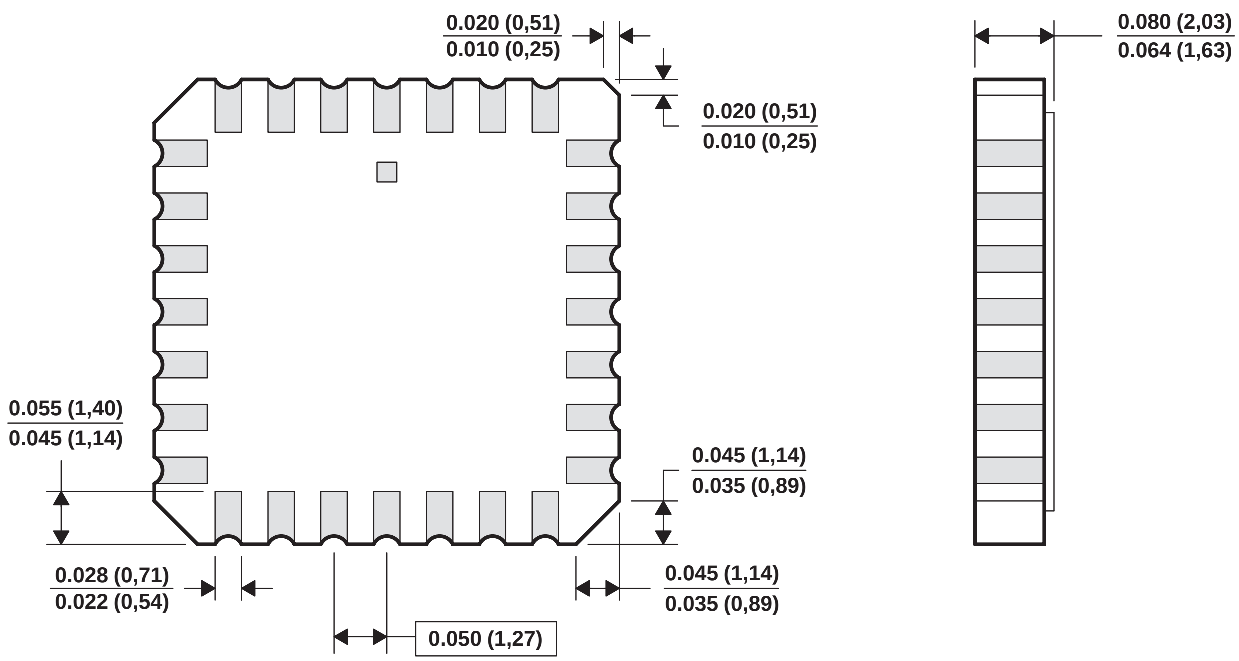
MLCC006B – OCTOBER 1996

FK (S-CQCC-N)** **LEADLESS CERAMIC CHIP CARRIER**

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)

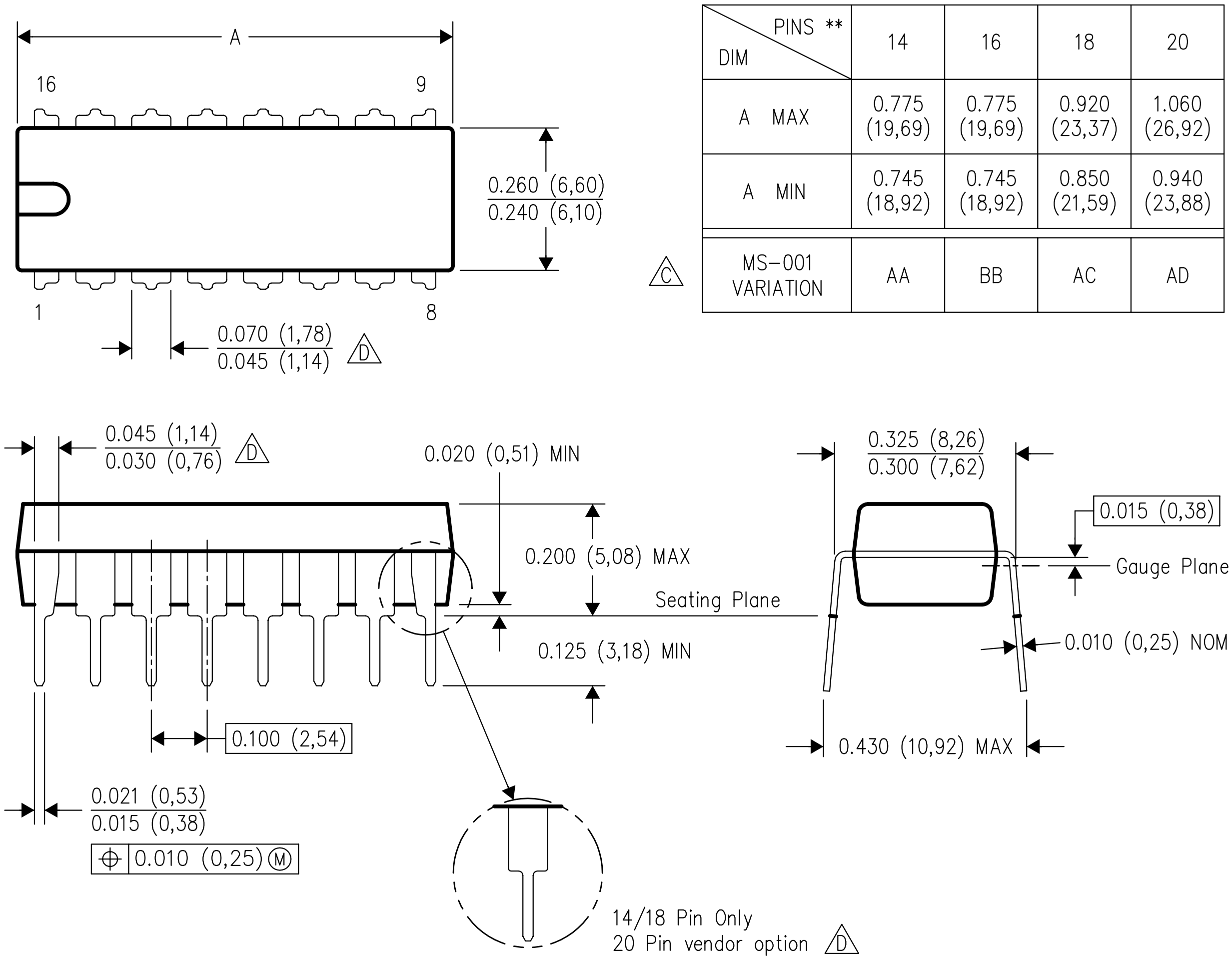


4040140 / D 10/96

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

N (R–PDIP–T**) PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN

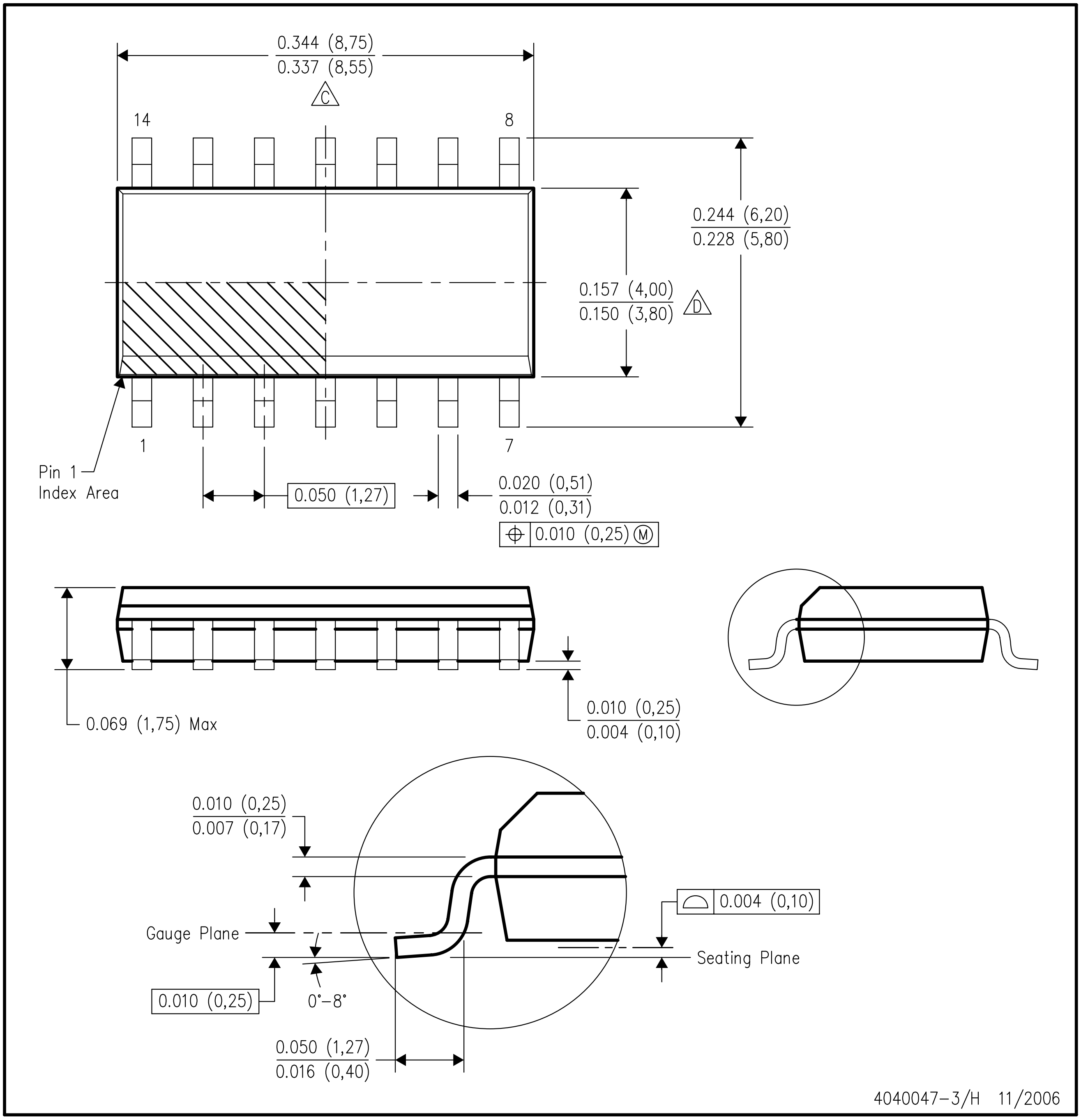


PINS ** / DIM	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS–001 VARIATION	AA	BB	AC	AD

4040049/E 12/2002

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
- D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

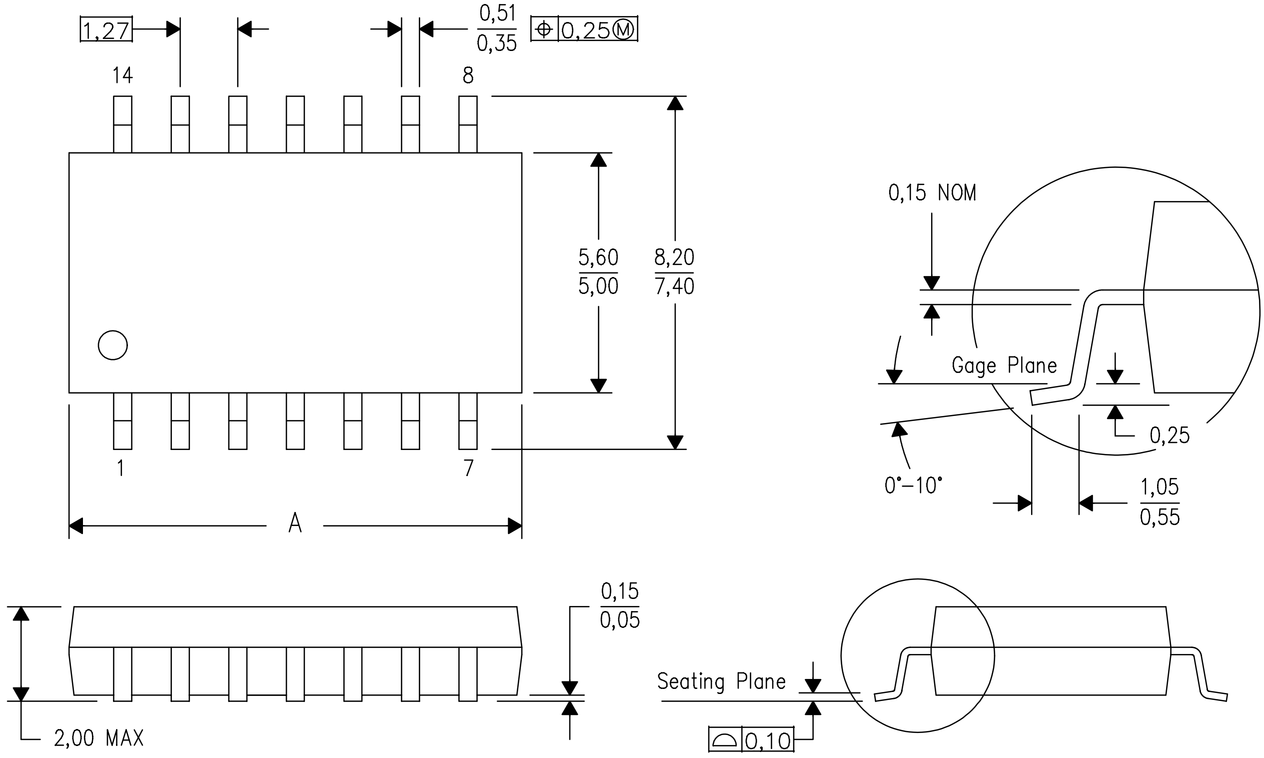
D (R–PDSO–G14) PLASTIC SMALL–OUTLINE PACKAGE



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
E. Reference JEDEC MS-012 variation AB.

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



PINS ** / DIM	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

5. SN74HCT74: Dual D-Type Positive-Edge-Triggered Flip Flops

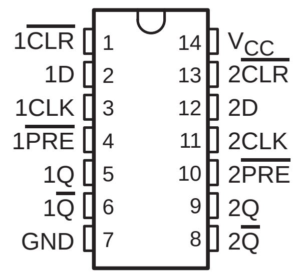
Texas Instruments

Dual D-Type Positive-Edge-Triggered
Flip Flops with Clear and Preset

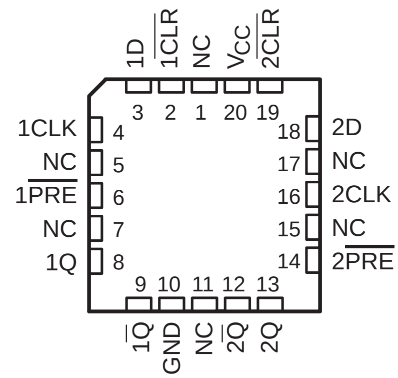
SN74HCT74

- **Operating Voltage Range of 4.5 V to 5.5 V**
- **Outputs Can Drive Up To 10 LSTTL Loads**
- **Low Power Consumption, 40-µA Max I_{CC}**
- **Typical t_{pd} = 17 ns**
- **±4-mA Output Drive at 5 V**
- **Low Input Current of 1 µA Max**
- **Inputs Are TTL-Voltage Compatible**

SN54HCT74 . . . J OR W PACKAGE
SN74HCT74 . . . D, DB, N, NS, OR PW PACKAGE
(TOP VIEW)



SN54HCT74 . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

description/ordering information

The ’HCT74 devices contain two independent D-type positive-edge-triggered flip-flops. A low level at the preset ($\overline{PRE}$) or clear ($\overline{CLR}$) inputs sets or resets the outputs, regardless of the levels of the other inputs. When $\overline{PRE}$ and $\overline{CLR}$ are inactive (high), data at the data (D) input meeting the setup time requirements are transferred to the outputs on the positive-going edge of the clock (CLK) pulse. Clock triggering occurs at a voltage level and is not directly related to the rise time of CLK. Following the hold-time interval, data at the D input may be changed without affecting the levels at the outputs.

ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	PDIP – N	Tube of 25	SN74HCT74N	SN74HCT74N
	SOIC – D	Tube of 50	SN74HCT74D	HCT74
		Reel of 2500	SN74HCT74DR	
		Reel of 250	SN74HCT74DT	
	SOP – NS	Reel of 2000	SN74HCT74NSR	HCT74
	SSOP – DB	Reel of 2000	SN74HCT74DBR	HT74
	TSSOP – PW	Tube of 90	SN74HCT74PW	HT74
		Reel of 2000	SN74HCT74PWR	
		Reel of 250	SN74HCT74PWT	
–55°C to 125°C	CDIP – J	Tube of 25	SNJ54HCT74J	SNJ54HCT74J
	CFP – W	Tube of 150	SNJ54HCT74W	SNJ54HCT74W
	LCCC – FK	Tube of 55	SNJ54HCT74FK	SNJ54HCT74FK

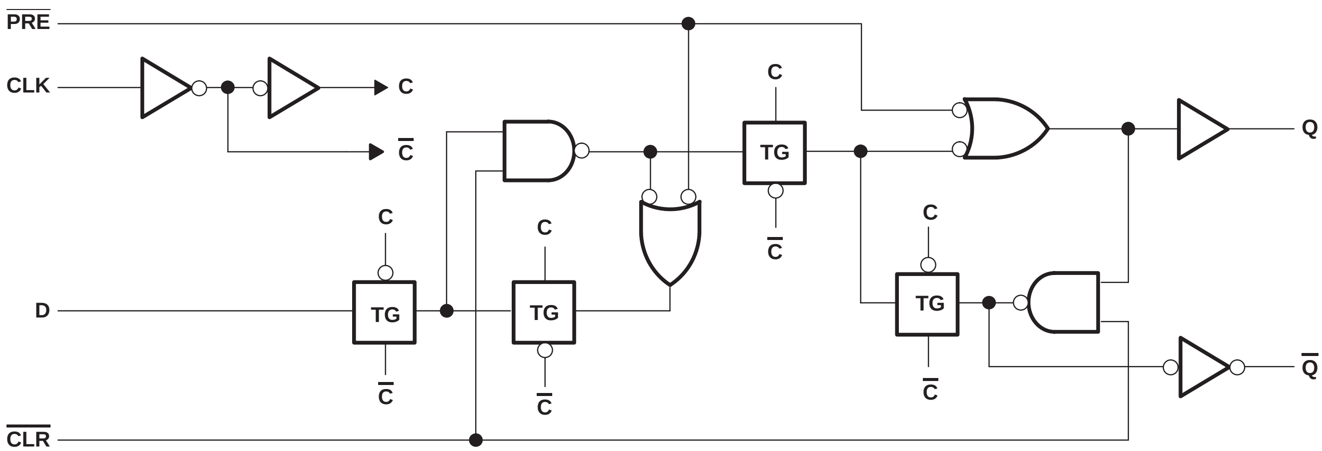
† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

FUNCTION TABLE

INPUTS				OUTPUT	
$\overline{PRE}$	$\overline{CLR}$	CLK	D	Q	$\overline{Q}$
L	H	X	X	H	L
H	L	X	X	L	H
L	L	X	X	H†	H†
H	H	↑	H	H	L
H	H	↑	L	L	H
H	H	L	X	Q_0	$\overline{Q}_0$

† This configuration is nonstable; that is, it does not persist when $\overline{PRE}$ or $\overline{CLR}$ returns to its inactive (high) level.

logic diagram (positive logic)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)‡

Supply voltage range, V_{CC} . . . –0.5 V to 7 V
Input clamp current, I_{IK} (V_I < 0 or V_I > V_{CC}) (see Note 1) . . . ±20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{CC}) (see Note 1) . . . ±20 mA
Continuous output current, I_O (V_O = 0 to V_{CC}) . . . ±25 mA
Continuous current through V_{CC} or GND . . . ±50 mA
Package thermal impedance, θ_{JA} (see Note 2): D package . . . 86°C/W
DB package . . . 96°C/W
N package . . . 80°C/W
NS package . . . 76°C/W
PW package . . . 113°C/W
Storage temperature range, T_{stg} . . . –65°C to 150°C

‡ Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. The input and output voltage ratings may be exceeded if the input and output current ratings are observed.
2. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions (see Note 3)

			SN54HCT74			SN74HCT74			UNIT
			MIN	NOM	MAX	MIN	NOM	MAX	
V_{CC}	Supply voltage		4.5	5	5.5	4.5	5	5.5	V
V_{IH}	High-level input voltage	V_{CC} = 4.5 V to 5.5 V	2			2			V
V_{IL}	Low-level input voltage	V_{CC} = 4.5 V to 5.5 V			0.8			0.8	V
V_I	Input voltage		0		V_{CC}	0		V_{CC}	V
V_O	Output voltage		0		V_{CC}	0		V_{CC}	V
$\Delta t/\Delta v$	Input transition rise/fall time				500			500	ns
T_A	Operating free-air temperature		–55		125	–40		85	°C

NOTE 3: All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS		V_{CC}	T_A = 25°C			SN54HCT74		SN74HCT74		UNIT
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
V_{OH}	$V_I = V_{IH}$ or V_{IL}	I_{OH} = –20 µA	4.5 V	4.4	4.499		4.4		4.4		V
		I_{OH} = –4 mA		3.98	4.3		3.7		3.84		
V_{OL}	$V_I = V_{IH}$ or V_{IL}	I_{OL} = 20 µA	4.5 V		0.001	0.1		0.1		0.1	V
		I_{OL} = 4 mA			0.17	0.26		0.4		0.33	
I_I	$V_I = V_{CC}$ or 0		5.5 V		±0.1	±100		±1000		±1000	nA
I_{CC}	$V_I = V_{CC}$ or 0,	I_O = 0	5.5 V			4		80		40	µA
ΔI_{CC}†	One input at 0.5 V or 2.4 V, Other inputs at 0 or V_{CC}		5.5 V		1.4	2.4		3		2.9	mA
C_i			4.5 V to 5.5 V		3	10		10		10	pF

† This is the increase in supply current for each input that is at one of the specified TTL voltage levels, rather than 0 V or V_{CC}.

timing requirements over recommended operating free-air temperature range (unless otherwise noted)

			V_{CC}	T_A = 25°C		SN54HCT74		SN74HCT74		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
f_{clock}	Clock frequency		4.5 V		27		18		22	MHz
			5.5 V		30		20		24	
t_w	Pulse duration	$\overline{PRE}$ or $\overline{CLR}$ low	4.5 V	16		24		20		ns
			5.5 V	14		21		18		
		CLK high or low	4.5 V	18		27		23		
			5.5 V	16		24		21		
t_{su}	Setup time before CLK↑	Data	4.5 V	12		18		15		ns
			5.5 V	11		16		14		
		$\overline{PRE}$ or $\overline{CLR}$ inactive	4.5 V	0		0		0		
			5.5 V	0		0		0		
t_h	Hold time, data after CLK↑		4.5 V	0		0		0		ns
			5.5 V	0		0		0		

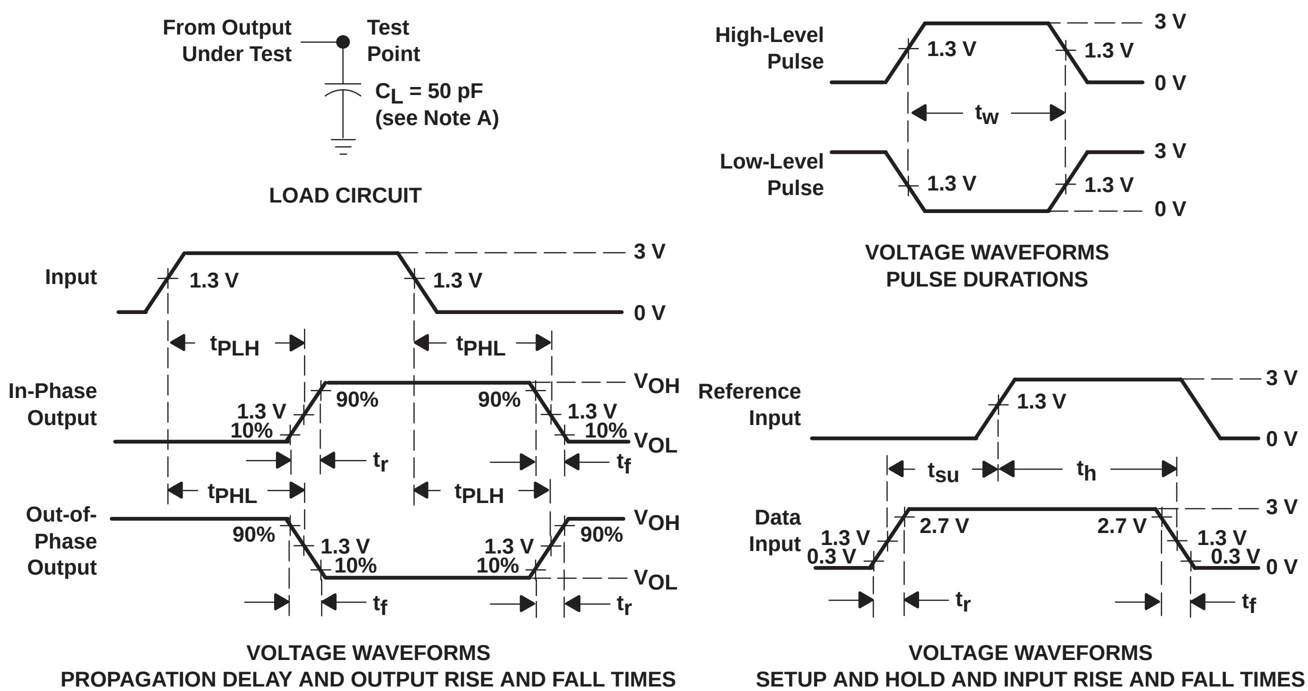
switching characteristics over recommended operating free-air temperature range, C_L = 50 pF (unless otherwise noted) (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	V_{CC}	T_A = 25°C			SN54HCT74		SN74HCT74		UNIT
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
f_{max}			4.5 V	27	40		18		22		MHz
			5.5 V	30	46		20		24		
t_{pd}	$\overline{PRE}$ or $\overline{CLR}$	Q or $\overline{Q}$	4.5 V		21	35		53		44	ns
			5.5 V		17	31		48		40	
	CLK	Q or $\overline{Q}$	4.5 V		20	28		42		35	
			5.5 V		18	25		38		31	
t_t		Q or $\overline{Q}$	4.5 V		8	15		22		19	ns
			5.5 V		7	14		20		17	

operating characteristics, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
C_{pd}	Power dissipation capacitance per flip-flop	No load	35	pF

PARAMETER MEASUREMENT INFORMATION



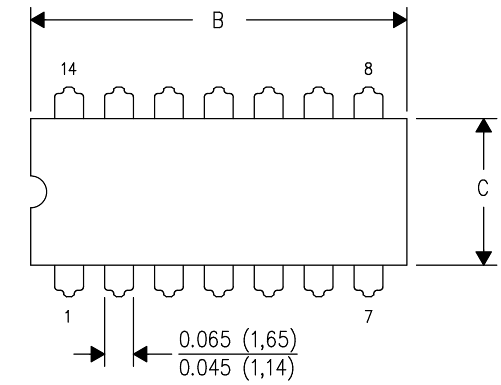
NOTES: A. C_L includes probe and test-fixture capacitance.
B. Phase relationships between waveforms were chosen arbitrarily. All input pulses are supplied by generators having the following characteristics: PRR ≤ 1 MHz, Z_O = 50 Ω, t_r = 6 ns, t_f = 6 ns.
C. For clock inputs, f_{max} is measured when the input duty cycle is 50%.
D. The outputs are measured one at a time with one input transition per measurement.
E. t_{PLH} and t_{PHL} are the same as t_{pd}.

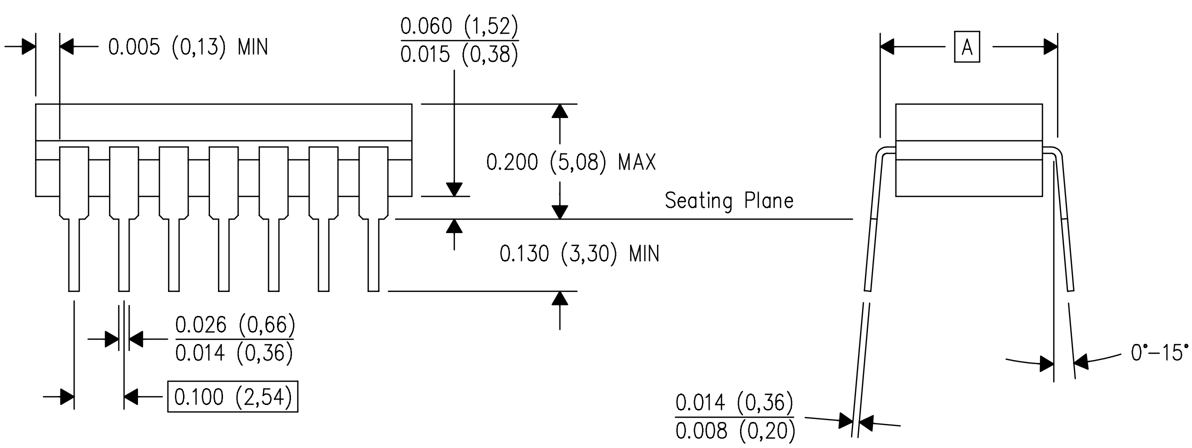
Figure 1. Load Circuit and Voltage Waveforms

J (R-GDIP-T**) CERAMIC DUAL IN-LINE PACKAGE

14 LEADS SHOWN

PINS ** / DIM	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	—	—	—	—
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)

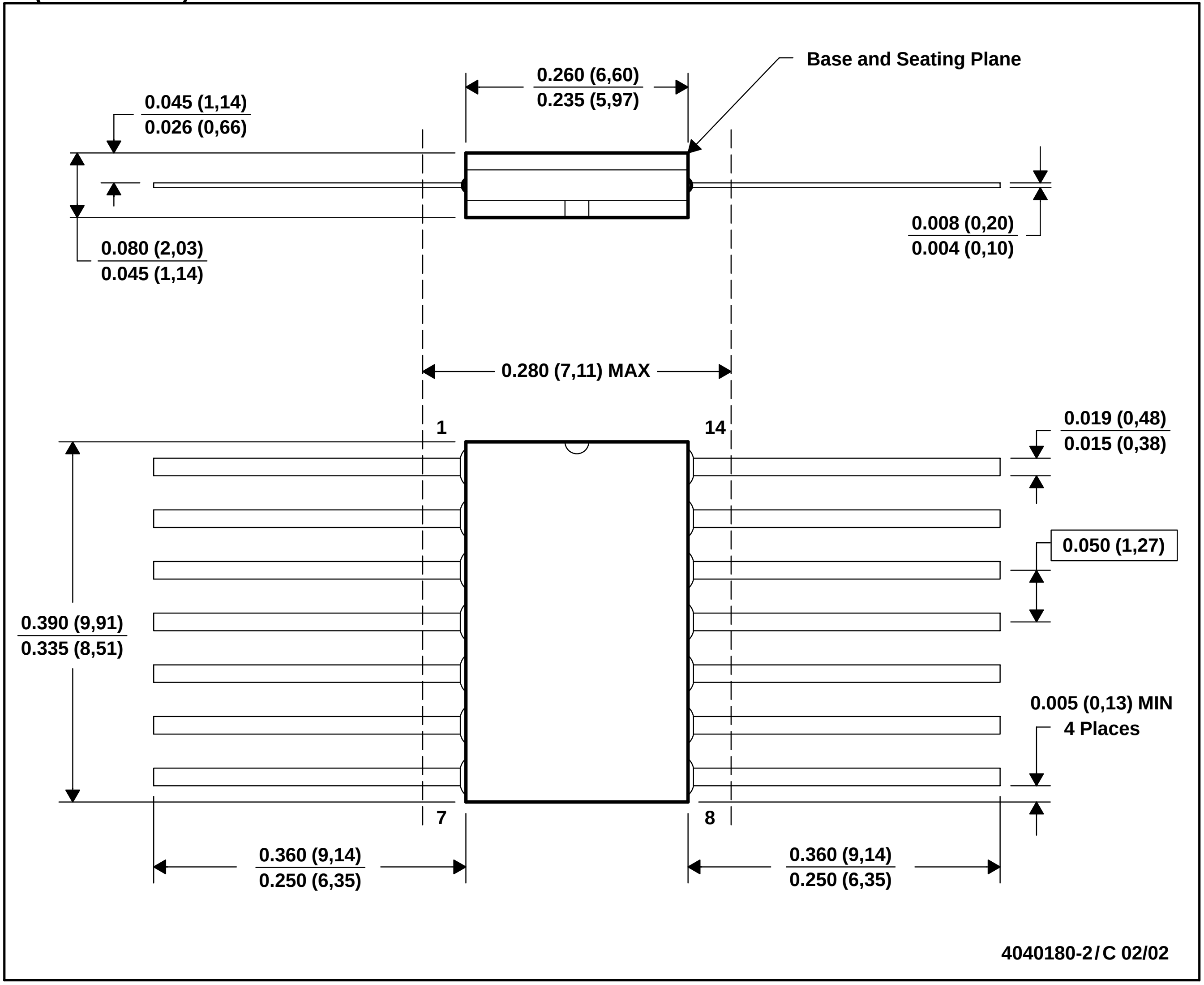




4040083/F 03/03

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package is hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL STD 1835 GDIP1-T14, GDIP1-T16, GDIP1-T18 and GDIP1-T20.

W (R-GDFP-F14) **CERAMIC DUAL FLATPACK**

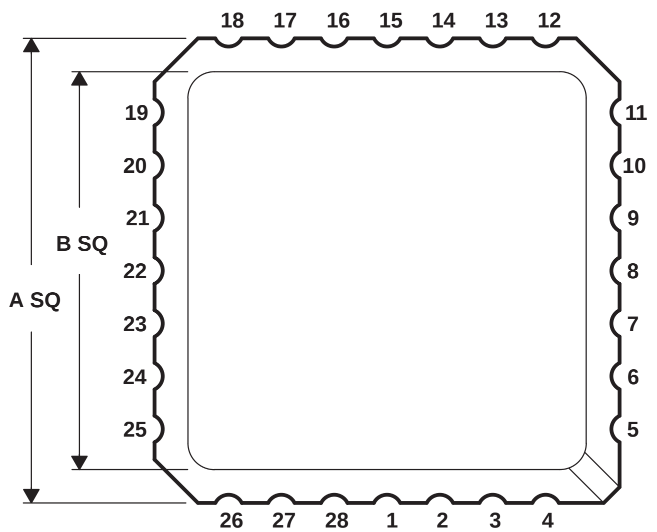


NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only.
E. Falls within MIL STD 1835 GDFP1-F14 and JEDEC MO-092AB

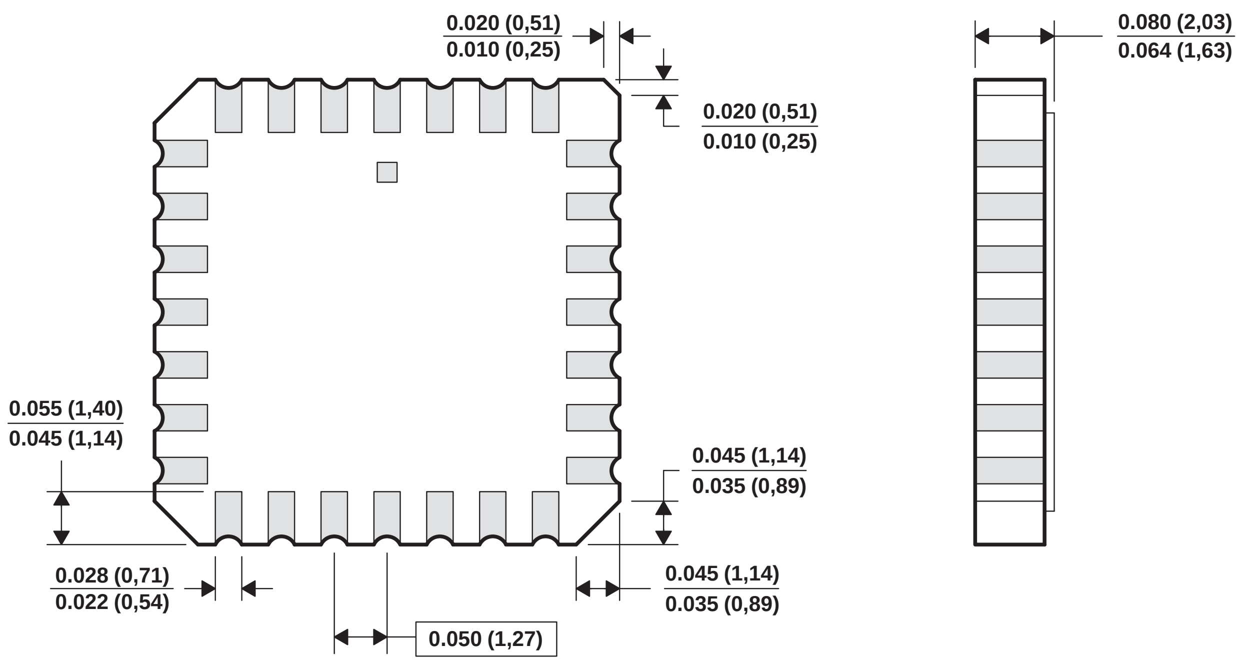
MLCC006B – OCTOBER 1996

FK (S-CQCC-N**) LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



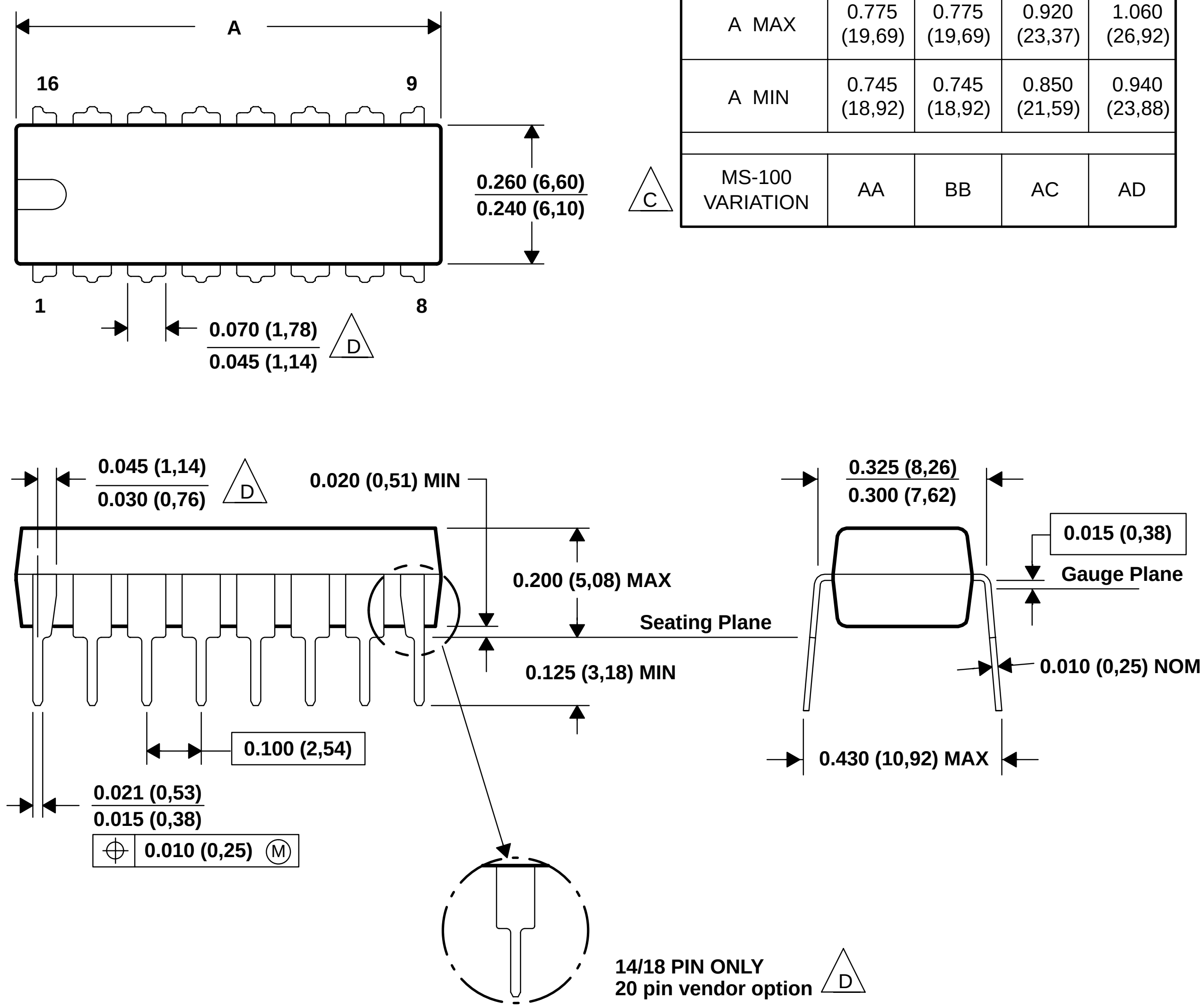
4040140 / D 10/96

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

N (R-PDIP-T)** **PLASTIC DUAL-IN-LINE PACKAGE**

16 PINS SHOWN

DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-100 VARIATION	AA	BB	AC	AD

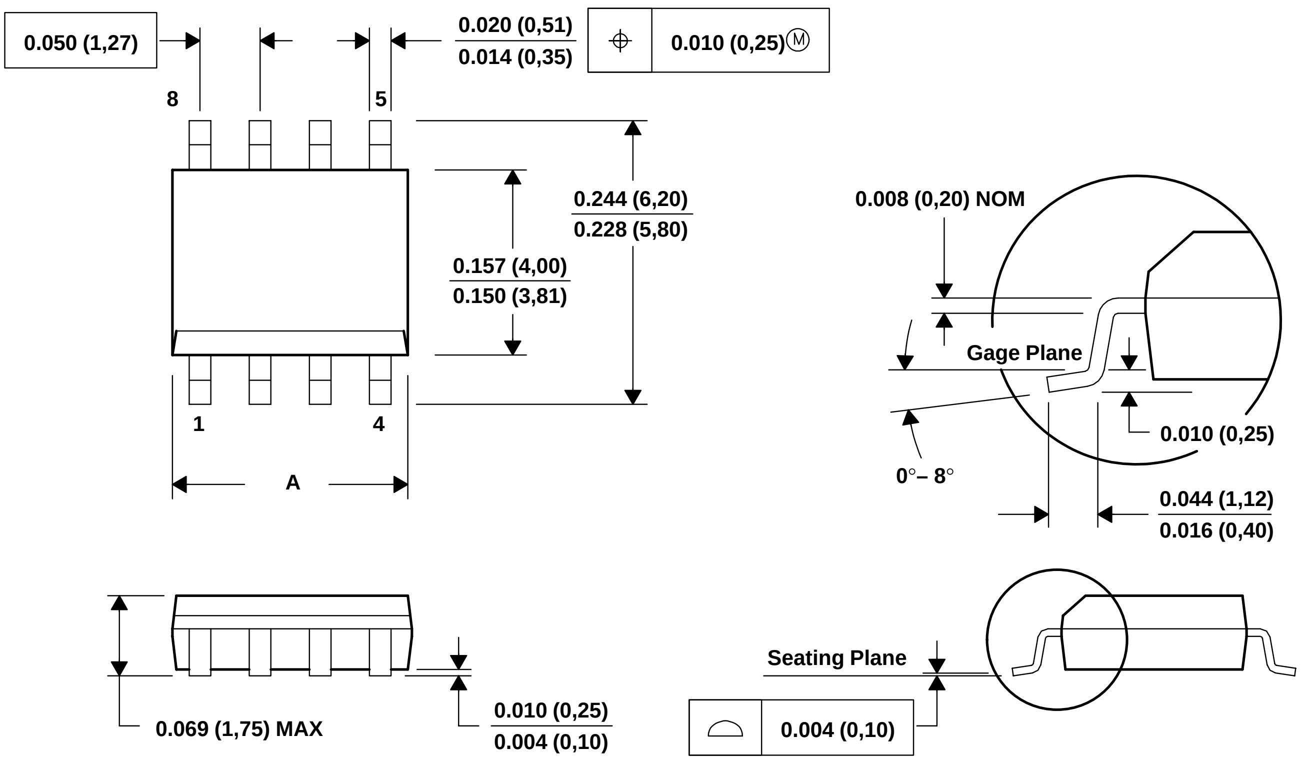


4040049/E 12/2002

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001, except 18 and 20 pin minimum body lrngth (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN



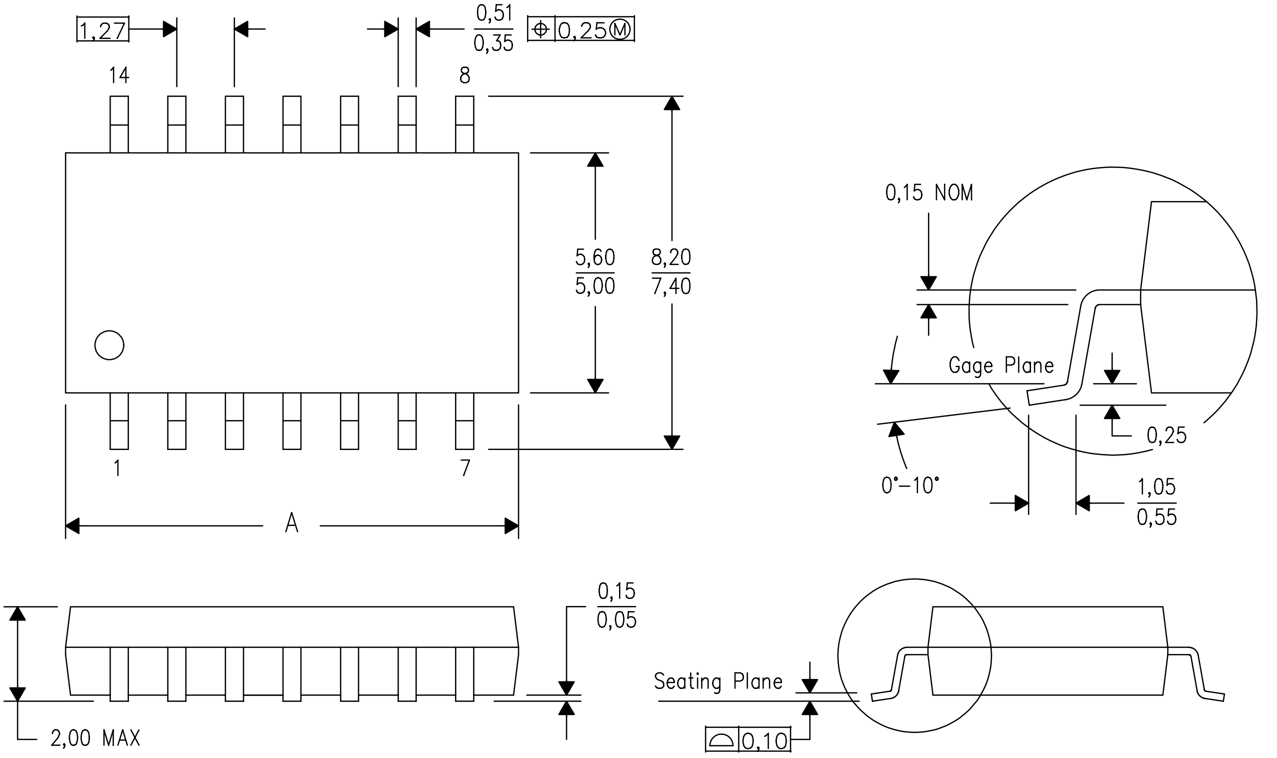
PINS ** / DIM	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



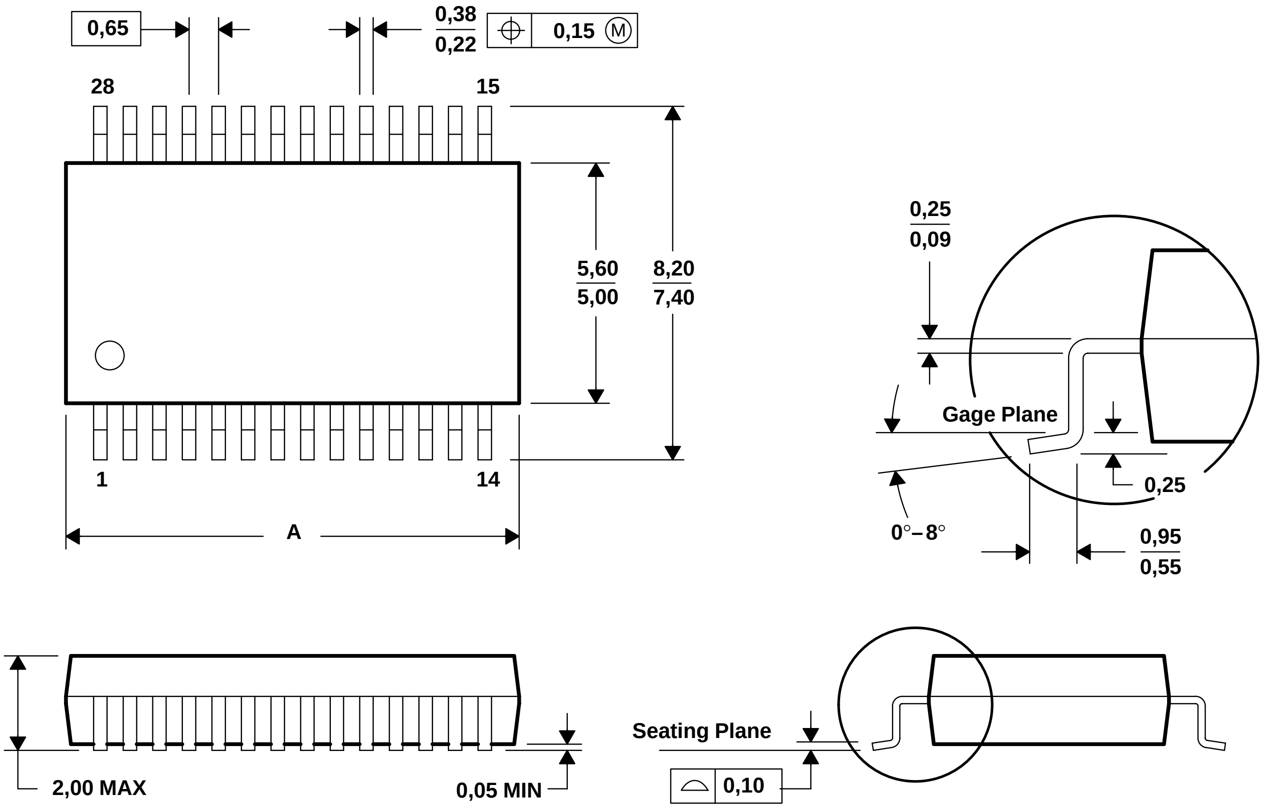
PINS ** / DIM	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

DB (R-PDSO-G)** **PLASTIC SMALL-OUTLINE**

28 PINS SHOWN



PINS ** / DIM	14	16	20	24	28	30	38
A MAX	6,50	6,50	7,50	8,50	10,50	10,50	12,90
A MIN	5,90	5,90	6,90	7,90	9,90	9,90	12,30

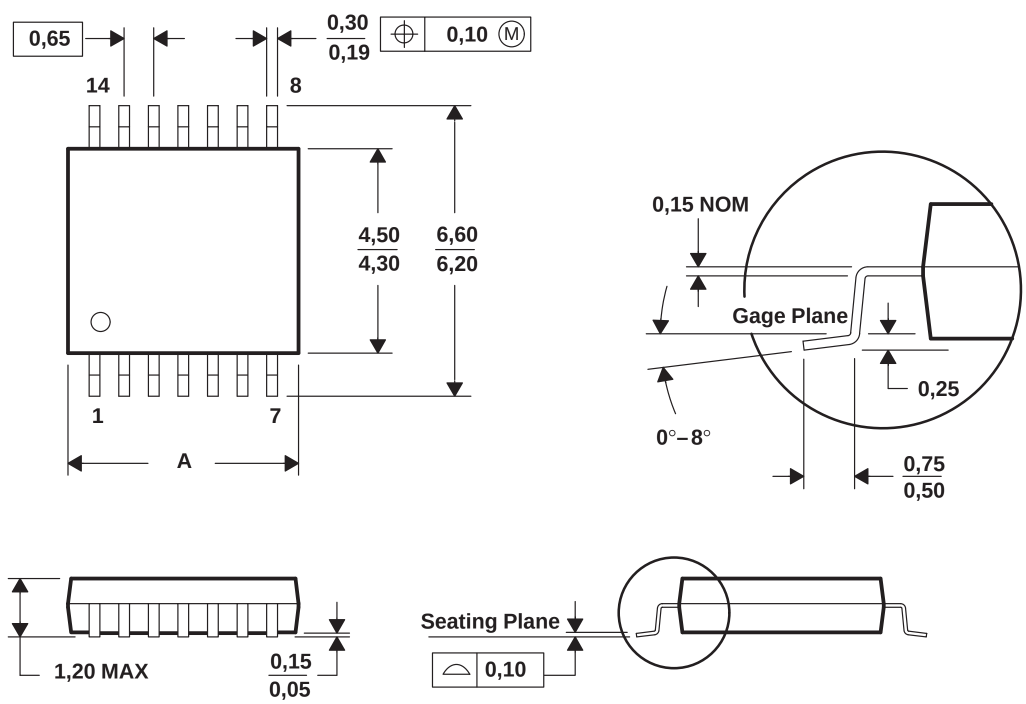
4040065 /E 12/01

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-150

PW (R-PDSO-G)**

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

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		Video & Imaging	www.ti.com/video
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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

6. SN74AHCT541: Octal Buffers/Drivers with 3-State Outputs

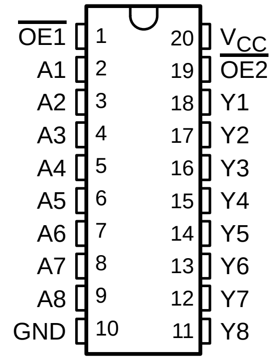
Texas Instruments

Octal Buffers/Drivers with 3-State Outputs

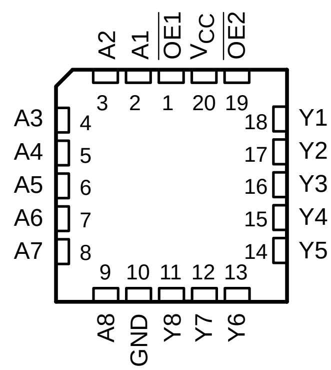
SN74AHCT541

- **Inputs Are TTL-Voltage Compatible**
- **Latch-Up Performance Exceeds 250 mA Per JESD 17**
- **ESD Protection Exceeds JESD 22**
  - **2000-V Human-Body Model (A114-A)**
  - **200-V Machine Model (A115-A)**
  - **1000-V Charged-Device Model (C101)**

SN54AHCT541 . . . J OR W PACKAGE
SN74AHCT541 . . . DB, DGV, DW, N, NS, OR PW PACKAGE
(TOP VIEW)



SN54AHCT541 . . . FK PACKAGE
(TOP VIEW)



description/ordering information

The ’AHCT541 octal buffers/drivers are ideal for driving bus lines or buffer memory address registers. These devices feature inputs and outputs on opposite sides of the package to facilitate printed circuit board layout.

The 3-state control gate is a 2-input AND gate with active-low inputs so that if either output-enable ($\overline{OE1}$ or $\overline{OE2}$) input is high, all corresponding outputs are in the high-impedance state. The outputs provide noninverted data when they are not in the high-impedance state.

To ensure the high-impedance state during power up or power down, $\overline{OE}$ should be tied to V_{CC} through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

ORDERING INFORMATION

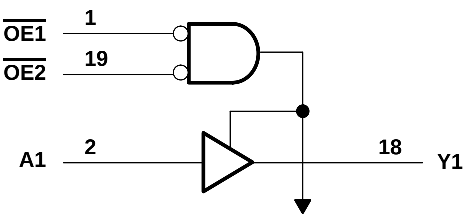
T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	PDIP – N	Tube	SN74AHCT541N	SN74AHCT541N
	SOIC – DW	Tube	SN74AHCT541DW	AHCT541
		Tape and reel	SN74AHCT541DWR	
	SOP – NS	Tape and reel	SN74AHCT541NSR	AHCT541
	SSOP – DB	Tape and reel	SN74AHCT541DBR	HB541
	TSSOP – PW	Tube	SN74AHCT541PW	HB541
		Tape and reel	SN74AHCT541PWR	
	TVSOP – DGV	Tape and reel	SN74AHCT541DGVR	HB541
–55°C to 125°C	CDIP – J	Tube	SNJ54AHCT541J	SNJ54AHCT541J
	CFP – W	Tube	SNJ54AHCT541W	SNJ54AHCT541W
	LCCC – FK	Tube	SNJ54AHCT541FK	SNJ54AHCT541FK

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

FUNCTION TABLE
(each buffer/driver)

INPUTS			OUTPUT
$\overline{OE1}$	$\overline{OE2}$	A	Y
L	L	L	L
L	L	H	H
H	X	X	Z
X	H	X	Z

logic diagram (positive logic)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, V_{CC} . . . . –0.5 V to 7 V
Input voltage range, V_I (see Note 1) . . . . –0.5 V to 7 V
Output voltage range, V_O (see Note 1) . . . . –0.5 V to V_{CC} + 0.5 V
Input clamp current, I_{IK} (V_I < 0) . . . . –20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{CC}) . . . . ±20 mA
Continuous output current, I_O (V_O = 0 to V_{CC}) . . . . ±25 mA
Continuous current through V_{CC} or GND . . . . ±75 mA
Package thermal impedance, θ_{JA} (see Note 2): DB package . . . . 70°C/W
DGV package . . . . 92°C/W
DW package . . . . 58°C/W
N package . . . . 69°C/W
NS package . . . . 60°C/W
PW package . . . . 83°C/W
Storage temperature range, T_{stg} . . . . –65°C to 150°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. The input and output voltage ratings may be exceeded if the input and output current ratings are observed.
2. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions (see Note 3)

		SN54AHCT541		SN74AHCT541		UNIT
		MIN	MAX	MIN	MAX	
V_{CC}	Supply voltage	4.5	5.5	4.5	5.5	V
V_{IH}	High-level input voltage	2		2		V
V_{IL}	Low-level input voltage		0.8		0.8	V
V_I	Input voltage	0	5.5	0	5.5	V
V_O	Output voltage	0	V_{CC}	0	V_{CC}	V
I_{OH}	High-level output current		–8		–8	mA
I_{OL}	Low-level output current		8		8	mA
$\Delta t/\Delta v$	Input transition rise or fall rate		20		20	ns/V
T_A	Operating free-air temperature	–55	125	–40	85	°C

NOTE 3: All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	V_{CC}	T_A = 25°C			SN54AHCT541		SN74AHCT541		UNIT
			MIN	TYP	MAX	MIN	MAX	MIN	MAX	
V_{OH}	I_{OH} = –50 μA	4.5 V	4.4	4.5		4.4		4.4		V
	I_{OH} = –8 mA		3.94			3.8		3.8		
V_{OL}	I_{OL} = 50 μA	4.5 V			0.1		0.1		0.1	V
	I_{OL} = 8 mA				0.36		0.44		0.44	
I_I	V_I = 5.5 V or GND	0 V to 5.5 V			±0.1		±1*		±1	μA
I_{OZ}	V_O = V_{CC} or GND	5.5 V			±0.25		±2.5		±2.5	μA
I_{CC}	V_I = V_{CC} or GND, I_O = 0	5.5 V			4		40		40	μA
ΔI_{CC}†	One input at 3.4 V, Other inputs at V_{CC} or GND	5.5 V			1.35		1.5		1.5	mA
C_i	V_I = V_{CC} or GND	5 V		2	10				10	pF
C_o	V_O = V_{CC} or GND	5 V		4						pF

* On products compliant to MIL-PRF-38535, this parameter is not production tested at V_{CC} = 0 V.
† This is the increase in supply current for each input at one of the specified TTL voltage levels, rather than 0 V or V_{CC}.

switching characteristics over recommended operating free-air temperature range, V_{CC} = 5 V ± 0.5 V (unless otherwise noted) (see Figure 1)

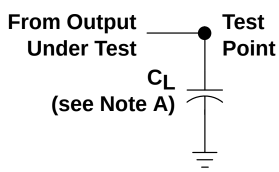
PARAMETER	FROM (INPUT)	TO (OUTPUT)	LOAD CAPACITANCE	T_A = 25°C			SN54AHCT541		SN74AHCT541		UNIT
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
t_{PLH}	A	Y	C_L = 15 pF		4.1*	6*	1*	6.5*	1	6.5	ns
t_{PHL}					3.7*	5.5*	1*	6.5*	1	6.5	
t_{PZH}	$\overline{OE}$	Y	C_L = 15 pF		5*	7*	1*	8*	1	8	ns
t_{PZL}					5*	7*	1*	8*	1	8	
t_{PHZ}	$\overline{OE}$	Y	C_L = 15 pF		4.5*	7*	1*	8*	1	8	ns
t_{PLZ}					4.5*	7*	1*	8*	1	8	
t_{PLH}	A	Y	C_L = 50 pF		6.2	8.5	1	9.5	1	9.5	ns
t_{PHL}					6	8.5	1	9.5	1	9.5	
t_{PZH}	$\overline{OE}$	Y	C_L = 50 pF		7.5	10	1	12	1	12	ns
t_{PZL}					7.5	10	1	12	1	12	
t_{PHZ}	$\overline{OE}$	Y	C_L = 50 pF		7	10	1	12	1	12	ns
t_{PLZ}					7	10	1	12	1	12	
$t_{sk(o)}$			C_L = 50 pF			1**				1	ns

* On products compliant to MIL-PRF-38535, this parameter is not production tested.
** On products compliant to MIL-PRF-38535, this parameter does not apply.

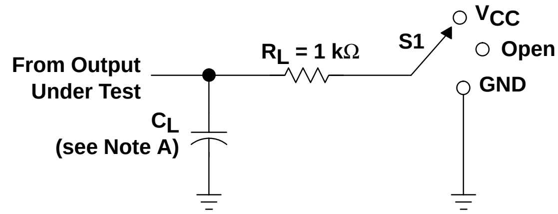
operating characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
C_{pd}	Power dissipation capacitance	No load, f = 1 MHz	12	pF

PARAMETER MEASUREMENT INFORMATION

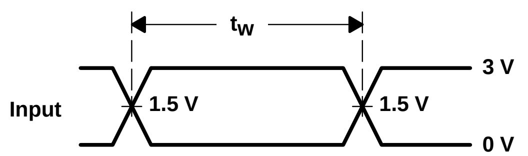


LOAD CIRCUIT FOR
TOTEM-POLE OUTPUTS

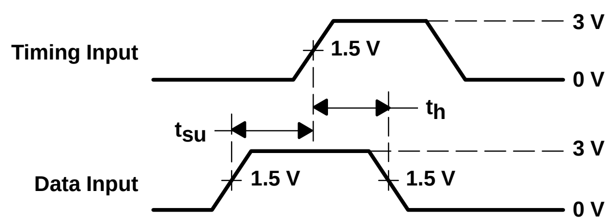


LOAD CIRCUIT FOR
3-STATE AND OPEN-DRAIN OUTPUTS

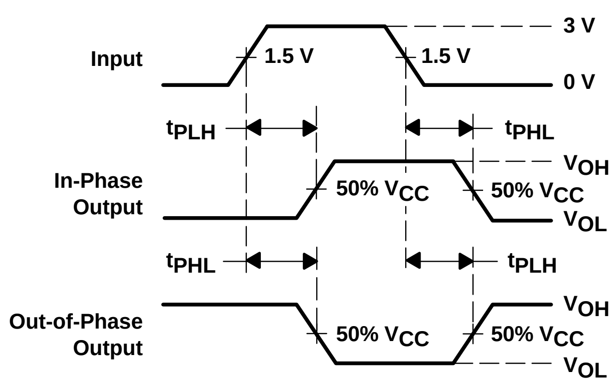
TEST	S1
t_{PLH}/t_{PHL}	Open
t_{PLZ}/t_{PZL}	V_{CC}
t_{PHZ}/t_{PZH}	GND
Open Drain	V_{CC}



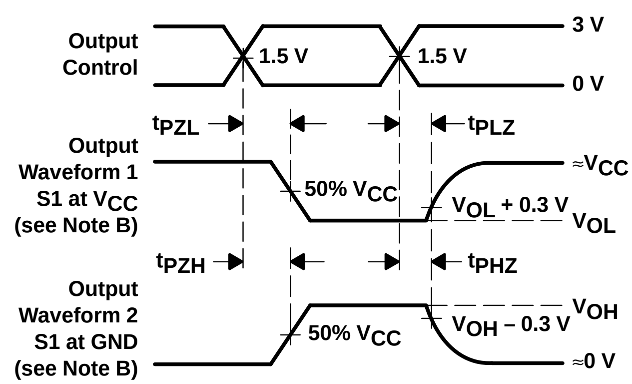
VOLTAGE WAVEFORMS
PULSE DURATION



VOLTAGE WAVEFORMS
SETUP AND HOLD TIMES



VOLTAGE WAVEFORMS
PROPAGATION DELAY TIMES
INVERTING AND NONINVERTING OUTPUTS



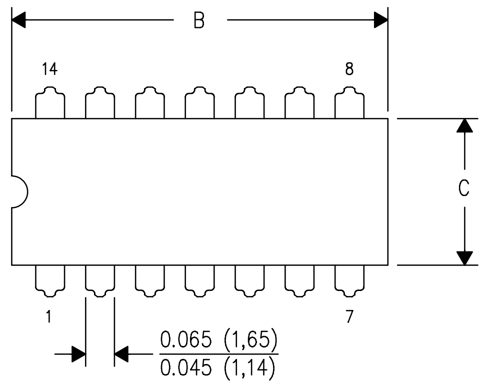
VOLTAGE WAVEFORMS
ENABLE AND DISABLE TIMES
LOW- AND HIGH-LEVEL ENABLING

NOTES: A. C_L includes probe and jig capacitance.
B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.
C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 1 MHz, Z_O = 50 Ω, t_r ≤ 3 ns, t_f ≤ 3 ns.
D. The outputs are measured one at a time with one input transition per measurement.
E. All parameters and waveforms are not applicable to all devices.

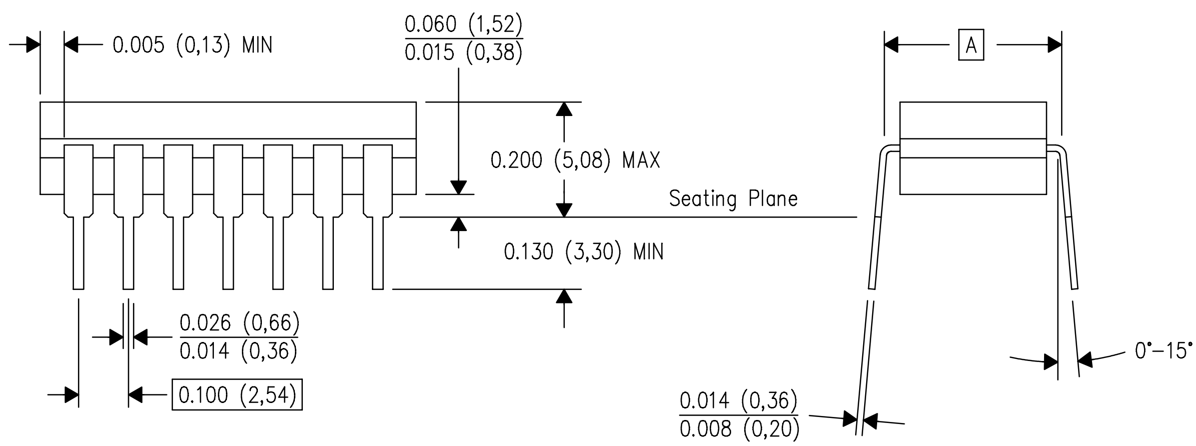
Figure 1. Load Circuit and Voltage Waveforms

J (R–GDIP–T**) CERAMIC DUAL IN–LINE PACKAGE

14 LEADS SHOWN



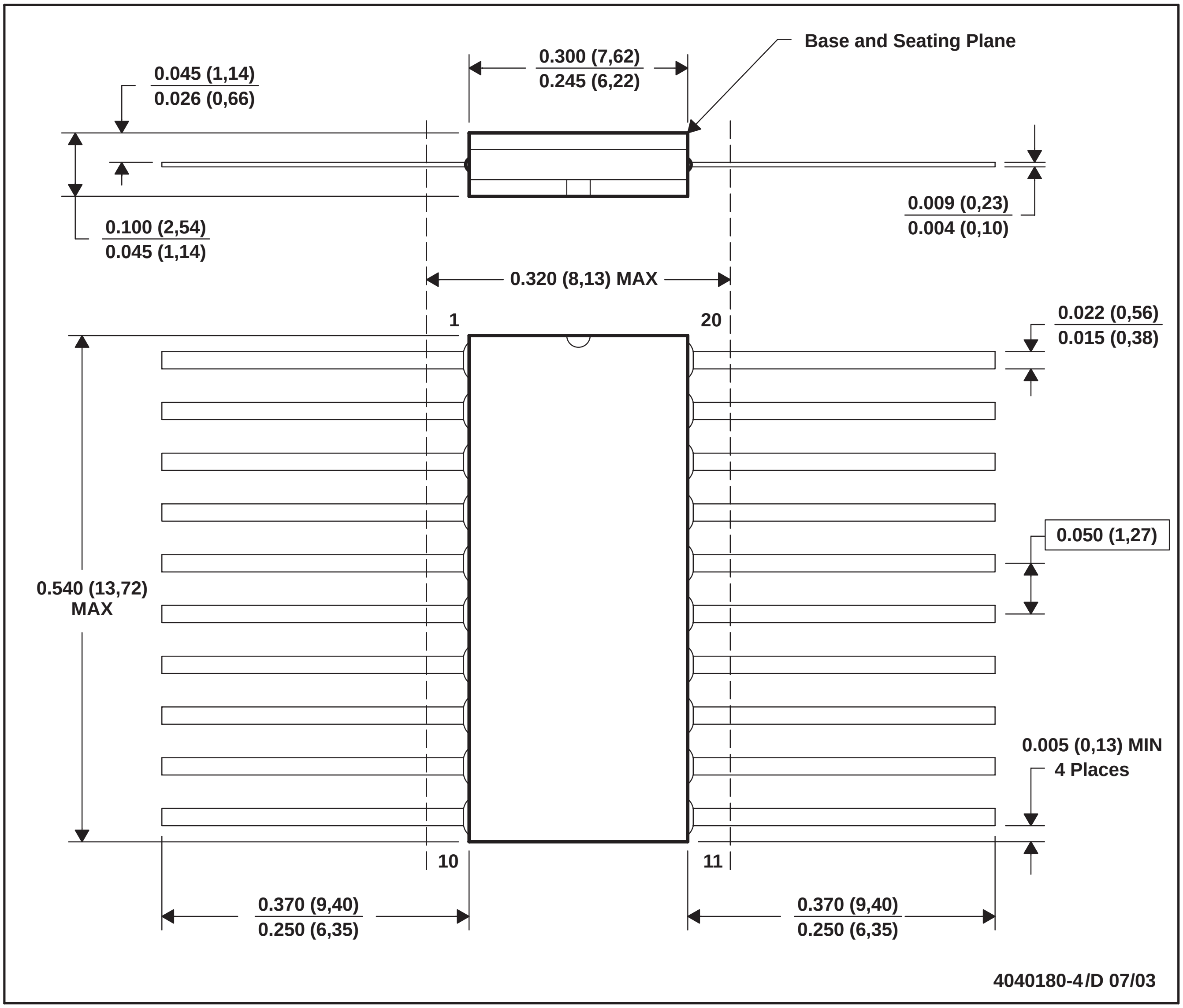
DIM \ PINS **	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	——	——	——	——
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)



4040083/F 03/03

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package is hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL STD 1835 GDIP1–T14, GDIP1–T16, GDIP1–T18 and GDIP1–T20.

W (R-GDFP-F20) **CERAMIC DUAL FLATPACK**

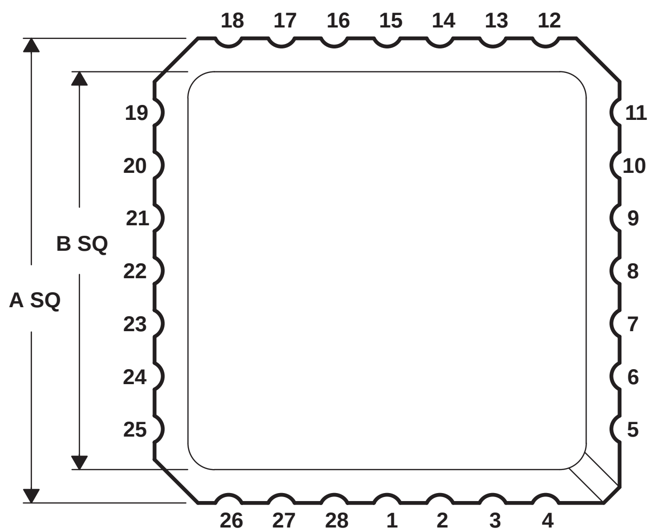


NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only.
E. Falls within Mil-Std 1835 GDFP2-F20

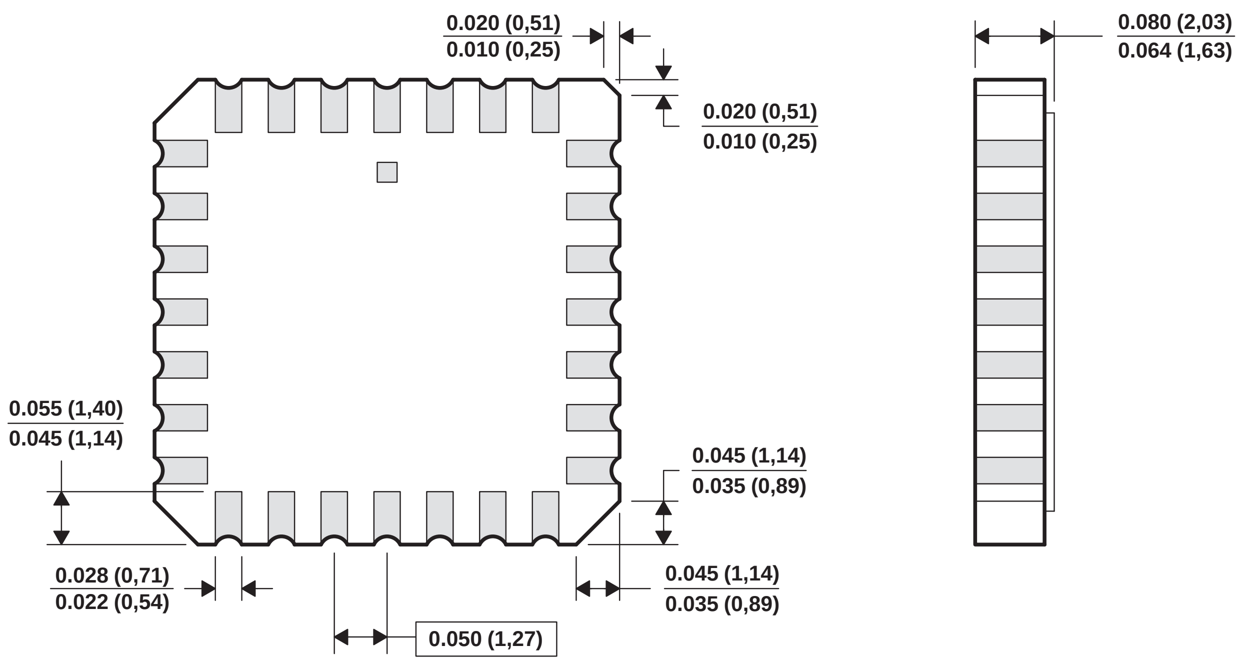
MLCC006B – OCTOBER 1996

FK (S-CQCC-N**) LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



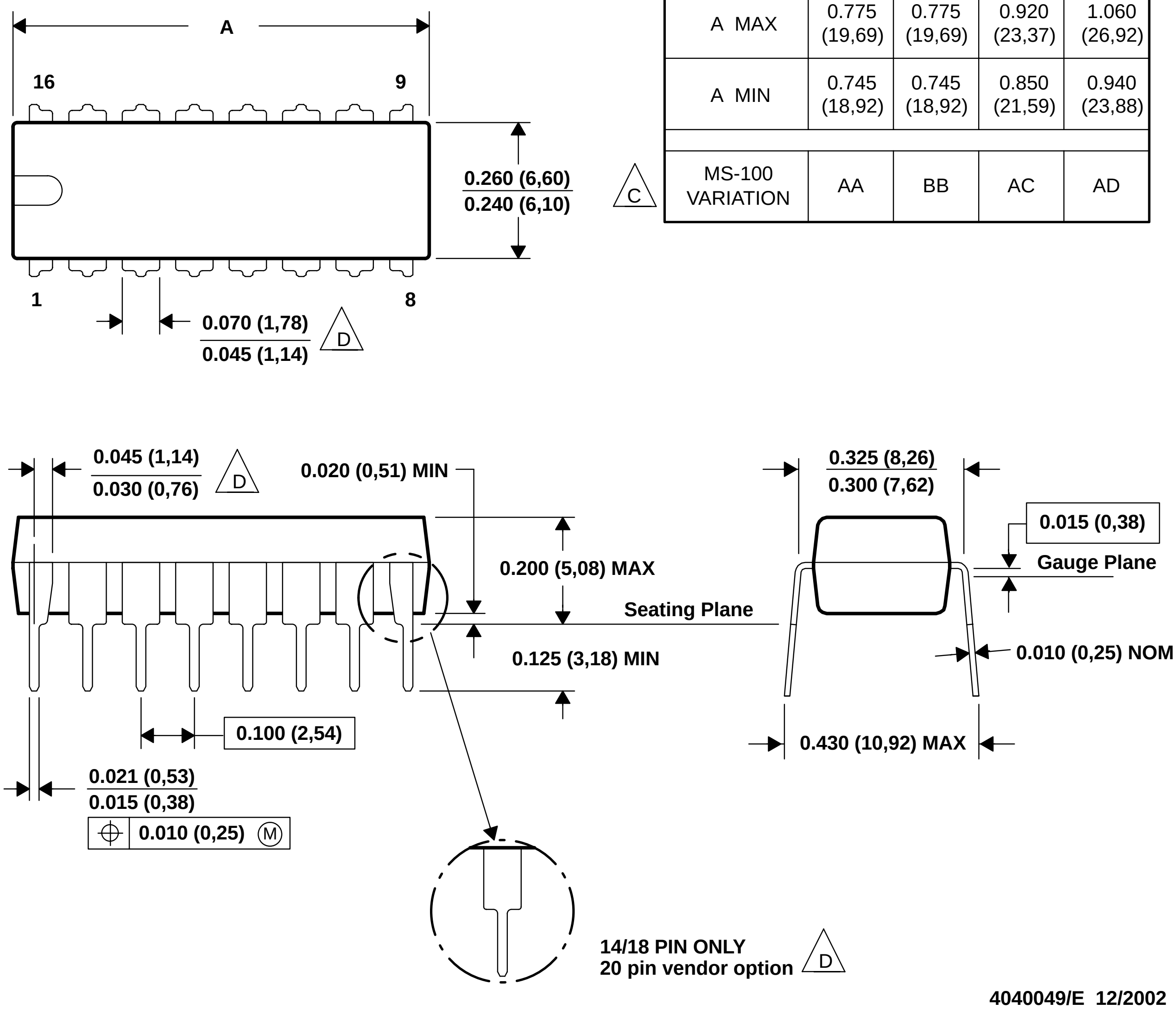
4040140 / D 10/96

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

N (R-PDIP-T)** **PLASTIC DUAL-IN-LINE PACKAGE**

16 PINS SHOWN

DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-100 VARIATION	AA	BB	AC	AD



NOTES: A. All linear dimensions are in inches (millimeters).

B. This drawing is subject to change without notice.

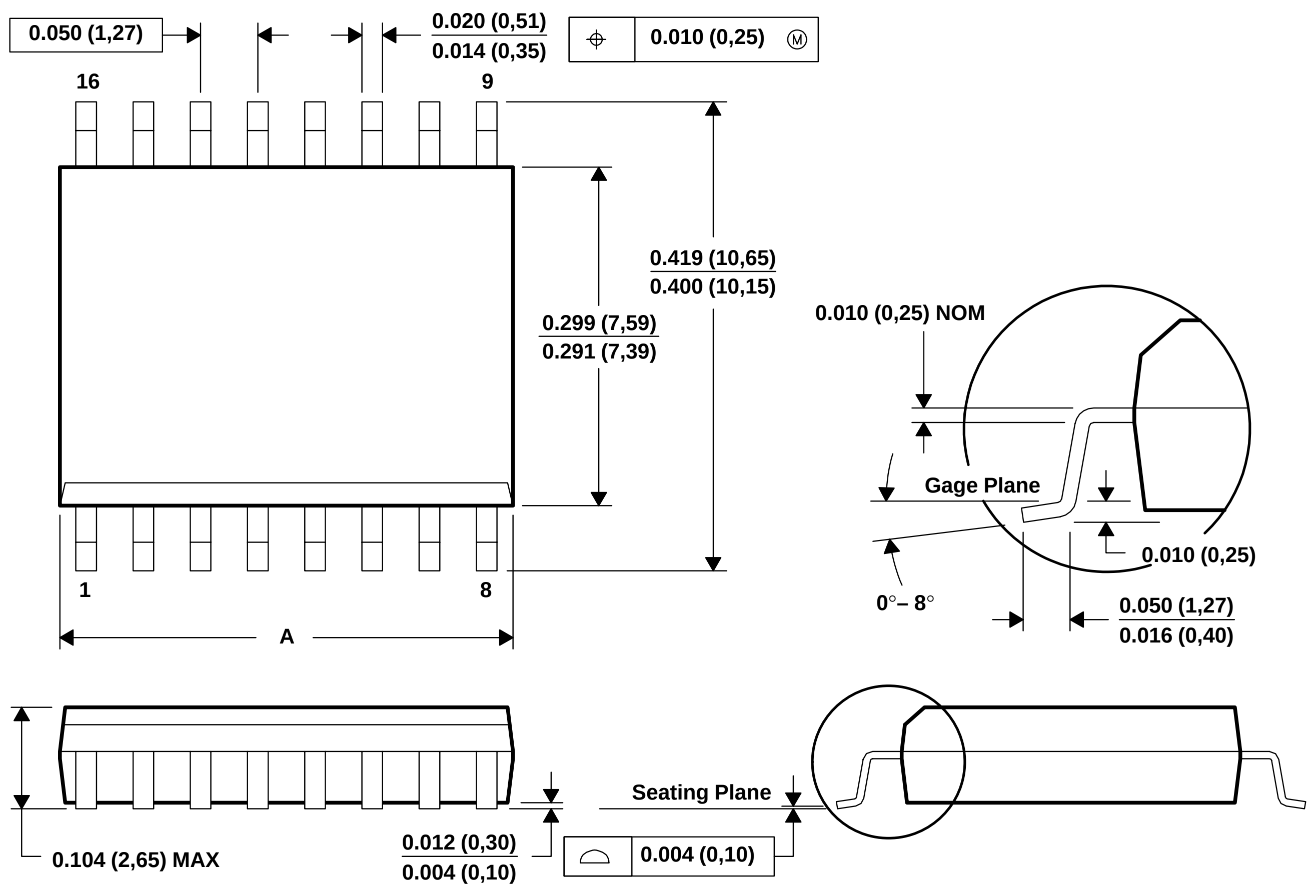
C. Falls within JEDEC MS-001, except 18 and 20 pin minimum body lrngth (Dim A).

D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

MSOI003E – JANUARY 1995 – REVISED SEPTEMBER 2001

DW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

16 PINS SHOWN



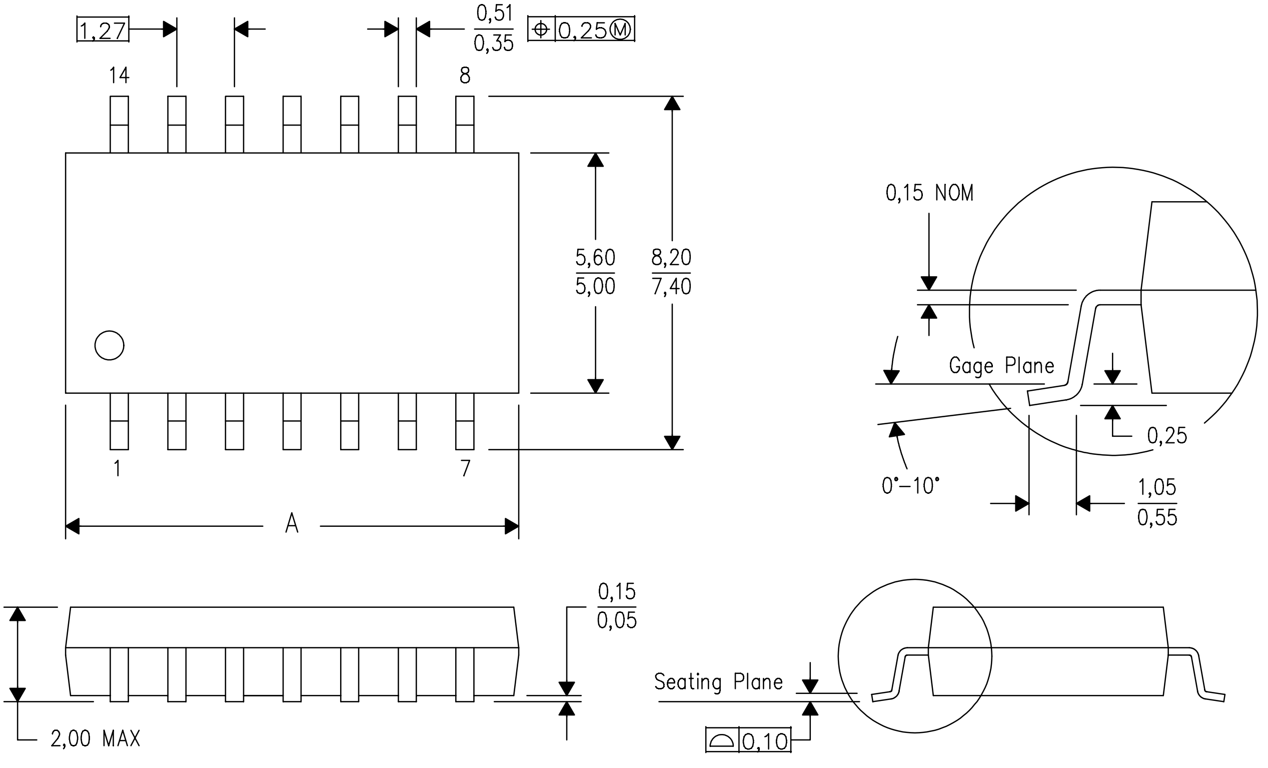
PINS ** / DIM	16	18	20	24	28
A MAX	0.410 (10,41)	0.462 (11,73)	0.510 (12,95)	0.610 (15,49)	0.710 (18,03)
A MIN	0.400 (10,16)	0.453 (11,51)	0.500 (12,70)	0.600 (15,24)	0.700 (17,78)

4040000/E 08/01

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
- D. Falls within JEDEC MS-013

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



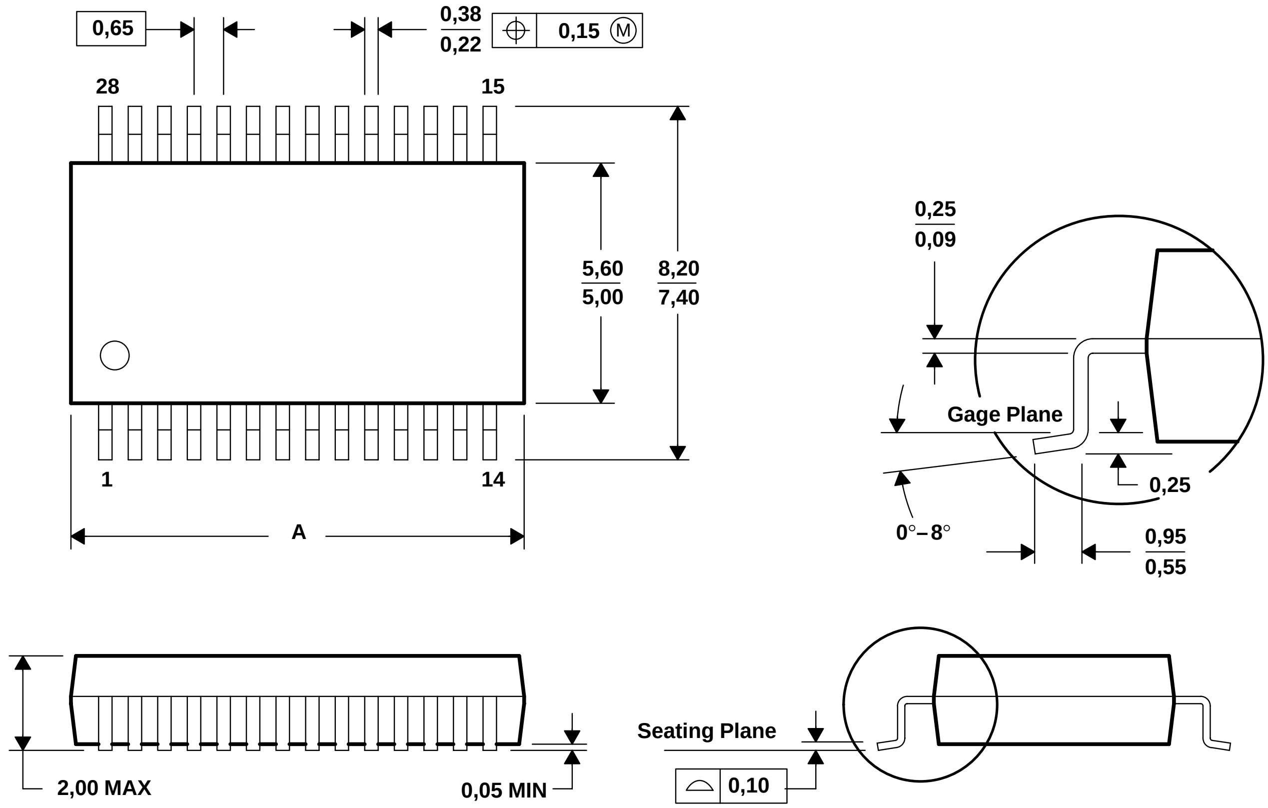
DIM \ PINS **	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

DB (R-PDSO-G)** **PLASTIC SMALL-OUTLINE**

28 PINS SHOWN



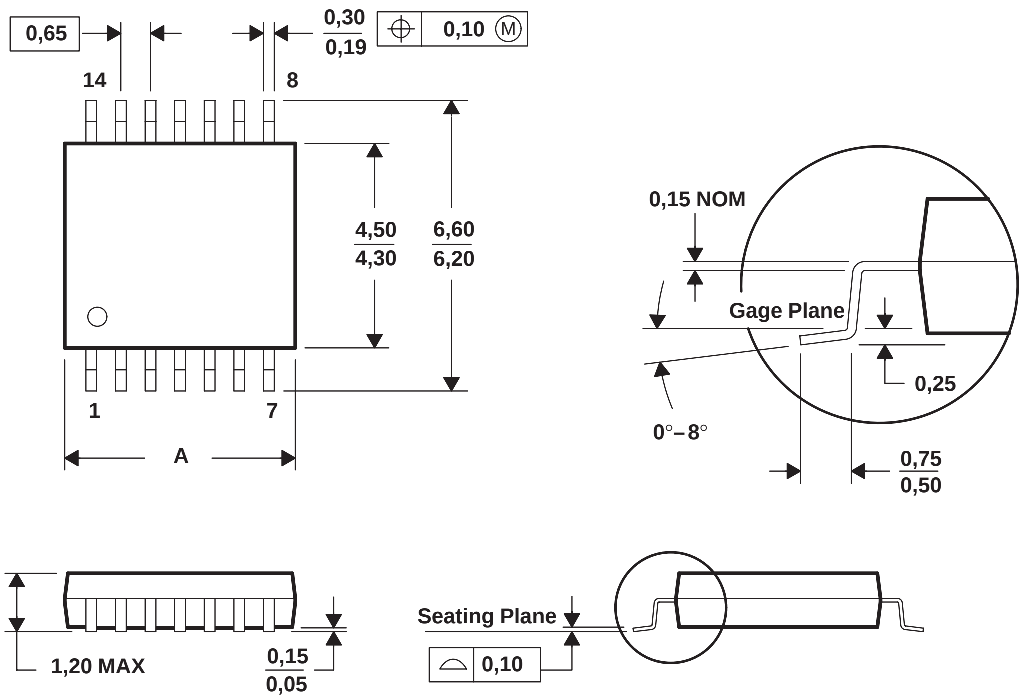
PINS ** / DIM	14	16	20	24	28	30	38
A MAX	6,50	6,50	7,50	8,50	10,50	10,50	12,90
A MIN	5,90	5,90	6,90	7,90	9,90	9,90	12,30

4040065 /E 12/01

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-150

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

7. SN74HC21: Dual 4-Input Positive-AND Gates

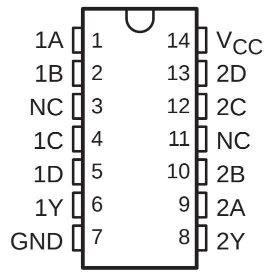
Texas Instruments

Dual 4-Input Positive-AND Gates

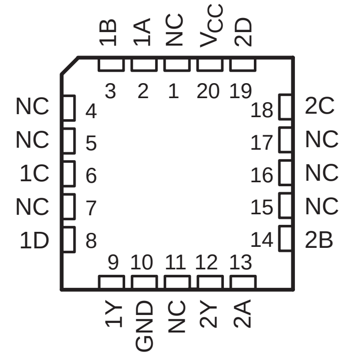
SN74HC21

- **Wide Operating Voltage Range of 2 V to 6 V**
- **Outputs Can Drive Up To 10 LSTTL Loads**
- **Low Power Consumption, 20-μA Max I_{CC}**
- **Typical t_{pd} = 11 ns**
- **±4-mA Output Drive at 5 V**
- **Low Input Current of 1 μA Max**

SN54HC21 . . . J OR W PACKAGE
SN74HC21 . . . D, N, NS, OR PW PACKAGE
(TOP VIEW)



SN54HC21 . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

description/ordering information

These devices contain two independent 4-input AND gates. They perform the Boolean function $Y = A \bullet B \bullet C \bullet D$ or $Y = \overline{\overline{A} + \overline{B} + \overline{C} + \overline{D}}$ in positive logic.

ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	PDIP – N	Tube of 25	SN74HC21N	SN74HC21N
	SOIC – D	Tube of 50	SN74HC21D	HC21
		Reel of 2500	SN74HC21DR	
		Reel of 250	SN74HC21DT	
	SOP – NS	Reel of 2000	SN74HC21NSR	HC21
	TSSOP – PW	Tube of 90	SN74HC21PW	HC21
		Reel of 2000	SN74HC21PWR	
		Reel of 250	SN74HC21PWT	
–55°C to 125°C	CDIP – J	Tube of 25	SNJ54HC21J	SNJ54HC21J
	CFP – W	Tube of 150	SNJ54HC21W	SNJ54HC21W
	LCCC – FK	Tube of 55	SNJ54HC21FK	SNJ54HC21FK

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

FUNCTION TABLE
(each gate)

INPUTS				OUTPUT
A	B	C	D	Y
H	H	H	H	H
L	X	X	X	L
X	L	X	X	L
X	X	L	X	L
X	X	X	L	L

logic diagram (positive logic)

Pin numbers shown are for the D, J, N, NS, PW, and W packages.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, V_{CC} . . . . –0.5 V to 7 V
Input clamp current, I_{IK} (V_I < 0 or V_I > V_{CC}) (see Note 1) . . . . ±20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{CC}) (see Note 1) . . . . ±20 mA
Continuous output current, I_O (V_O = 0 to V_{CC}) . . . . ±25 mA
Continuous current through V_{CC} or GND . . . . ±50 mA
Package thermal impedance, θ_{JA} (see Note 2): D package . . . . 86°C/W
N package . . . . 80°C/W
NS package . . . . 76°C/W
PW package . . . . 113°C/W
Storage temperature range, T_{stg} . . . . –65°C to 150°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. The input and output voltage ratings may be exceeded if the input and output current ratings are observed.
2. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions (see Note 3)

			SN54HC21 MIN	SN54HC21 NOM	SN54HC21 MAX	SN74HC21 MIN	SN74HC21 NOM	SN74HC21 MAX	UNIT
V_{CC}	Supply voltage		2	5	6	2	5	6	V
V_{IH}	High-level input voltage	V_{CC} = 2 V	1.5			1.5			V
		V_{CC} = 4.5 V	3.15			3.15			
		V_{CC} = 6 V	4.2			4.2			
V_{IL}	Low-level input voltage	V_{CC} = 2 V			0.5			0.5	V
		V_{CC} = 4.5 V			1.35			1.35	
		V_{CC} = 6 V			1.8			1.8	
V_I	Input voltage		0		V_{CC}	0		V_{CC}	V
V_O	Output voltage		0		V_{CC}	0		V_{CC}	V
$\Delta t/\Delta v$	Input transition rise/fall time	V_{CC} = 2 V			1000			1000	ns
		V_{CC} = 4.5 V			500			500	
		V_{CC} = 6 V			400			400	
T_A	Operating free-air temperature		–55		125	–40		85	°C

NOTE 3: All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS		V_{CC}	T_A = 25°C MIN	T_A = 25°C TYP	T_A = 25°C MAX	SN54HC21 MIN	SN54HC21 MAX	SN74HC21 MIN	SN74HC21 MAX	UNIT
V_{OH}	$V_I = V_{IH}$ or V_{IL}	I_{OH} = –20 µA	2 V	1.9	1.998		1.9		1.9		V
			4.5 V	4.4	4.499		4.4		4.4		
			6 V	5.9	5.999		5.9		5.9		
		I_{OH} = –4 mA	4.5 V	3.98	4.3		3.7		3.84		
		I_{OH} = –5.2 mA	6 V	5.48	5.8		5.2		5.34		
V_{OL}	$V_I = V_{IH}$ or V_{IL}	I_{OL} = 20 µA	2 V		0.002	0.1		0.1		0.1	V
			4.5 V		0.001	0.1		0.1		0.1	
			6 V		0.001	0.1		0.1		0.1	
		I_{OL} = 4 mA	4.5 V		0.17	0.26		0.4		0.33	
		I_{OL} = 5.2 mA	6 V		0.15	0.26		0.4		0.33	
I_I	$V_I = V_{CC}$ or 0		6 V		±0.1	±100		±1000		±1000	nA
I_{CC}	$V_I = V_{CC}$ or 0,	I_O = 0	6 V			2		40		20	µA
C_i			2 V to 6 V		3	10		10		10	pF

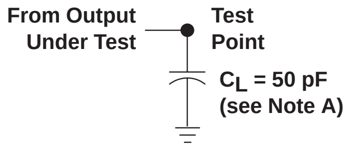
switching characteristics over recommended operating free-air temperature range, C_L = 50 pF (unless otherwise noted) (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	V_{CC}	T_A = 25°C			SN54HC21		SN74HC21		UNIT
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
t_{pd}	A, B, C, or D	Y	2 V		44	110		165		140	ns
			4.5 V		14	22		33		28	
			6 V		11	19		28		24	
t_t		Y	2 V		29	75		110		95	ns
			4.5 V		10	15		22		19	
			6 V		8	13		19		16	

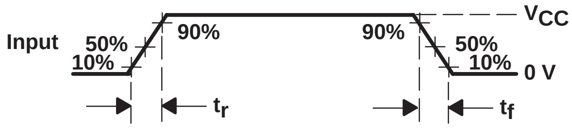
operating characteristics, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
C_{pd}	Power dissipation capacitance per gate	No load	25	pF

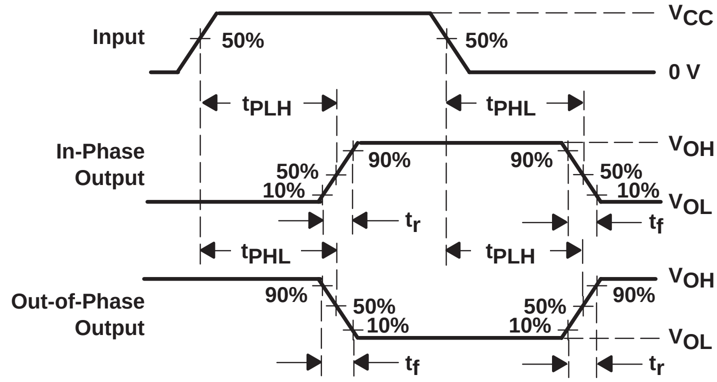
PARAMETER MEASUREMENT INFORMATION



LOAD CIRCUIT



VOLTAGE WAVEFORM
INPUT RISE AND FALL TIMES



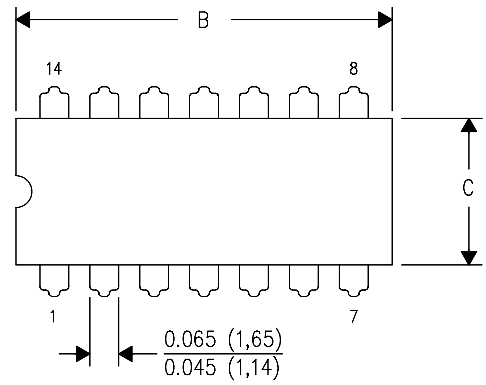
VOLTAGE WAVEFORMS
PROPAGATION DELAY AND OUTPUT TRANSITION TIMES

NOTES:
A. C_L includes probe and test-fixture capacitance.
B. Phase relationships between waveforms were chosen arbitrarily. All input pulses are supplied by generators having the following characteristics: PRR ≤ 1 MHz, Z_O = 50 Ω, t_r = 6 ns, t_f = 6 ns.
C. The outputs are measured one at a time with one input transition per measurement.
D. t_{PLH} and t_{PHL} are the same as t_{pd}.

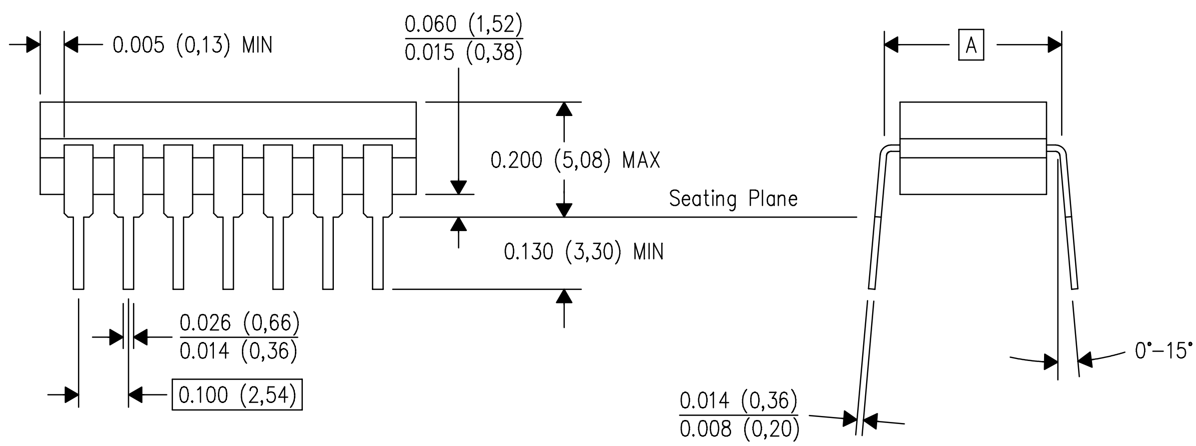
Figure 1. Load Circuit and Voltage Waveforms

J (R–GDIP–T**) CERAMIC DUAL IN–LINE PACKAGE

14 LEADS SHOWN



PINS ** / DIM	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	—	—	—	—
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)

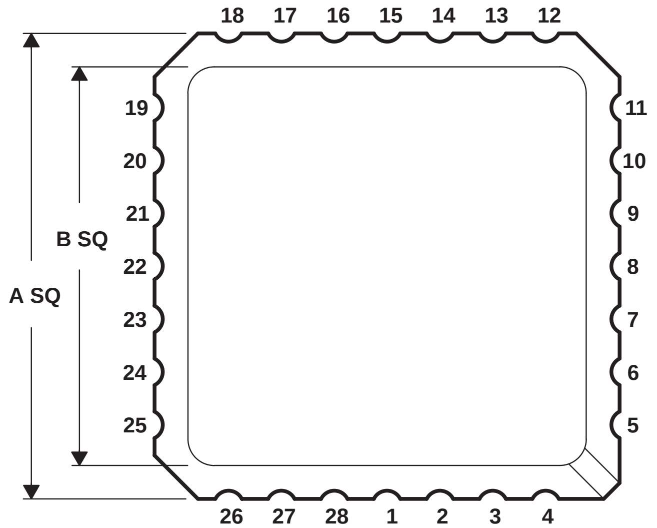


4040083/F 03/03

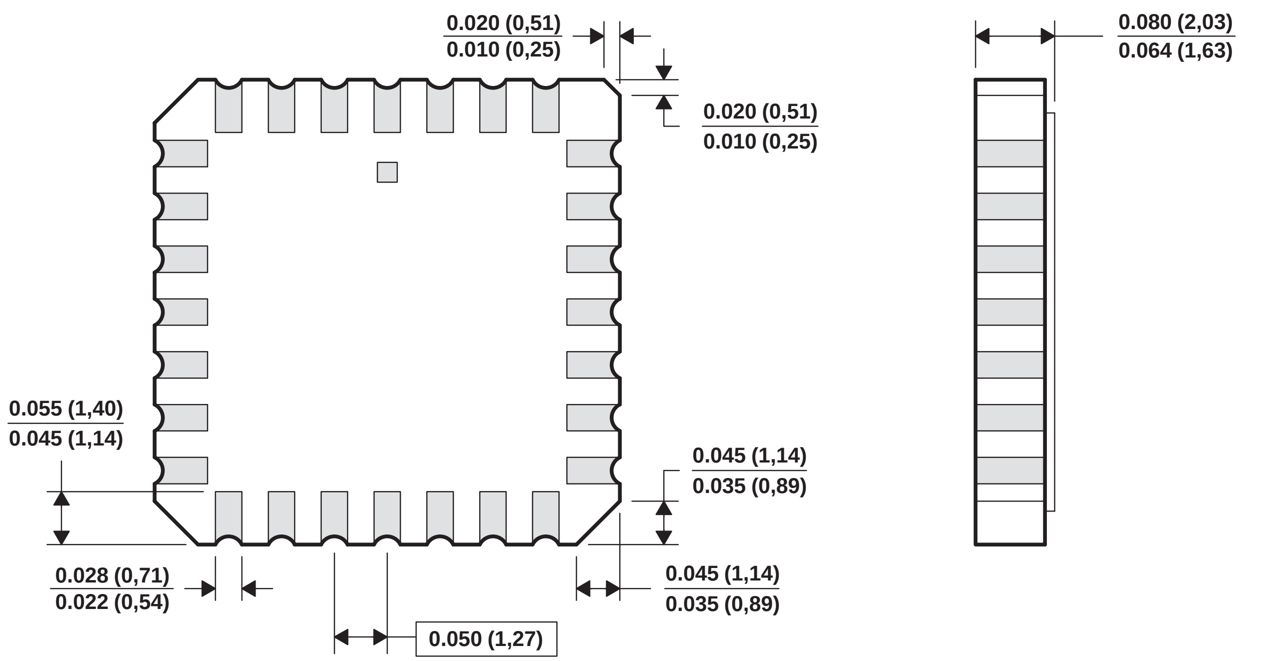
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package is hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL STD 1835 GDIP1–T14, GDIP1–T16, GDIP1–T18 and GDIP1–T20.

FK (S-CQCC-N)** **LEADLESS CERAMIC CHIP CARRIER**

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



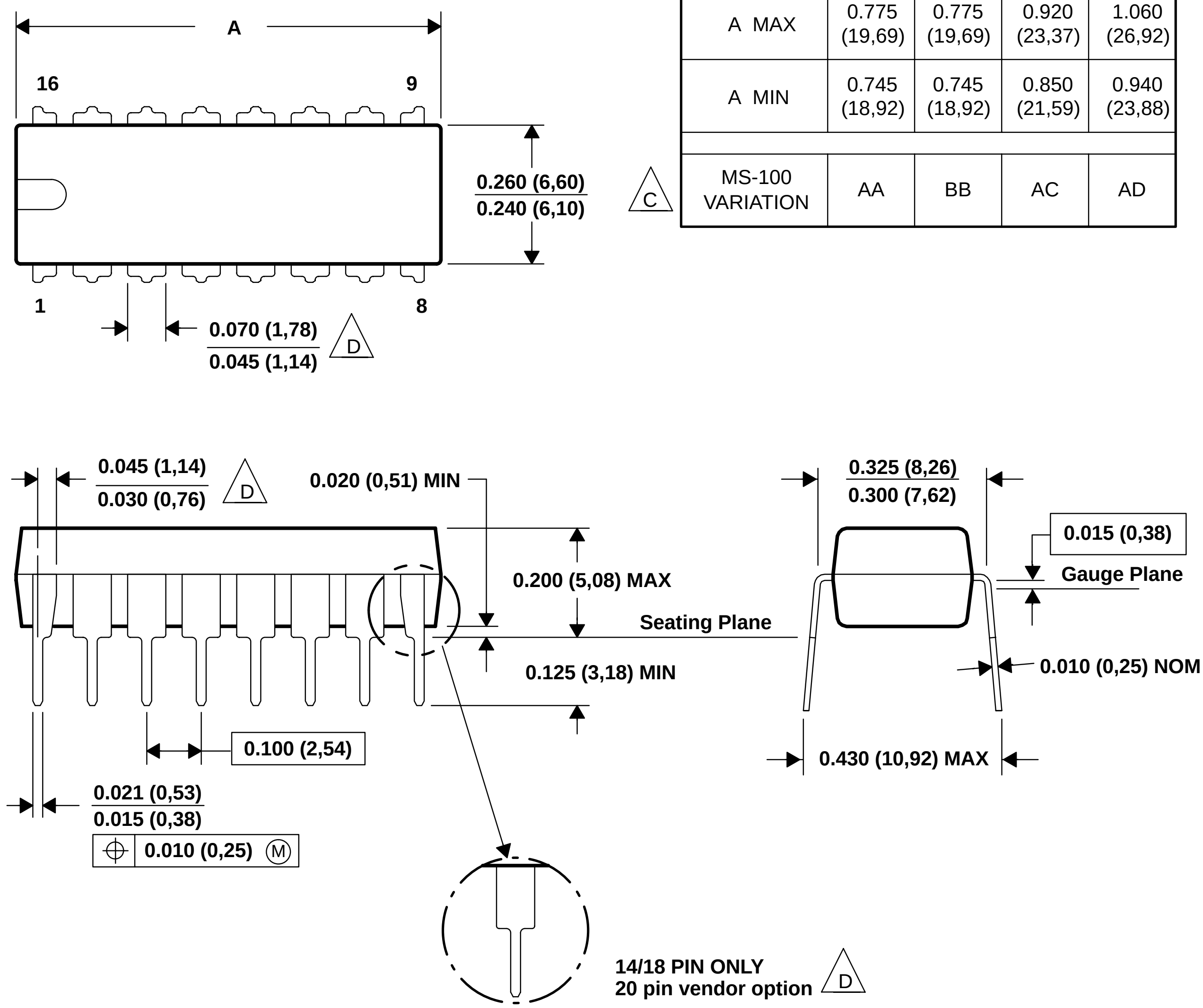
4040140 / D 10/96

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

N (R-PDIP-T)** **PLASTIC DUAL-IN-LINE PACKAGE**

16 PINS SHOWN

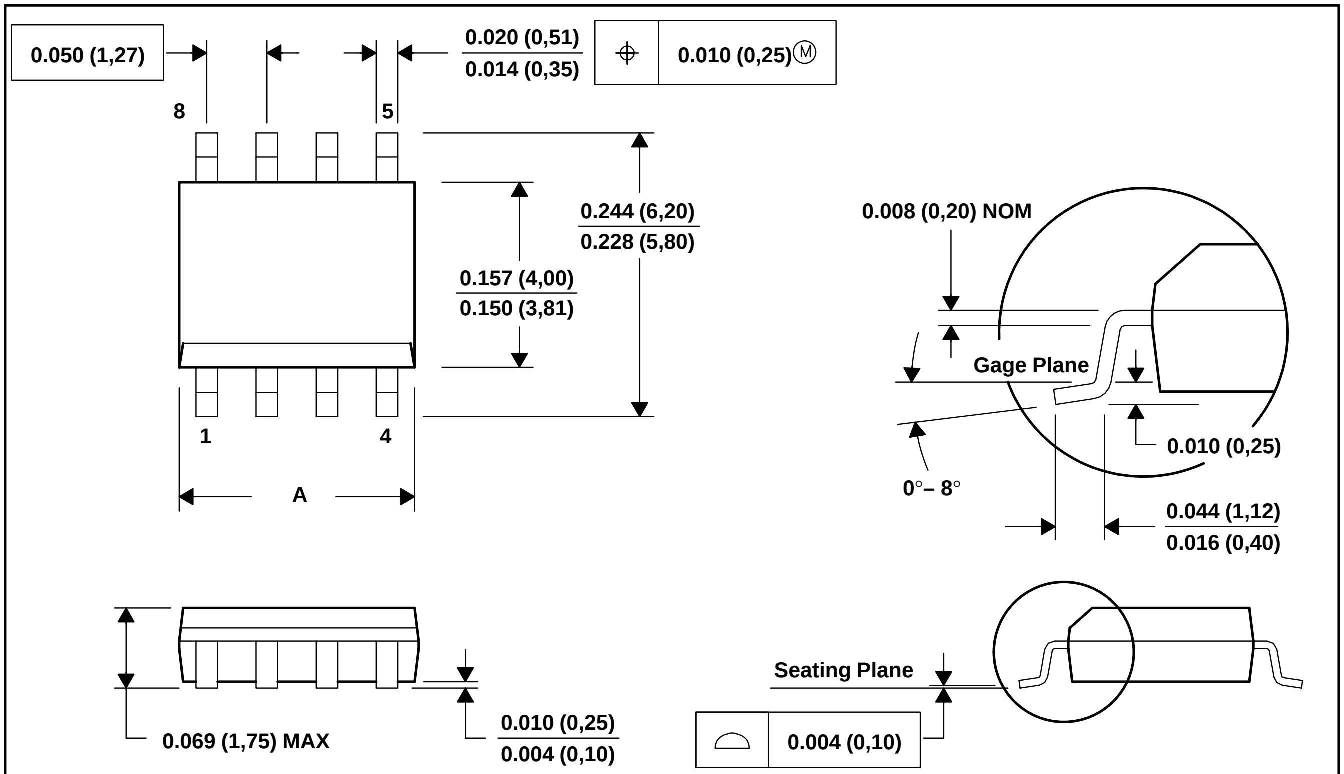
DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-100 VARIATION	AA	BB	AC	AD



NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001, except 18 and 20 pin minimum body lrngth (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN



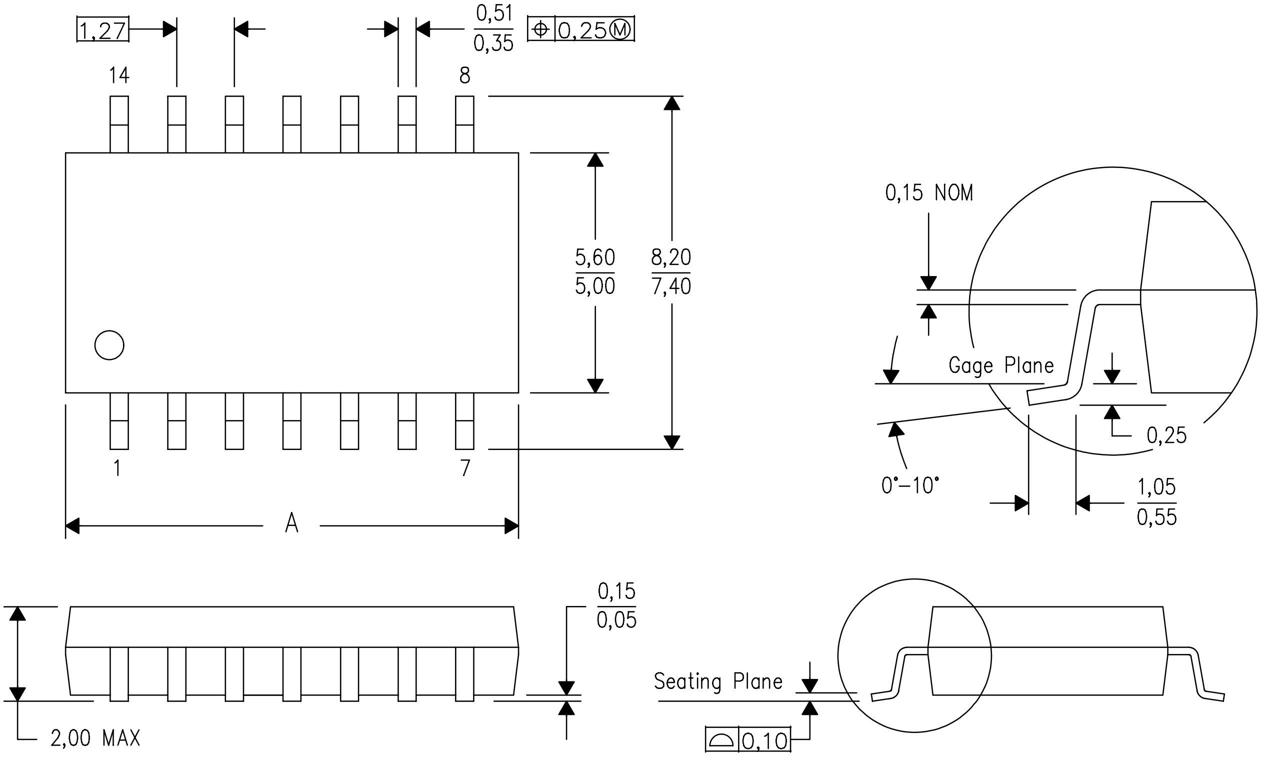
DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
- D. Falls within JEDEC MS-012

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



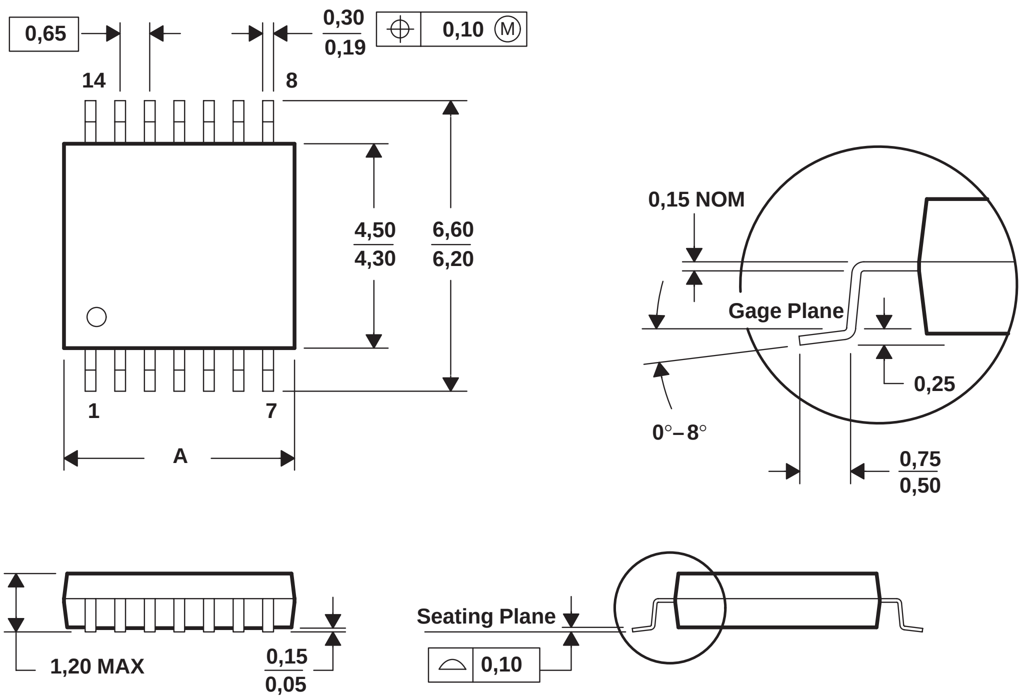
PINS ** / DIM	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

8. 564-0700-111F: 3mm LED CBI Tri-Level Circuit Board Indicator

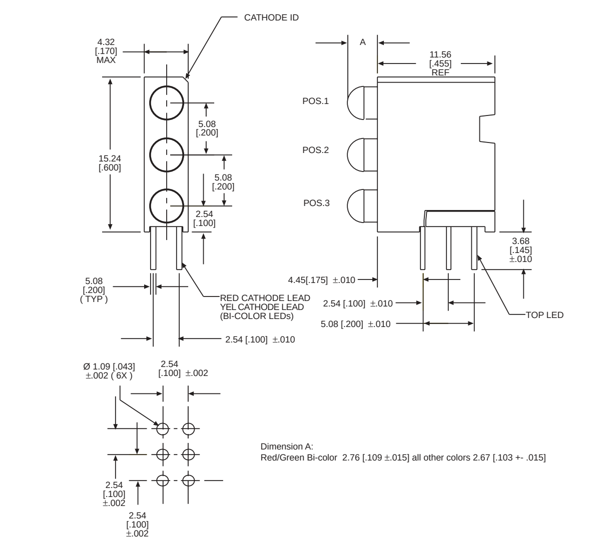
Dialight

3mm LED CBI Tri-Level
Circuit Board Indicator
564-0700-111F

3mm
LED CBI® Circuit Board Indicator
Tri-Level

Dialight

564-0x00-xxx



Dimensions in mm [inches]

PART NO.	COLOR*
HIGH EFFICIENCY - LED TYPE 01	
564-0100-111	Red-Red-Red
564-0100-132	Red-Yellow-Green
564-0100-222	Green-Green-Green
564-0100-777	Orange-Orange-Orange
564-0100-999	Blue-Blue-Blue (NEW)
LOW CURRENT - LED TYPE 02	
564-0200-111	Red-Red-Red
564-0200-132	Red-Yellow-Green
564-0200-222	Green-Green-Green
INTEGRAL RESISTOR, 5 VOLTS - LED TYPE 03	
564-0300-111	Red-Red-Red
564-0300-132	Red-Yellow-Green
564-0300-222	Green-Green-Green
BI-COLOR - LED TYPE 07	
564-0700-111	Red/Green-Red/Green-Red/Green
564-0700-444	Yellow/Green-Yellow/Green-Yellow/Green

* Top-Middle-Bottom LED

4

Features

- Multiple CBIs form horizontal LED arrays on 4.45mm (0.175”) center-lines.
- High Contrast, UL 94 V-0 rated, black housing
- Oxygen index: 29%
- Polymer content: PBT, 0.078 g
- Housing stand-offs facilitate PCB cleaning
- Solderability per MIL-STD-202F, method 208F
- LEDs are safe for direct viewing per IEC 825-1, EN-60825-1

Tolerance note: As noted, otherwise:

- LED Protrusion: ±0.04 mm [±0.016]
- CBI Housing: ±0.02mm[±0.008]

Custom Combinations

- Contact factory for information on custom color combinations

PART NUMBER ORDERING CODE

Series — LED Type — Top LED Position

5 6 4	- 0 x	0 0	- x	x	x

Middle LED Position — Bottom LED Position

Color = 0) Blank 1) Red or Red/Green Bi-color 2) Green 3) Yellow 4) Yellow/Green Bi-color 7) Orange 8) Blue[3]

3

ATTENTION
OBSERVE PRECAUTIONS FOR HANDLING ELECTROSTATIC SENSITIVE DEVICES

9. HEF4521B: 24-Stage Frequency Divider and Oscillator

Philips Semiconductor

24-Stage Frequency Divider and Oscillator

HEF4521B

DATA SHEET

For a complete data sheet, please also download:

- The IC04 LOCMOS HE4000B Logic Family Specifications HEF, HEC
- The IC04 LOCMOS HE4000B Logic Package Outlines/Information HEF, HEC

HEF4521B
MSI
24-stage frequency divider and oscillator

Product specification
File under Integrated Circuits, IC04

January 1995

Philips
Semiconductors

PHILIPS

DESCRIPTION

The HEF4521B consists of a chain of 24 toggle flip-flops with an overriding asynchronous master reset input (MR), and an input circuit that allows three modes of operation. The single inverting stage (I_2/O_2) will function as a crystal oscillator, or in combination with I_1 as an RC oscillator, or as an input buffer for an external oscillator. Low-power operation as a crystal oscillator is enabled by connecting external resistors to pins 3 (V_{SS}') and 5 (V_{DD}').

Each flip-flop divides the frequency of the previous flip-flop by two, consequently the HEF4521B will count up to 2^{24} = 16777216. The counting advances on the HIGH to LOW transition of the clock (I_2). The outputs of the last seven stages are available for additional flexibility.

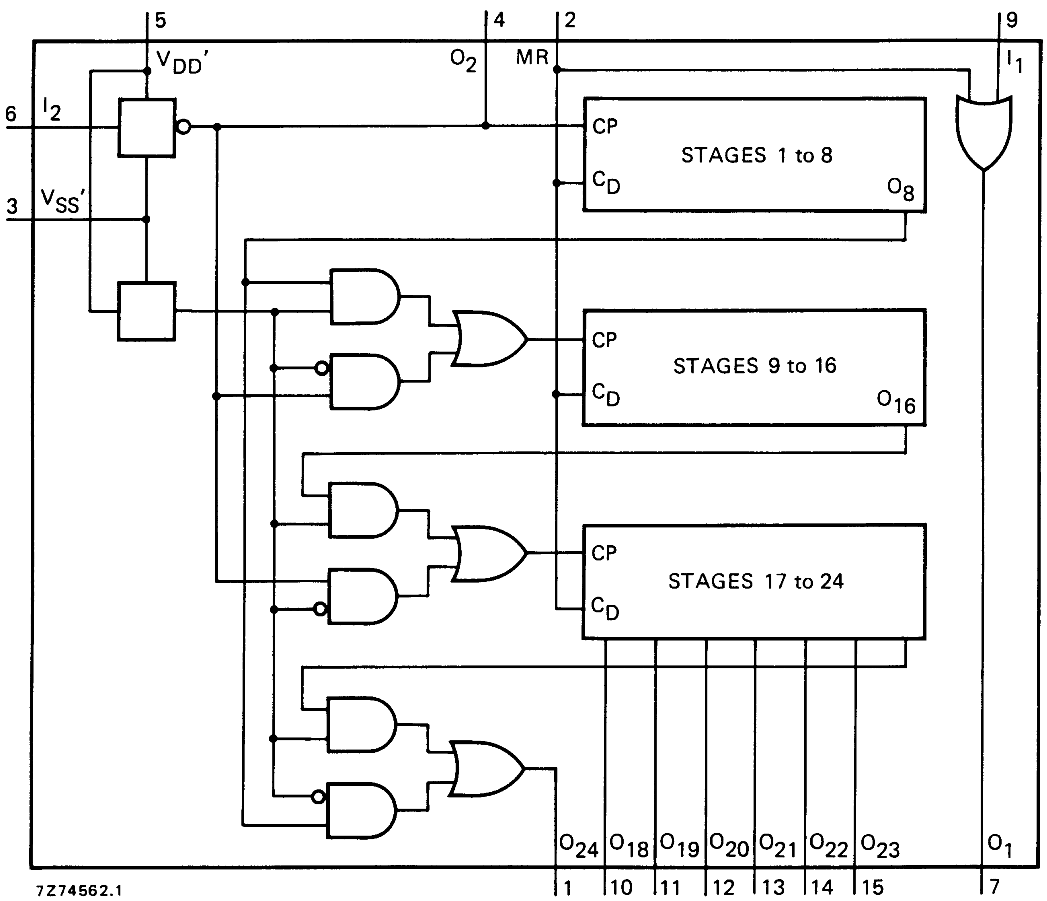


Fig.1 Functional diagram.

FAMILY DATA, I_{DD} LIMITS category MSI

See Family Specifications

24-stage frequency divider and oscillator

HEF4521B MSI

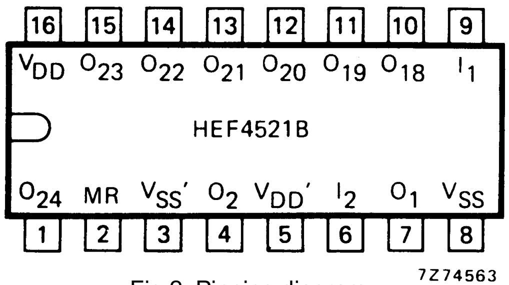


Fig.2 Pinning diagram.

COUNT CAPACITY

OUTPUT	COUNT CAPACITY
O_{18}	2^{18} = 262 144
O_{19}	2^{19} = 524 288
O_{20}	2^{20} = 1 048 576
O_{21}	2^{21} = 2 097 152
O_{22}	2^{22} = 4 194 304
O_{23}	2^{23} = 8 388 608
O_{24}	2^{24} = 16 777 216

HEF4521BP(N): 16-lead DIL; plastic (SOT38-1)
HEF4521BD(F): 16-lead DIL; ceramic (cerdip) (SOT74)
HEF4521BT(D): 16-lead SO; plastic (SOT109-1)
( ): Package Designator North America

FUNCTIONAL TEST SEQUENCE

INPUTS		CONTROL TERMINALS			OUTPUTS	REMARKS
MR	I_2	O_2	V_{SS}'	V_{DD}'	O_{18} to O_{24}	
H	L	L	V_{DD}	V_{SS}	L	counter is in three 8-stage sections in parallel mode; I_2 and O_2 are interconnected (O_2 is now input); counter is reset by MR
L	⎍	⎍	V_{DD}	V_{SS}	H	255 pulses are clocked into I_2, O_2 (the counter advances on the LOW to HIGH transition)
L	L	L	V_{SS}	V_{SS}	H	V_{SS}' is connected to V_{SS}
L	H	L	V_{SS}	V_{SS}	H	the input I_2 is made HIGH
L	H	L	V_{SS}	V_{DD}	H	V_{DD}' is connected to V_{DD}; O_2 is now made floating and becomes an output; the device is now in the 2^{24} mode
L	↓		V_{SS}	V_{DD}	L	counter ripples from an all HIGH state to an all LOW state

A test function has been included for the reduction of the test time required to exercise all 24 counter stages. This test function divides the counter into three 8-stage sections by connecting V_{SS}' to V_{DD} and V_{DD}' to V_{SS}. Via I_2 (connected to O_2) 255 counts are loaded into each of the 8-stage sections in parallel. All flip-flops are now at a HIGH state.

The counter is now returned to the normal 24-stage in series configuration by connecting V_{SS}' to V_{SS} and V_{DD}' to V_{DD}. One more pulse is entered into input I_2, which will cause the counter to ripple from an all HIGH state to an all LOW state.

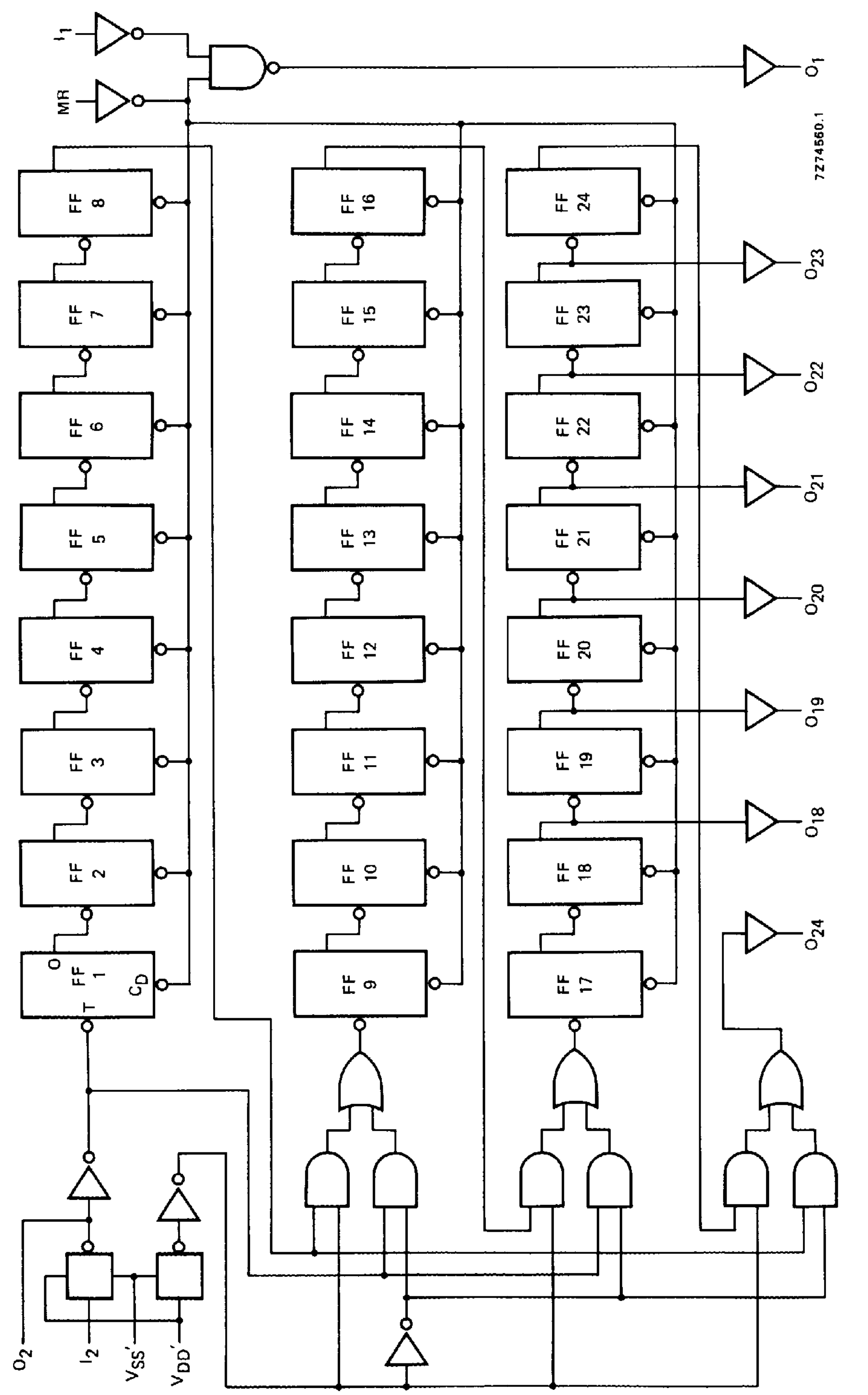


Fig.3 Logic diagram; for schematic diagram of clock circuit see Fig.4.

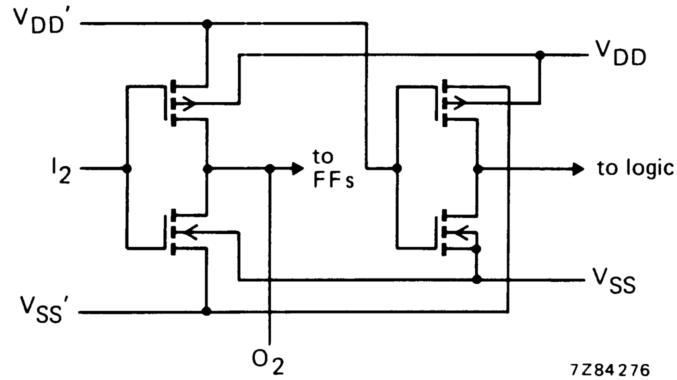


Fig.4 Schematic diagram of clock input circuitry.

AC CHARACTERISTICS

V_{SS} = 0 V; T_{amb} = 25 °C; C_L = 50 pF; input transition times ≤ 20 ns

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		TYPICAL EXTRAPOLATION FORMULA
Propagation delays							
$I_2 \rightarrow O_{18}$	5			950	1900	ns	923 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		350	700	ns	339 ns + (0,23 ns/pF) C_L
	15			220	440	ns	212 ns + (0,16 ns/pF) C_L
	5			950	1900	ns	923 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		350	700	ns	339 ns + (0,23 ns/pF) C_L
	15			220	440	ns	212 ns + (0,16 ns/pF) C_L
$O_n \rightarrow O_n + 1$	5			40	80	ns	13 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		15	30	ns	4 ns + (0,23 ns/pF) C_L
	15			10	20	ns	2 ns + (0,16 ns/pF) C_L
	5			40	80	ns	13 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		15	30	ns	4 ns + (0,23 ns/pF) C_L
	15			10	20	ns	2 ns + (0,16 ns/pF) C_L
$MR \rightarrow O_n$	5			120	240	ns	93 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		55	110	ns	44 ns + (0,23 ns/pF) C_L
	15			40	80	ns	32 ns + (0,16 ns/pF) C_L
$I_1 \rightarrow O_1$	5			90	180	ns	63 ns + (0,55 ns/pF) C_L
HIGH to LOW	10	t_{PHL}		35	70	ns	24 ns + (0,23 ns/pF) C_L
	15			25	50	ns	17 ns + (0,16 ns/pF) C_L
	5			60	120	ns	33 ns + (0,55 ns/pF) C_L
LOW to HIGH	10	t_{PLH}		30	60	ns	19 ns + (0,23 ns/pF) C_L
	15			20	40	ns	12 ns + (0,16 ns/pF) C_L

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		TYPICAL EXTRAPOLATION FORMULA
Output transition times	5			60	120	ns	10 ns + (1,0 ns/pF) C_L
HIGH to LOW	10	t_{THL}		30	60	ns	9 ns + (0,42 ns/pF) C_L
	15			20	40	ns	6 ns + (0,28 ns/pF) C_L
	5			60	120	ns	10 ns + (1,0 ns/pF) C_L
LOW to HIGH	10	t_{TLH}		30	60	ns	9 ns + (0,42 ns/pF) C_L
	15			20	40	ns	6 ns + (0,28 ns/pF) C_L

AC CHARACTERISTICS

V_{SS} = 0 V; T_{amb} = 25 °C; C_L = 50 pF; input transition times ≤ 20 ns

	V_{DD} V	SYMBOL	MIN.	TYP.	MAX.		
Minimum I_2 pulse	5		80	40		ns	
width; HIGH	10	t_{WI2H}	40	20		ns	
	15		30	15		ns	
Minimum MR	5		70	35		ns	see also waveforms Fig.5
pulse width; HIGH	10	t_{WMRH}	40	20		ns	
	15		30	15		ns	
Recovery time	5		20	–10		ns	
for MR	10	t_{RMR}	15	–5		ns	
	15		15	0		ns	
Maximum clock	5		6	12		MHz	
pulse frequency	10	f_{max}	12	25		MHz	
	15		17	35		MHz	

	V_{DD} V	TYPICAL FORMULA FOR P (μW)	
Dynamic power	5	$1\,200\ f_i + \sum (f_oC_L) \times V_{DD}^2$	where
dissipation per	10	$5\,100\ f_i + \sum (f_oC_L) \times V_{DD}^2$	f_i = input freq. (MHz)
package (P)	15	$13\,050\ f_i + \sum (f_oC_L) \times V_{DD}^2$	f_o = output freq. (MHz)
			C_L = load capacitance (pF)
			$\sum (f_oC_L)$ = sum of outputs
			V_{DD} = supply voltage (V)

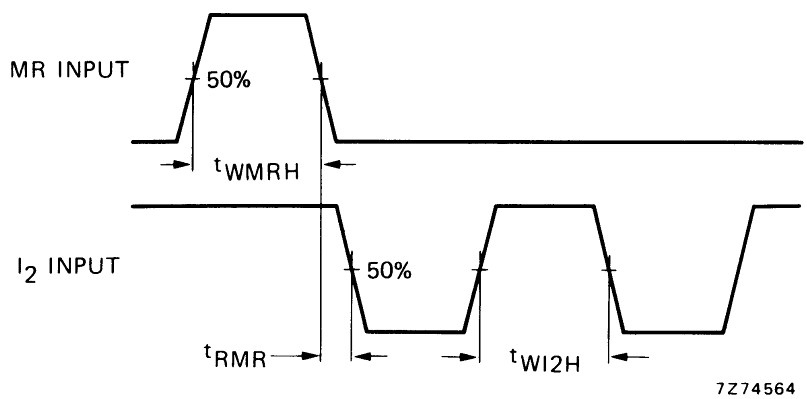
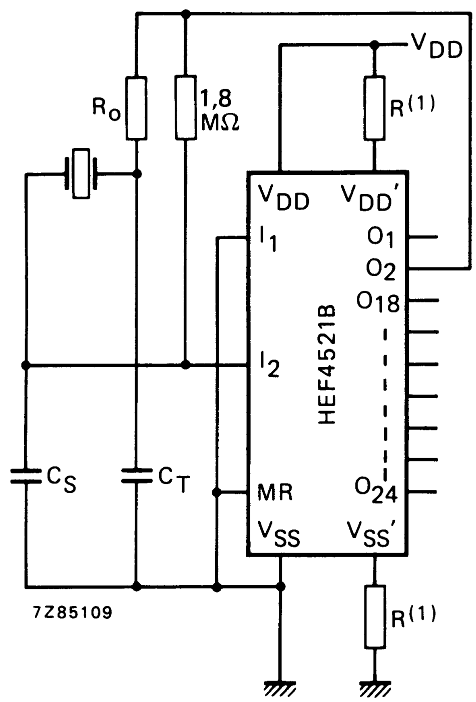


Fig.5 Waveforms showing minimum pulse widths for MR and I_2, recovery time for MR.

APPLICATION INFORMATION



(1) Optional for low power operation.

Fig.6 Crystal oscillator circuit.

Typical characteristics for crystal oscillator circuit (Fig.6):

	500 kHz CIRCUIT	50 kHz CIRCUIT	UNIT
Crystal characteristics			
resonance frequency	500	50	kHz
crystal cut	S	N	–
equivalent resistance; R_S	1	6,2	kΩ
External resistor/capacitor values			
R_o	47	750	kΩ
C_T	82	82	pF
C_S	20	20	pF

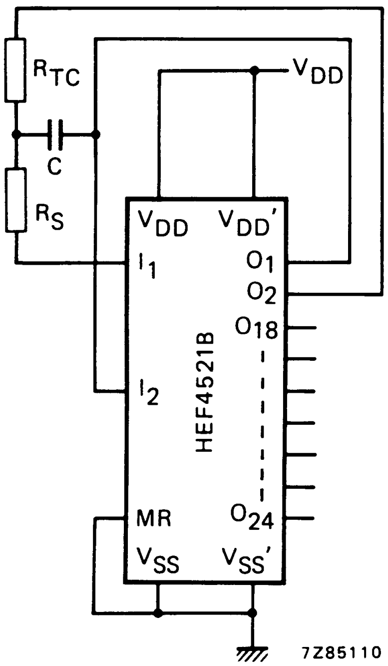


Fig.7 RC oscillator circuit;

$f \approx \frac{1}{2{,}3 \times R_{TC} \times C}$; $R_S \geq 2\ R_{TC}$, in which:

f in Hz, R in Ω, C in F.

$R_S + R_{TC} < \frac{V_{IL\ max}}{I_{LI}}$ (maximum input voltage LOW) (input leakage current)

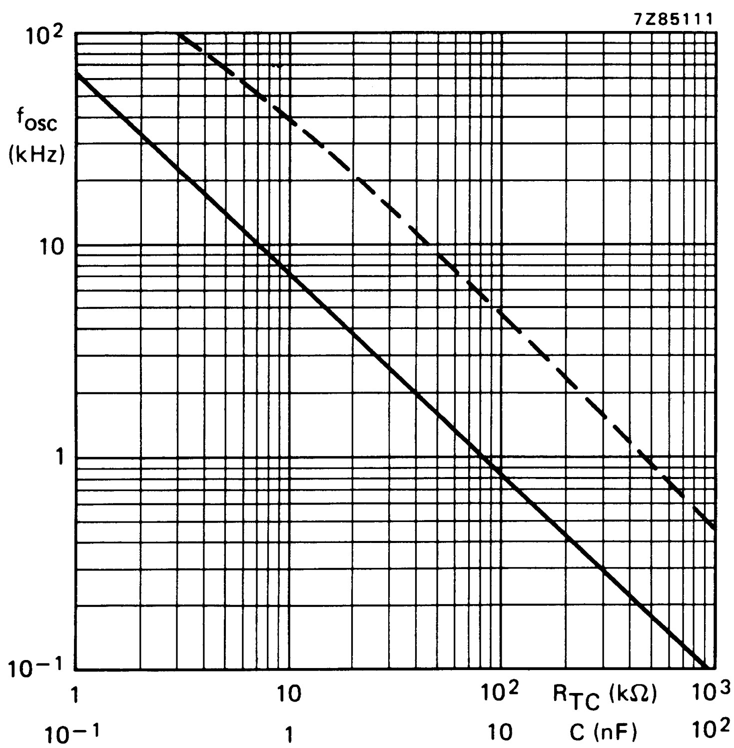


Fig.8 Oscillator frequency as a function of R_{TC} and C; V_{DD} = 10 V; test circuit is Fig.7.

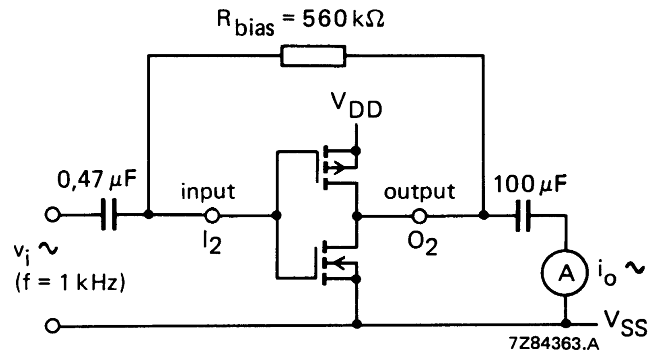
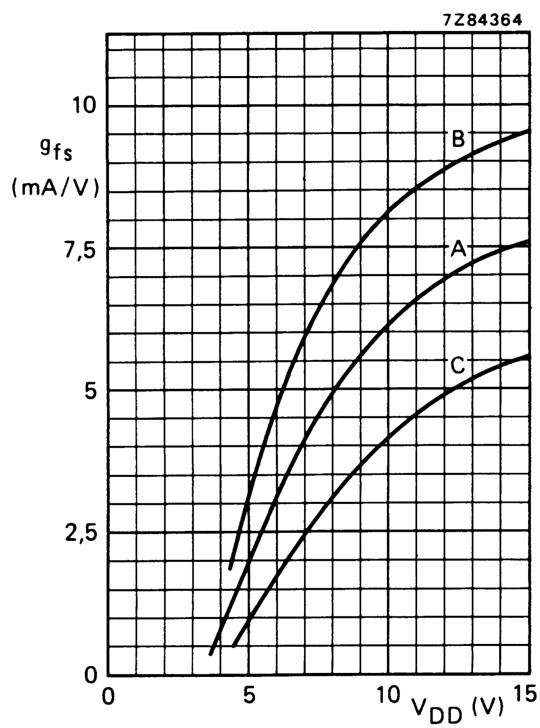


Fig.9 Test set-up for measuring forward transconductance $g_{fs} = di_o/d_{vi}$ at v_o is constant (see also graph Fig.10).



A: average,
B: average + 2 s,
C: average – 2 s, in which: ‘s’ is the observed standard deviation.

Fig.10 Typical forward transconductance g_{fs} as a function of the supply voltage at T_{amb} = 25 °C.

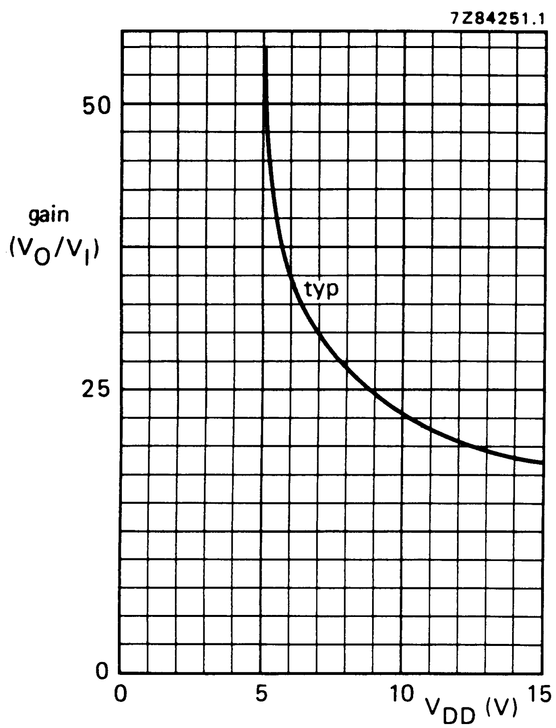


Fig.11 Voltage gain V_O/V_I as a function of supply voltage.

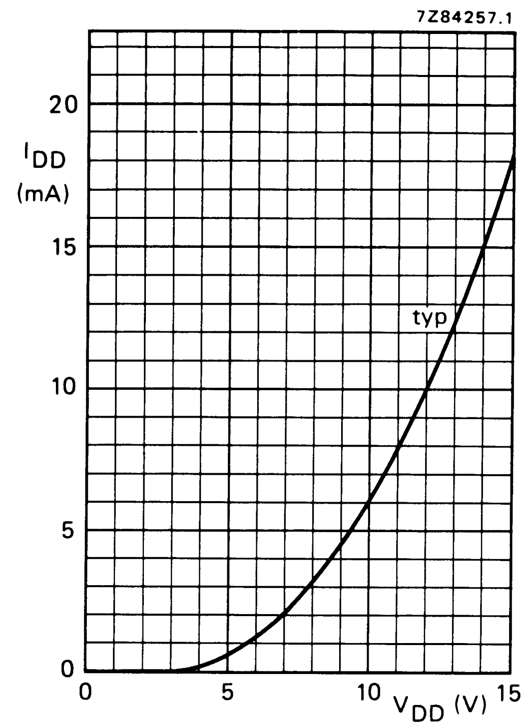


Fig.12 Supply current as a function of supply voltage.

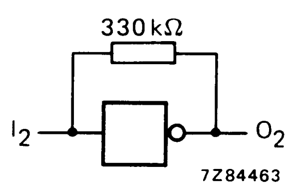


Fig.13 Test set-up for measuring graphs of Figs 11 and 12.

10. 179-009-513R571: Center Dual Port D-SUB Female/Female

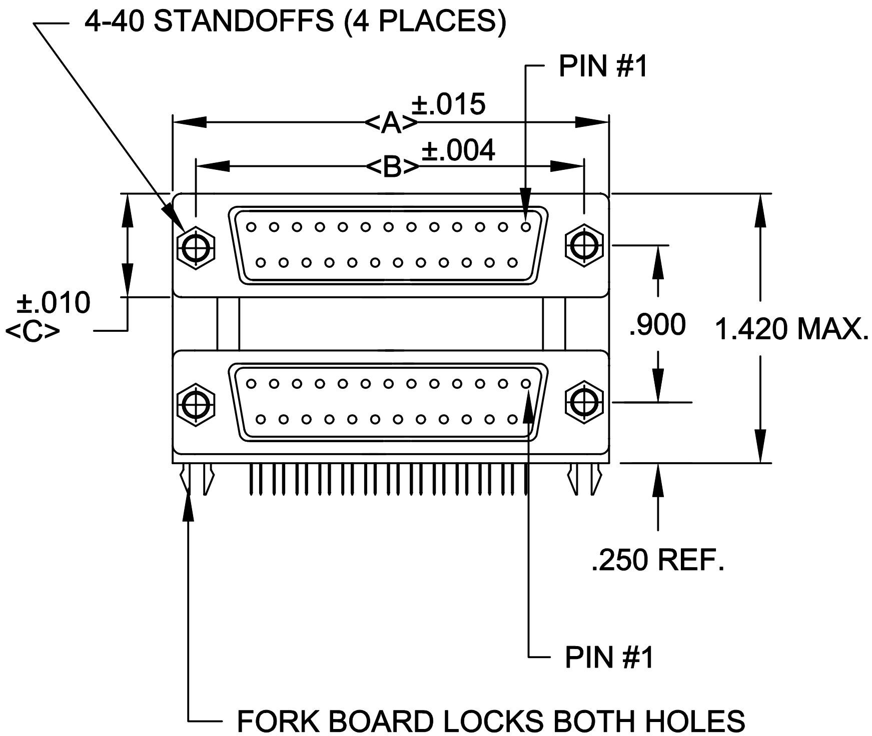
NorComp

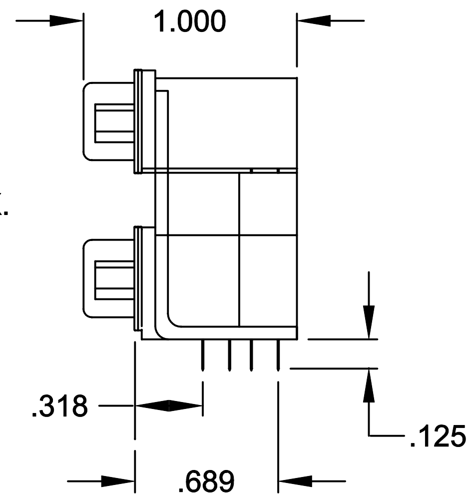
Center Dual Port D-SUB

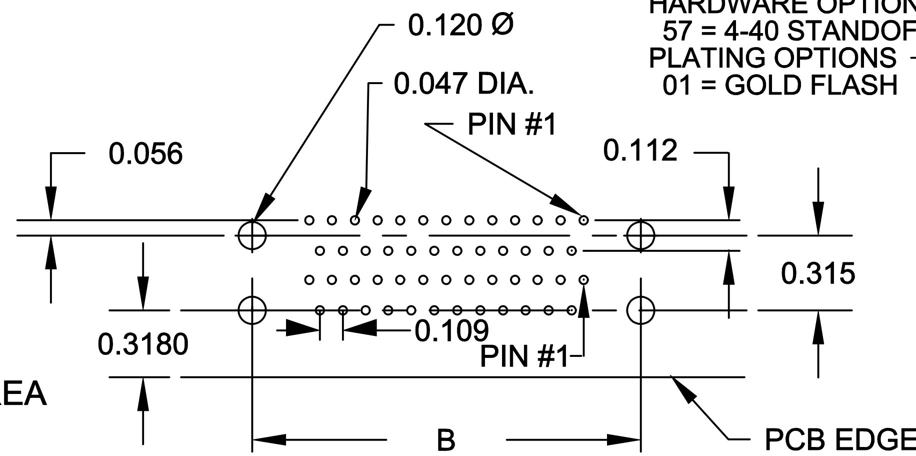
Female/Female

179-009-513R571

DESCRIPTION: .900 CENTER DUAL PORT D-SUB FEMALE/FEMALE







		A	B	C
9		1.204	.984	.494
		30.6	25.0	12.55
15		1.535	1.312	.494
		39.0	33.3	12.55
25		2.078	1.850	.494
		52.8	47.0	12.55
37		2.724	2.500	.494
		69.2	63.5	12.55

179-XXX-513R571

SERIES
POSITIONS
009
015
025
037
GENDER
61 = MALE OVER MALE
41 = MALE OVER FEMALE
51 = FEMALE OVER FEMALE
31 = FEMALE OVER MALE
SHELL PLATING
3 = NICKEL
HARDWARE OPTIONS
57 = 4-40 STANDOFFS/BOARD LOCKS
PLATING OPTIONS
01 = GOLD FLASH

SPECIFICATIONS:

MATERIALS:
- SHELL: STEEL, NICKEL PLATED
- INSULATOR: NYLON - UL 94V-0 RATED BLACK
- CONTACTS: BRASS - GOLD FLASH IN MATING AREA
  TIN ON SOLDER TAILS
- RoHS COMPLIANT

ELECTRICALS:
- CURRENT RATING: 5 AMPS
- DIELECTRIC STRENGTH: 1000V AC RMS
- INSULTOR RESISTANCE: 1000 MOHMS MIN
- TEMPERATURE: -55°C TO +105°C

NorComp

DRAWN: PAM JENKINS
DATE: 4-28-05
CHECKED:
DATE:
SCALE: 1:1
SHEET 1 OF 1
REV 1
DWG NO. 179-XXX-513R571

11. LTC1441/SO: Ultra Low Power Dual Comparator with Reference

Linear Technology

Ultra Low Power Dual Comparator
with Reference

LTC1441/SO

Ultralow Power Single/Dual Comparator with Reference

FEATURES

- **Ultralow Quiescent Current: 2.1µA Typ (LTC1440)**
- **Reference Output Drives 0.01µF Capacitor**
- **Adjustable Hysteresis (LTC1440/LTC1442)**
- Wide Supply Range:
  - Single: 2V to 11V
  - Dual: ±1V to ±5.5V
- Input Voltage Range Includes the Negative Supply
- TTL/CMOS Compatible Outputs
- 12µs Propagation Delay with 10mV Overdrive
- No Crowbar Current
- 40mA Continuous Source Current
- Pin Compatible Upgrades for MAX921/922/923
- 3mm x 3mm x 0.75mm DFN Package (LTC1440)

APPLICATIONS

- Battery-Powered System Monitoring
- Threshold Detectors
- Window Comparators
- Oscillator Circuits

DESCRIPTION

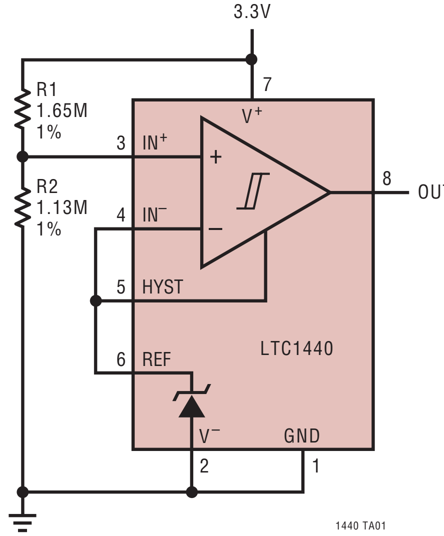
The LTC®1440/LTC1441/LTC1442 are ultralow power single and dual comparators with built-in references. The comparators feature less than 3.7µA supply current over temperature (LTC1440), a 1.182V ±1% reference, programmable hysteresis (LTC1440/LTC1442) and TTL/CMOS outputs that sink and source current. The reference output can drive a bypass capacitor of up to 0.01µF without oscillation.

The comparators operate from a single 2V to 11V supply or a dual ±1V to ±5.5V supply (LTC1440). Comparator hysteresis is easily programmed by using two resistors and the HYST pin (LTC1440/LTC1442). Each comparator's input operates from the negative supply to within 1.3V of the positive supply. The comparator output stage can continuously source up to 40mA. By eliminating the cross-conducting current that normally happens when the comparator changes logic states, the power supply glitches are eliminated.

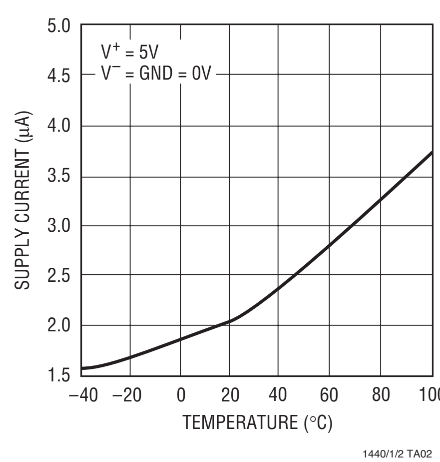
The LTC1440 is available in 8-pin PDIP, SO, MSOP and DFN packages. The LTC1441/LTC1442 are available in 8-pin PDIP and SO packages.

TYPICAL APPLICATION

Micropower 2.9V V_{CC} Threshold Detector



LTC1440 Supply Current vs Temperature



ABSOLUTE MAXIMUM RATINGS

(Note 1)

Voltage
- V^+ to V^-, V^+ to GND, GND to V^- .... 12V to –0.3V
- IN^+, IN^-, HYST .... (V^+ + 0.3V) to (V^- – 0.3V)
- REF .... (V^+ + 0.3V) to (V^- – 0.3V)
- OUT (LTC1440) .... (V^+ + 0.3V) to (GND – 0.3V)
- OUT (LTC1441/LTC1442) ... (V^+ + 0.3V) to (V^- – 0.3V)

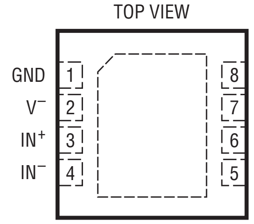
Current
- IN^+, IN^-, HYST 20mA
- REF 20mA
- OUT 50mA

OUT Short-Circuit Duration ($V^+ \le 5.5V$) .... Continuous
Power Dissipation 500mW
Operating Temperature Range
- LTC144XC .... 0°C to 70°C
- LTC144XI .... –40°C to 85°C

Storage Temperature Range .... –65°C to 150°C
Storage Temperature Range
- (DD Package) .... –65°C to 125°C

Junction Temperature .... 150°C
Junction Temperature (DD Package) .... 125°C
Lead Temperature (Soldering, 10 sec) .... 300°C

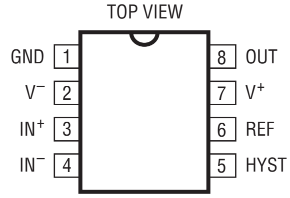
PACKAGE/ORDER INFORMATION



DD PACKAGE
8-LEAD (3mm × 3mm) PLASTIC DFN

T_{JMAX} = 125°C, θ_{JA} = 160°C/W (DD)
UNDERSIDE METAL CONNECTED TO V–
(PCB CONNECTION OPTIONAL)

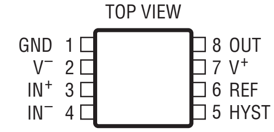
ORDER PART NUMBER	DD8 PART MARKING*
LTC1440CDD LTC1440IDD	LBTH



N8 PACKAGE 8-LEAD PDIP   S8 PACKAGE 8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N8)
T_{JMAX} = 150°C, θ_{JA} = 175°C/W (S8)

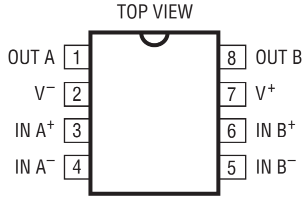
ORDER PART NUMBER	S8 PART MARKING
LTC1440CN8	1440
LTC1440CS8	1440
LTC1440IN8	1440I
LTC1440IS8	1440I



MS8 PACKAGE
8-LEAD PLASTIC MSOP

T_{JMAX} = 150°C, θ_{JA} = 250°C/W

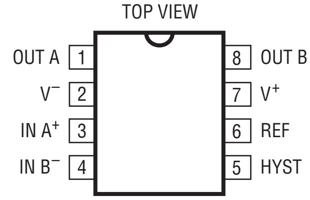
ORDER PART NUMBER	MS8 PART MARKING*
LTC1440CMS8 LTC1440IMS8	LTBX



N8 PACKAGE 8-LEAD PDIP   S8 PACKAGE 8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N8)
T_{JMAX} = 150°C, θ_{JA} = 175°C/W (S8)

ORDER PART NUMBER
LTC1441CN8
LTC1441CS8
LTC1441IN8
LTC1441IS8
S8 PART MARKING
1441
1441I



N8 PACKAGE 8-LEAD PDIP   S8 PACKAGE 8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N8)
T_{JMAX} = 150°C, θ_{JA} = 175°C/W (S8)

ORDER PART NUMBER
LTC1442CN8
LTC1442CS8
LTC1442IN8
LTC1442IS8
S8 PART MARKING
1442
1442I

Order Options Tape and Reel: Add #TR
Lead Free: Add #PBF   Lead Free Tape and Reel: Add #TRPBF   Lead Free Part Marking: http://www.linear.com/leadfree/

Consult LTC Marketing for parts specified with wider operating temperature ranges.
* The temperature grade is identified by a label on the shipping container.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V^+ = 5V and V^- = GND = 0V unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
Power Supply								
V^+	Supply Voltage Range			●	2.0		11.0	V
I_{CC}	Supply Current	$IN^+ = IN^- + 80mV$ HYST = REF (LTC1440/LTC1442)	LTC1440 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	● ●		2.1	4.0 4.4	µA µA
			LTC1441 LTC1442	● ●		3.5 3.5	5.7 5.7	µA µA
Comparator								
V_{OS}	Comparator Input Offset Voltage	V_{CM} = 2.5V		●		±3	±10	mV
I_{IN}	Input Leakage Current (IN^+, IN^-) Input Leakage Current (HYST)	$V_{IN}^+ = V_{IN}^-$ = 2.5V		● ●		±0.01 ±0.02	±1.0 ±1.0	nA nA
V_{CM}	Comparator Input Common Mode Range			●	V^-		V^+ – 1.3V	V
CMRR	Common Mode Rejection Ratio	V^- to V^+ – 1.3V				0.1	1	mV/V
PSRR	Power Supply Rejection Ratio	V^+ = 2V to 11V (LTC1441) V^+ = 2.5V to 11V (LTC1440/LTC1442)				0.1 0.1	1 1	mV/V mV/V
NOISE	Voltage Noise	100Hz to 100kHz				100		μV_{RMS}
V_{HYST}	Hysteresis Input Voltage Range	LTC1440/LTC1442		●	REF – 50mV		REF	V
t_{PD}	Propagation Delay	C_{OUT} = 100pF	Overdrive = 10mV Overdrive = 100mV			15 8		µs µs
V_{OH}	Output High Voltage	I_O = –13mA		●	V^+ – 0.4V			V
V_{OL}	Output Low Voltage	I_O = 1.8mA	LTC1440 LTC1441/LTC1442	● ●			GND + 0.4V V^- + 0.4V	V V
Reference								
V_{REF}	Reference Voltage	No Load	LTC1440/LTC1442 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	● ●	1.170 1.164		1.194 1.200	V V
			LTC1440 (MSOP, DFN)	●	1.164		1.200	V
I_{SOURCE}	Reference Output Source Current	ΔV_{REF} ≤ 1mV (LTC1442)		●	100			µA
I_{SINK}	Reference Output Sink Current	ΔV_{REF} ≤ 2.5mV (LTC1442)			10	20		µA
ΔV_{REF}	Reference Source Current	0 ≤ I_{SOURCE} ≤ 2mA (LTC1440)		●		0.8	5	mV
	Reference Sink Current	0 ≤ I_{SINK} ≤ 10µA (LTC1440)		 ●		0.5	1.5 5	mV mV
NOISE	Voltage Noise	100Hz to 100kHz				100		μV_{RMS}

ELECTRICAL CHARACTERISTICS

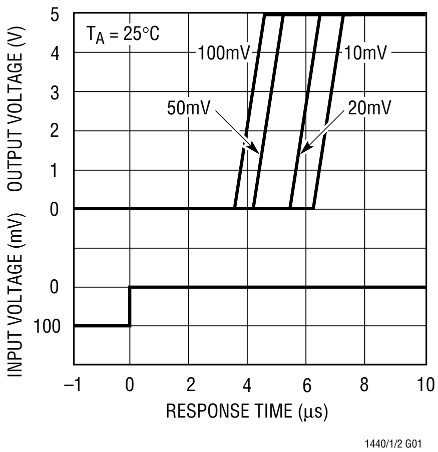
The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V^+ = 3V and V^- = GND = 0V unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
Power Supply								
V^+	Supply Voltage Range			●	2		11	V
I_{CC}	Supply Current	$IN^+ = IN^- + 80mV$ HYST = REF (LTC1440/LTC1442)	LTC1440 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	● ●		2	3.9 4.3	µA µA
			LTC1441 LTC1442	● ●		3.5 3.5	5.7 5.7	µA µA
Comparator								
V_{OS}	Comparator Input Offset Voltage	V_{CM} = 1.5V		●		±3	±10	mV
I_{IN}	Input Leakage Current (IN^+, IN^-) Input Leakage Current (HYST)	$V_{IN}^+ = V_{IN}^-$ = 1.5V		● ●		±0.01 ±0.02	±1 ±1	nA nA
V_{CM}	Comparator Input Common Mode Range			●	V^-		V^+ – 1.3V	V
CMRR	Common Mode Rejection Ratio	V^- to V^+ – 1.3V				0.1	1	mV/V
PSRR	Power Supply Rejection Ratio	V^+ = 2V to 11V (LTC1441) V^+ = 2.5V to 11V (LTC1440/LTC1442)				0.1 0.1	1 1	mV/V mV/V
NOISE	Voltage Noise	100Hz to 100kHz				100		μV_{RMS}
V_{HYST}	Hysteresis Input Voltage Range	LTC1440/LTC1442		●	REF – 50mV		REF	V
t_{PD}	Propagation Delay	C_{OUT} = 100pF	Overdrive = 10mV Overdrive = 100mV			14 5		µs µs
V_{OH}	Output High Voltage	I_O = –8mA		●	V^+ – 0.4V			V
Comparator								
V_{OL}	Output Low Voltage	I_O = 0.8mA	LTC1440 LTC1441/LTC1442	● ●			GND + 0.4V V^- + 0.4V	V V
Reference								
V_{REF}	Reference Voltage	No Load	LTC1440/LTC1442 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	 ● ●	 1.170 1.164	 1.182	 1.194 1.200	 V V
			LTC1440 (MSOP, DFN)	●	1.164		1.200	V
I_{SOURCE}	Reference Output Source Current	ΔV_{REF} ≤ 1mV (LTC1442)		●	60	120		µA
I_{SINK}	Reference Output Sink Current	ΔV_{REF} ≤ 2.5mV (LTC1442)			10	20		µA
ΔV_{REF}	Reference Source Current	0 ≤ I_{SOURCE} ≤ 1mA (LTC1440)		●		0.8	5.5	mV
	Reference Sink Current	0 ≤ I_{SINK} ≤ 10µA (LTC1440)		 ●		0.5	1.5 5	mV mV
NOISE	Voltage Noise	100Hz to 100kHz				100		μV_{RMS}

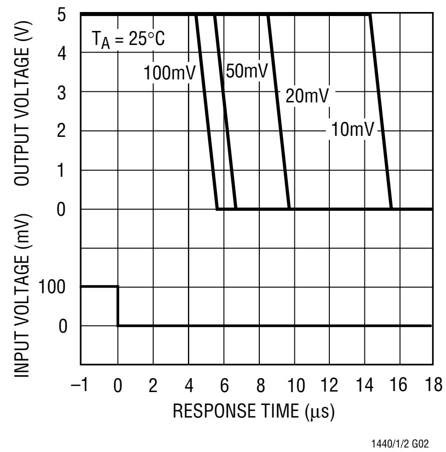
Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

TYPICAL PERFORMANCE CHARACTERISTICS

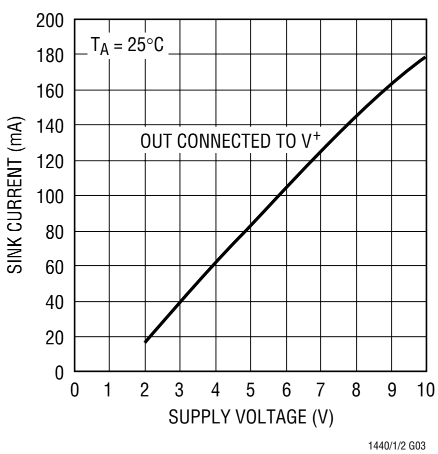
Comparator Response Time vs Input Overdrive



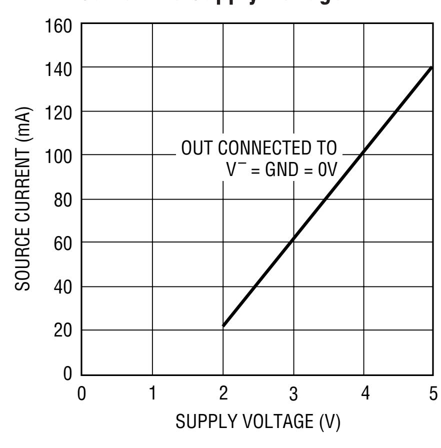
Comparator Response Time vs Input Overdrive



Comparator Short-Circuit Sink Current vs Supply Voltage

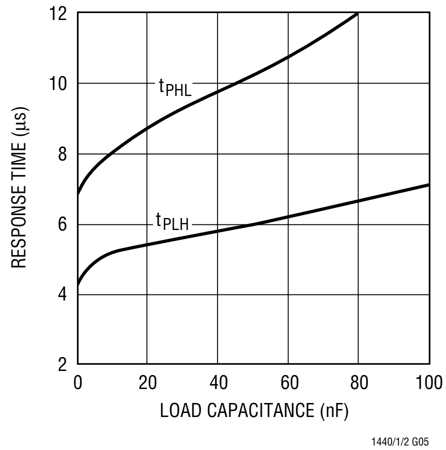


Comparator Short-Circuit Source Current vs Supply Voltage

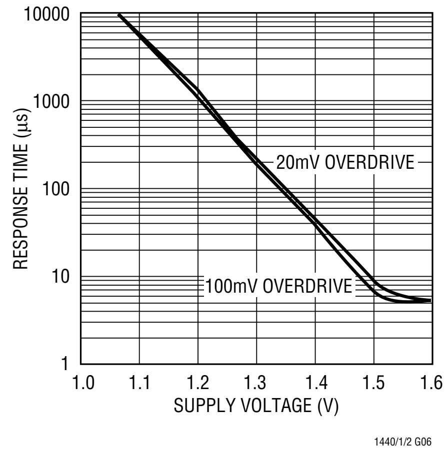


TYPICAL PERFORMANCE CHARACTERISTICS

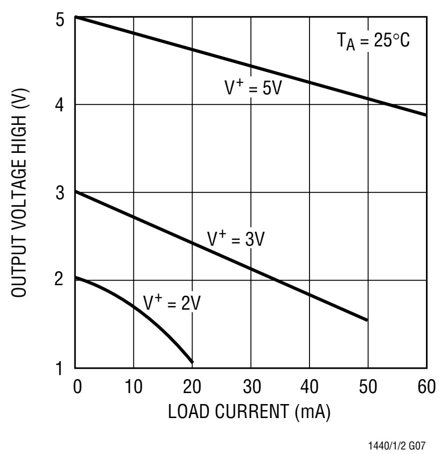
Comparator Response Time vs Load Capacitance with 100mV Input Overdrive



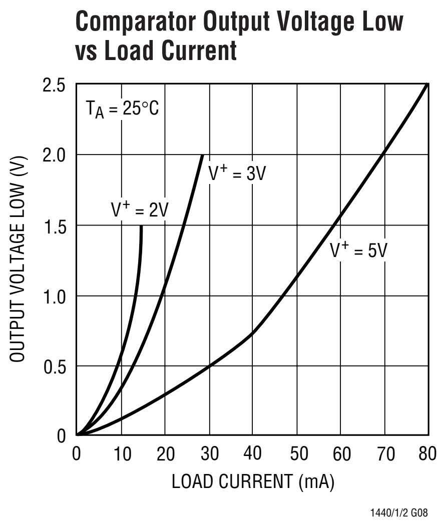
Comparator Response Time at Low Supply Voltage

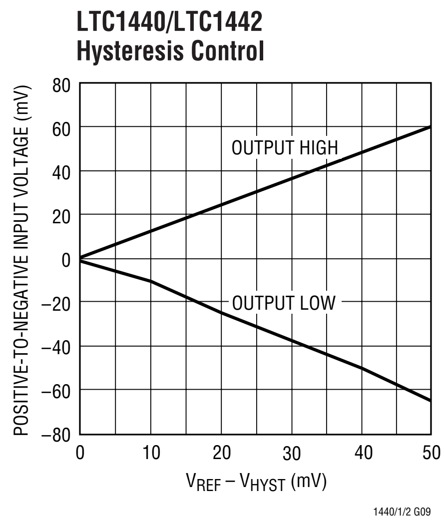


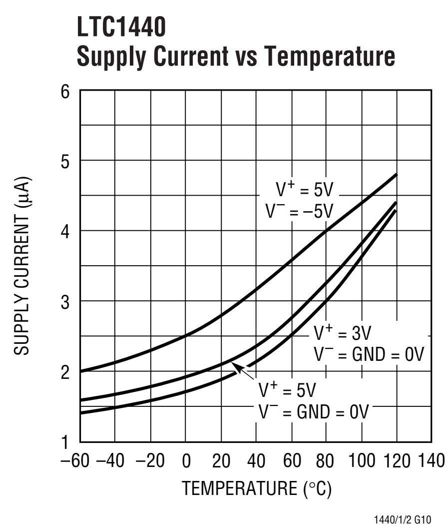
Comparator Output Voltage High vs Load Current



TYPICAL PERFORMANCE CHARACTERISTICS

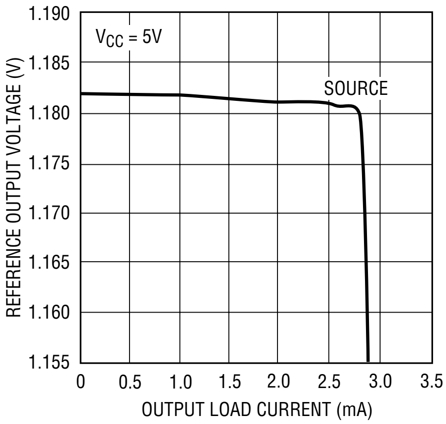




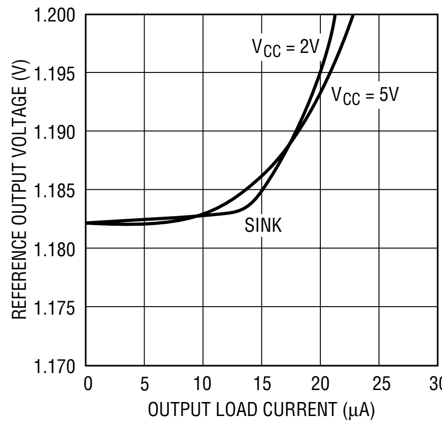


TYPICAL PERFORMANCE CHARACTERISTICS

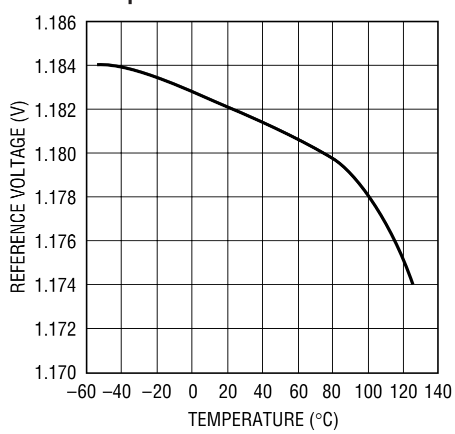
Reference Output Voltage vs Output Load Current



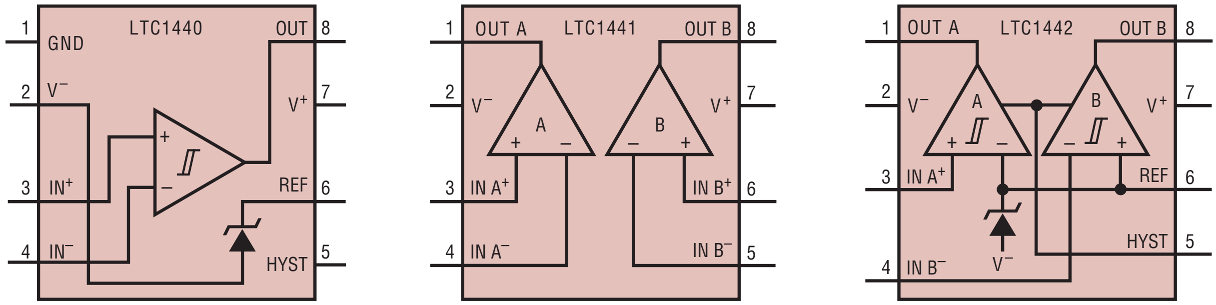
Reference Output Voltage vs Output Load Current (Sink)



Reference Voltage vs Temperature



PIN FUNCTIONS



1440/1/2 PD

LTC1440

GND (Pin 1): Ground. Connect to V^- for single supply operation.

V^- (Pin 2): Negative Supply. Connect to ground for single supply operation. Potential should be more negative than GND.

IN^+ (Pin 3): Noninverting Comparator Input. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

IN^- (Pin 4): Inverting Comparator Input. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

HYST (Pin 5): Hysteresis Input. Connect to REF if not used. Input voltage range is from V_{REF} to V_{REF} – 50mV.

REF (Pin 6): Reference Output. 1.182V with respect to V^-. Can source up to 200μA and sink 15μA at 25°C. Drive 0.01μF bypass capacitor without oscillation.

V^+ (Pin 7): Positive Supply. 2V to 11V.

OUT (Pin 8): Comparator CMOS Output. Swings from GND to V^+. Output can source up to 40mA and sink 5mA.

LTC1441

OUT A (Pin 1): Comparator A CMOS Output. Swings from V^- to V^+. Output can source up to 40mA and sink 5mA.

V^- (Pin 2): Negative Supply.

IN A^+ (Pin 3): Noninverting Input of Comparator A. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

IN A^- (Pin 4): Inverting Input of Comparator A. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

IN B^- (Pin 5): Inverting Input of Comparator B. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

IN B^+ (Pin 6): Noninverting Input of Comparator B. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

V^+ (Pin 7): Positive Supply. 2V to 11V.

OUT B (Pin 8): Comparator B CMOS Output. Swings from V^- to V^+. Output can source up to 40mA and sink 5mA.

LTC1442

OUT A (Pin 1): Comparator A CMOS Output. Swings from V^- to V^+. Output can source up to 40mA and sink 5mA.

V^- (Pin 2): Negative Supply.

IN A^+ (Pin 3): Noninverting Input of Comparator A. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

IN B^- (Pin 4): Inverting Input of Comparator B. Input common mode range from V^- to V^+ –1.3V. Input current typically 10pA at 25°C.

HYST (Pin 5): Hysteresis Input. Connect to REF if not used. Input voltage range is from V_{REF} to V_{REF} – 50mV.

REF (Pin 6): Reference Output. 1.182V with respect to V^-. Can source up to 200μA and sink 15μA at 25°C. Drive 0.01μF bypass capacitor without oscillation.

V^+ (Pin 7): Positive Supply. 2V to 11V.

OUT B (Pin 8): Comparator B CMOS Output. Swings from V^- to V^+. Output can source up to 40mA and sink 5mA.

APPLICATIONS INFORMATION

LTC1440/LTC1441/LTC1442 are a family of micropower comparators with built-in 1.182V reference. Features include programmable hysteresis (LTC1440/LTC1442), wide supply voltage range (2V to 11V) and the ability of the reference to drive up to a 0.01μF capacitor without oscillation. The comparators' CMOS outputs can source up to 40mA and the supply current glitches, that normally occur when switching logic states, have been eliminated.

Power Supplies

The comparator family operates from a single 2V to 11V supply. The LTC1440 includes a separate ground for the comparator output stage, allowing a split supply ranging from ±1V to ±5.5V. Connecting V^- to GND on the LTC1440 will allow single supply operation. If the comparator output is required to source more than 1mA, or the supply source impedance is high, V^+ should be bypassed with a 0.1μF capacitor.

Comparator Inputs

The comparator inputs can swing from the negative supply V^- to within 1.3V max of the positive supply V^+. The inputs can be forced 300mV below V^- or above V^+ without damage and the typical input leakage current is only ±10pA.

Comparator Outputs

The LTC1440 comparator output swings between GND and V^+ to assure TTL compatibility with a split supply. The LTC1441 and LTC1442 outputs swing between V^- and V^+. The outputs are capable of sourcing up to 40mA and sinking up to 5mA while still maintaining microampere quiescent currents. The output stage does not generate crowbar switching currents during transitions which helps minimize parasitic feedback through the supply pins.

Voltage Reference

The internal bandgap reference has a voltage of 1.182V referenced to V^-. The reference accuracy is 1.5% from –40°C to 85°C. It can source up to 200μA and sink up to 20μA with a 5V supply. The reference can drive a bypass capacitor of up to 0.01μF without oscillation and by inserting a series resistor, capacitance values up to 100μF can be used (Figure 1).

Figure 2 shows the resistor value required for different capacitor values to achieve critical damping. Bypassing the reference can help prevent false tripping of the comparators by preventing glitches on V^+ or reference load transients from disturbing the reference output voltage.

Figure 3 shows the bypassed reference output with a square wave applied to the V^+ pin. Resistors R2 and R3 set 10mV of hysteresis voltage band while R1 damps the reference response. Note that the comparator output doesn't trip.

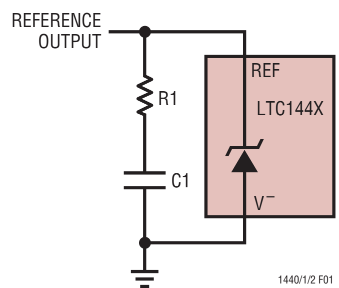


Figure 1. Damping the Reference Output

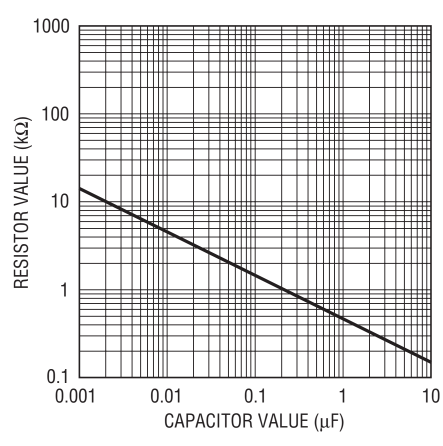


Figure 2. Damping Resistance vs Bypass Capacitor Value

APPLICATIONS INFORMATION

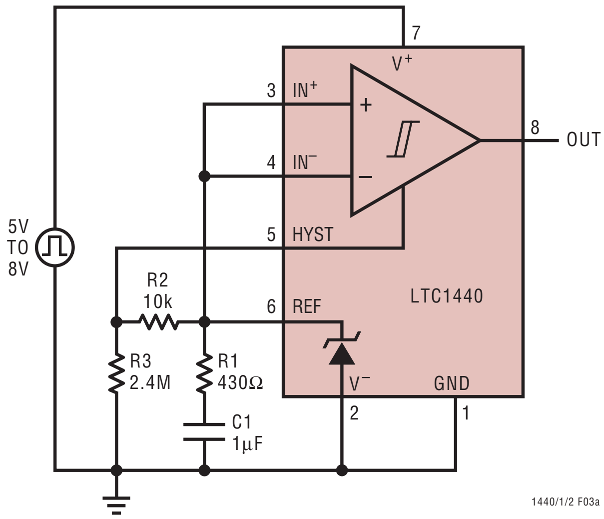


Figure 3a. Reference Transient Response Test Circuit

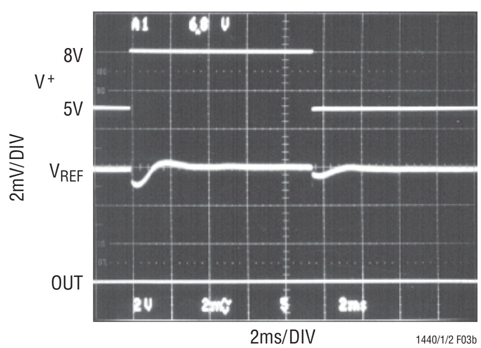


Figure 3b. Reference and Comparator Output Transient Response

Hysteresis

Hysteresis can be added to the LTC1440 by connecting a resistor (R1) between the REF and HYST pins and a second resistor (R2) from HYST to V^- (Figure 4).

The difference between the upper and lower threshold voltages, or hysteresis voltage band (V_{HB}), is equal to twice the voltage difference between the REF and HYST pins.

When more hysteresis is added, the upper threshold increases the same amount as the low threshold decreases. The maximum voltage allowed between REF and HYST pins is 50mV, producing a maximum hysteresis voltage band of 100mV. The hysteresis band could vary by up to 15%. If hysteresis is not wanted, the HYST pin should be shorted to REF. Acceptable values for I_{REF} range from 0.1µA to 5µA. If 2.4M is chosen for R2, then the value of R1 is equal to the value of V_{HB}.

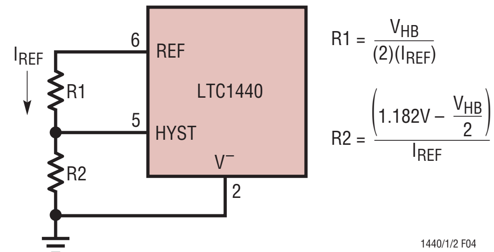


Figure 4. Programmable Hysteresis

Level Detector

The LTC1440 is ideal for use as a micropower level detector as shown in Figure 5. R1 and R2 form a voltage divider from V_{IN} to the noninverting comparator input. R3 and R4 set the hysteresis voltage, and R5 and C1 bypass the reference output. The following design procedure can be used to select the component values:

1. Choose the V_{IN} voltage trip level, in this example 4.65V.

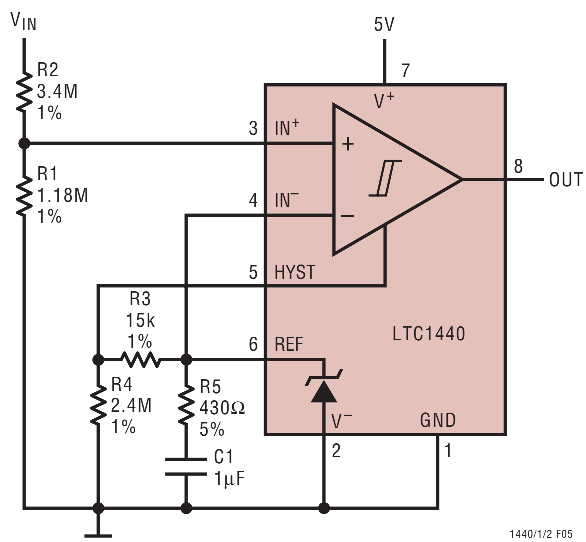


Figure 5. Glitch-Free Level Detector with Hysteresis

APPLICATIONS INFORMATION

2. Calculate the required resistive divider ratio.

   Ratio = V_{REF}/V_{IN}

   Ratio = 1.182V/4.65V = 0.254

3. Choose the required hysteresis voltage band at the input V_{HBIN}, in this example 60mV. Calculate the hysteresis voltage band referred to the comparator input V_{HB}.

   $V_{HB} = (V_{HBIN})(\text{Ratio})$

   $V_{HB} = (60mV)(0.254)$

   $V_{HB} = 15.24mV$

4. Choose the values for R3 and R4 to set the hysteresis.

   R4 = 2.4M

   $R3(k\Omega) = V_{HB} = 15k$

5. Choose the values for R1 and R2 to set the trip point.

$$R1 = \frac{V_{REF}}{I_{BIAS}} = \frac{1.182V}{1\mu A} = 1.18M$$

$$R2 = R1\left[\frac{V_{IN}}{V_{REF} + \frac{V_{HB}}{2}} - 1\right]$$

$$R2 = 1.18M\left[\frac{4.65V}{1.182V + \frac{15mV}{2}} - 1\right]$$

$$R2 = 3.40M$$

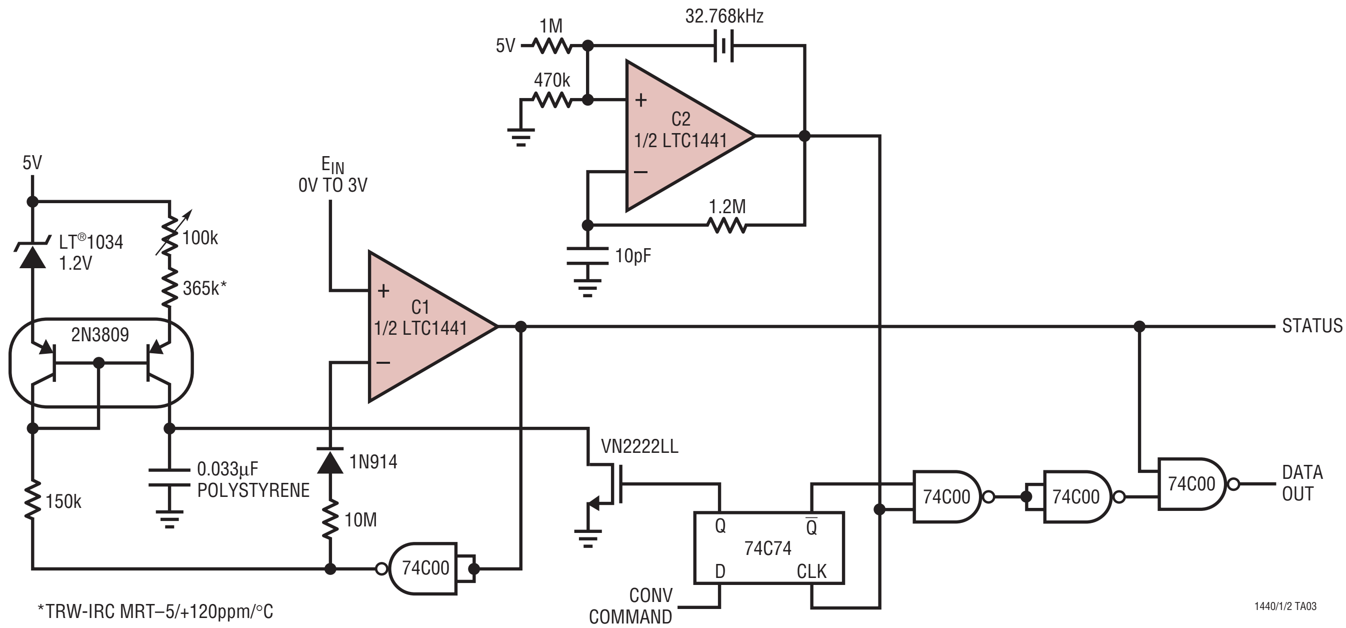
Low Voltage Operation

It is important to note that the voltage references internal to the LTC1440 and LTC1442 can exceed the common mode range of the comparators at low supply voltages. The input common mode range of the LTC1440/LTC1441/LTC1442 comparators is guaranteed to extend up to (V^+ - 1.3V). Therefore, if one of the comparator inputs is at the 1.182V reference voltage, the minimum supply voltage is 2.5V for a valid output reading.

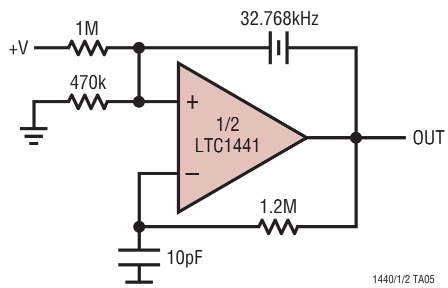
The guaranteed minimum operating voltage for the LTC1440/LTC1441/LTC1442 is 2V (or ±1V). However, both the reference and comparator(s) will function with a supply voltage as low as 1.5V, but performance will degrade as the voltage goes below 2V. The voltage reference temperature coefficient will degrade slightly, and the comparators will have less output drive with an increase in propagation delay. At the reduced supply voltages, the input common mode range of the comparator(s) will still typically extend from the negative supply to approximately 1.1V below the positive supply.

TYPICAL APPLICATIONS

10-Bit 30µA A/D Converter

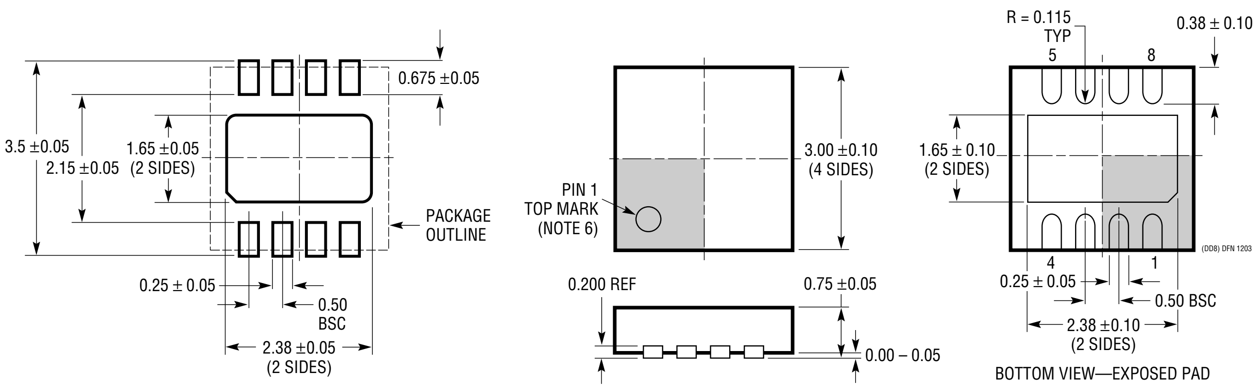


32.768kHz "Watch Crystal" Oscillator



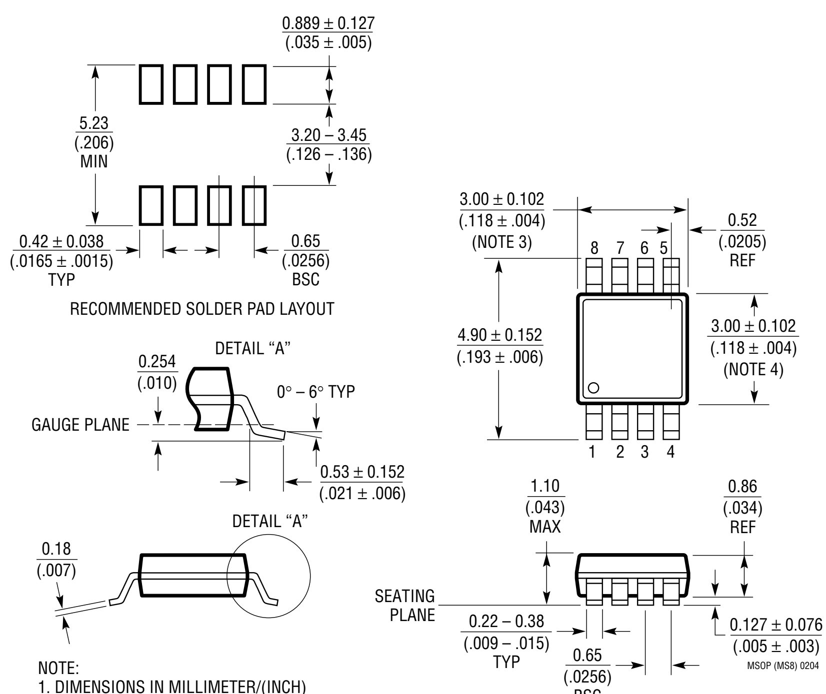
PACKAGE DESCRIPTION

DD Package
8-Lead Plastic DFN (3mm × 3mm)
(Reference LTC DWG # 05-08-1698)



NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-1)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON TOP AND BOTTOM OF PACKAGE

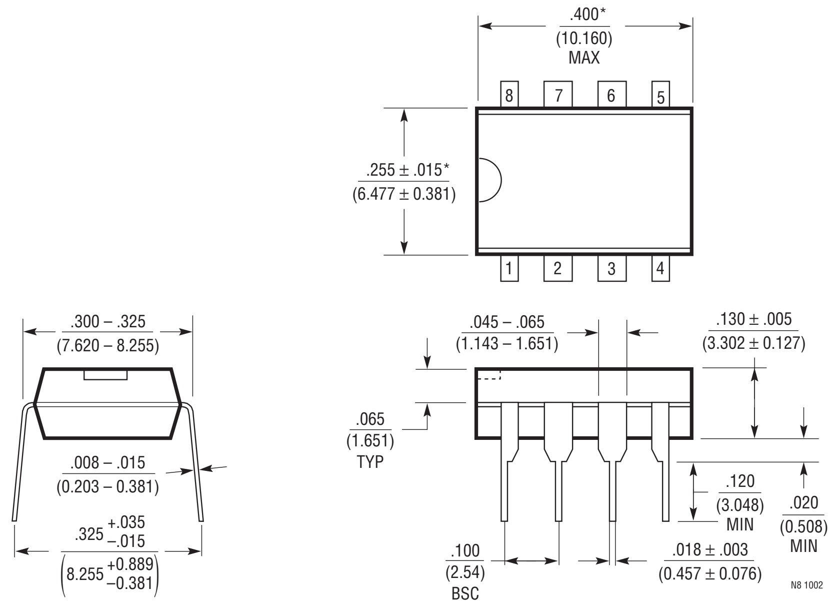
MS8 Package
8-Lead Plastic MSOP
(Reference LTC DWG # 05-08-1660)



NOTE:
1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS. INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

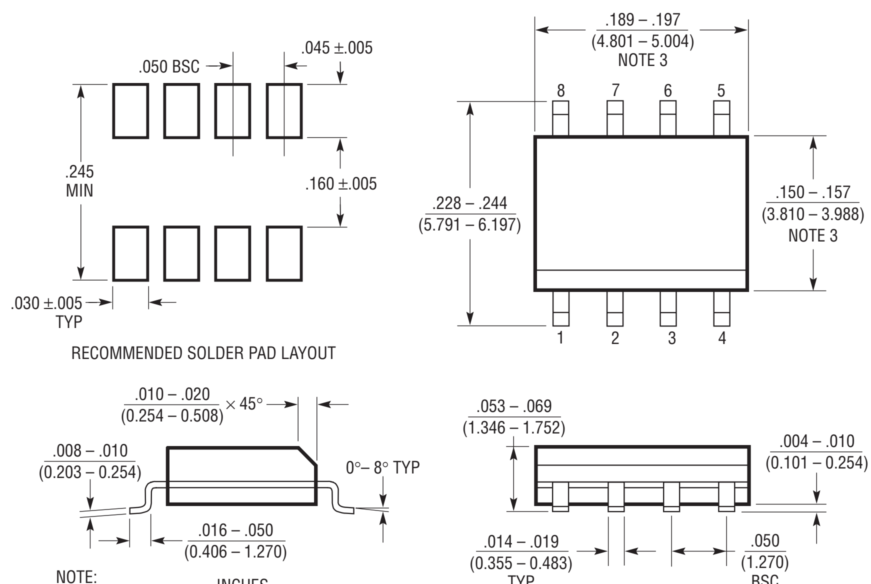
PACKAGE DESCRIPTION

N8 Package
8-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)



NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

S8 Package
8-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)



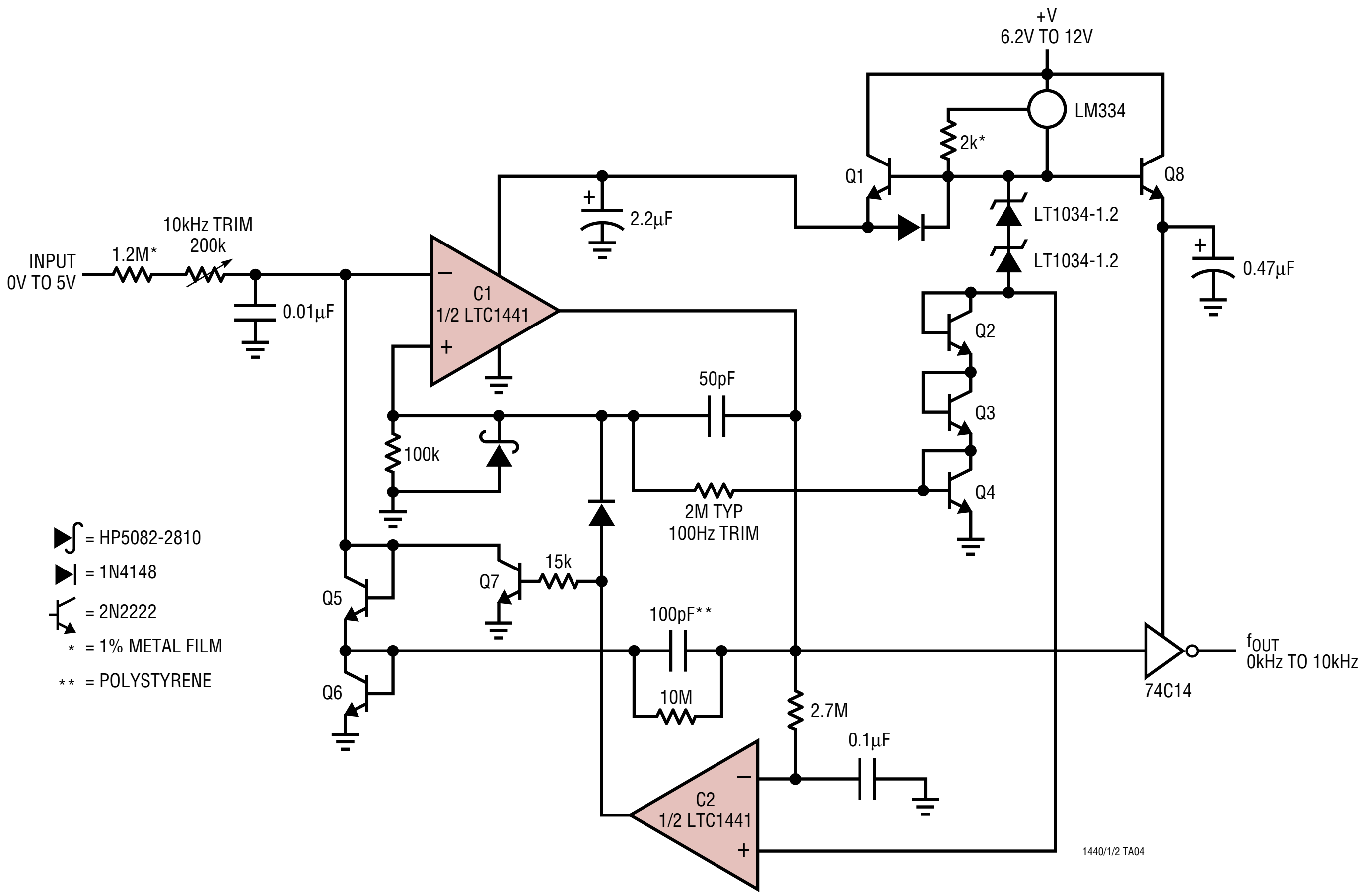
NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

SO8 0303

144012fd

TYPICAL APPLICATION

10kHz V/F Converter



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1443	1.182V Reference with Micropower Quad Comparators	1% Accuracy, 8.5µA Maximum Current, Ref Output Drives 0.01µF
LTC1444/LTC1445	1.2V Reference with Quad Comparator with Adjustable Hysteresis	1% Accuracy, 8.5µA Maximum Current, Ref Output Drives 0.01µF
LTC1540	1.182V Reference with Nanopower Comparator with Adjustable Hysteresis	DFN Package 0.3µA Quiescent Current (Typical), Reference Drives 0.01µF
LTC1541	1.2V Reference with Micropower Amplifier and Comparator	DFN Package 1.25% Accuracy, Rail-to-Rail Out, Low Offset Amplifier
LTC1842/LTC1843	1.82V Reference with Dual Comparators with Adjustable Hysteresis	1% Accuracy, Open-Drain Out, Reference Drives 0.01µF
LTC1998	1.2 Reference with Comparator with Adjustable Thesholds	Li-Ion Low Battery Monitor, SOT23, 1% Accuracy
LT6700-1 LT6700-2/LT6700-3	0.4 Reference with Low Voltage Dual Comparators	SOT23, 1.4V to 18.5V Supply Range, ±2% Over Temperature

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com
LT 0806 REV D • PRINTED IN USA

12. 5227161-2: BNC Jack, Right Angle

Tyco Electronics

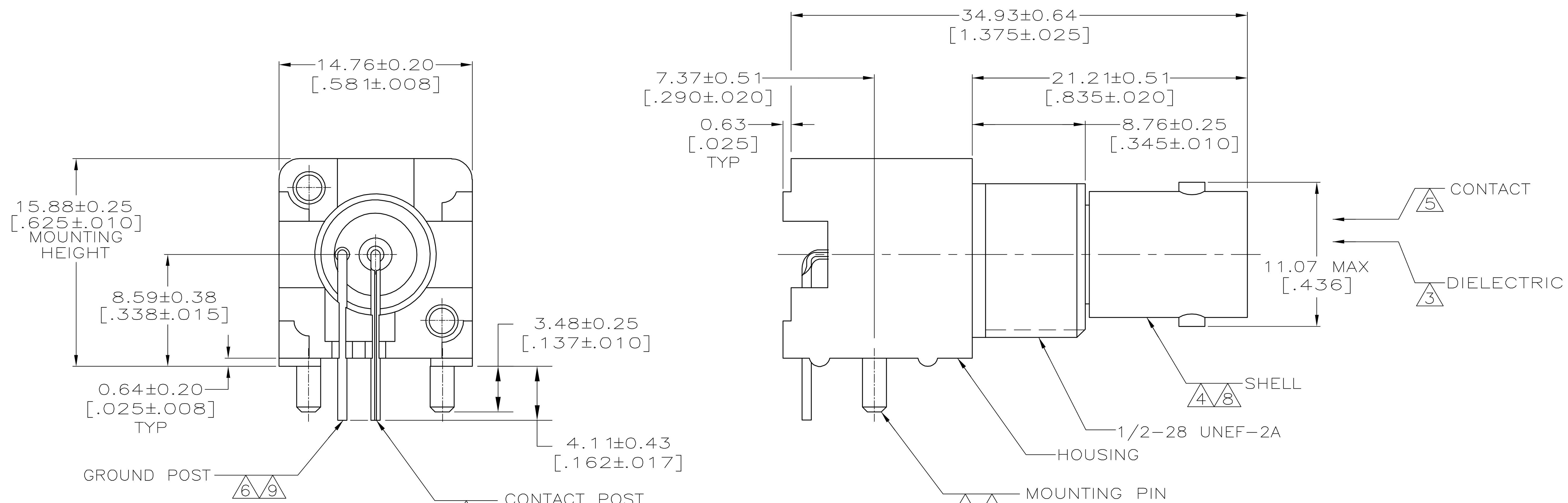
BNC Jack, Right Angle

5227161-2

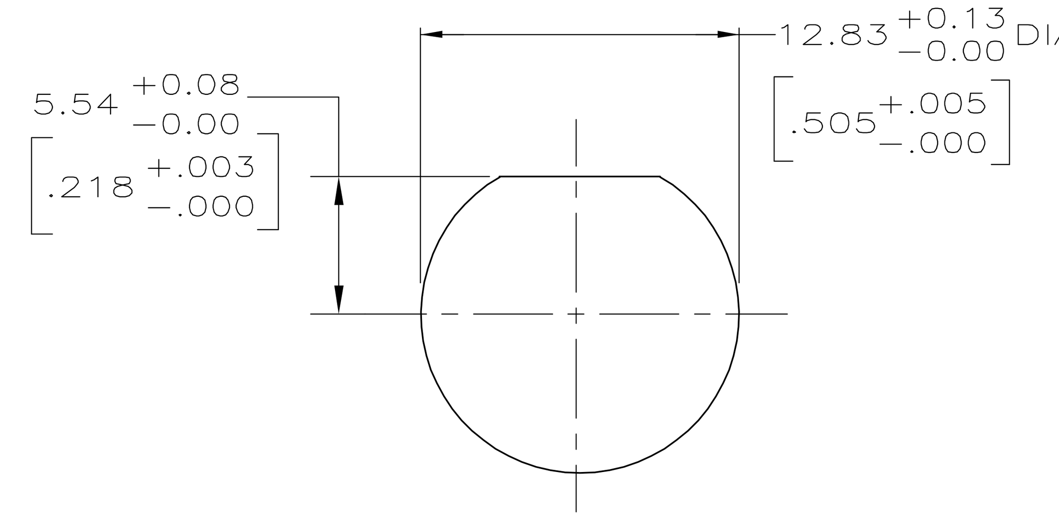
LOC	DIST	REVISIONS				
		P / LTR	DESCRIPTION	DATE	DWN	APVD
AJ	16	A	REVISED PER EC 0S14-0150-05	30AUG05	BM	JL

VIEW C
(SAME AS VIEW A
EXCEPT AS SHOWN)

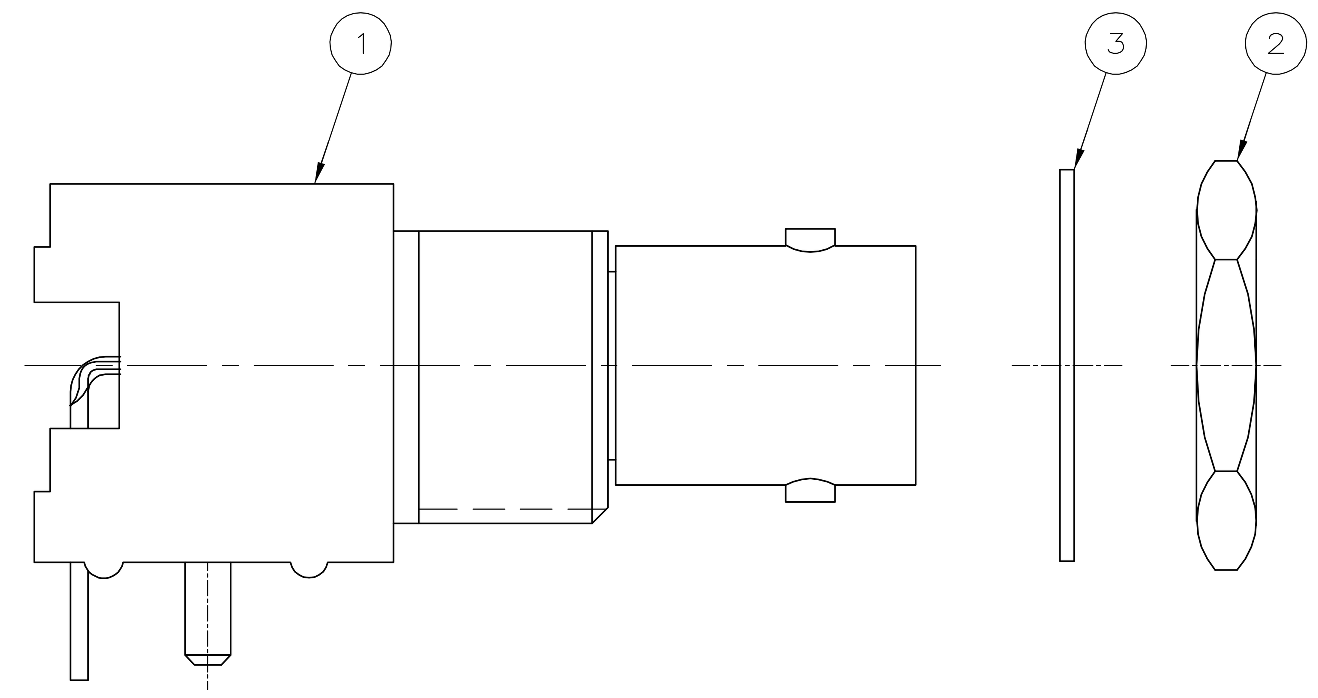
1. POLYESTER PBT PER MIL-M-24519, TYPE GPT-15F, UL94V-0 RATED, COLOR:WHITE
2. POLYESTER PBT PER MIL-M-24519, TYPE GPT-15F, UL94V-0 RATED, COLOR:BLACK
3. POLYMETHYLPENTENE, GENERAL PURPOSE.
4. ZINC PER QQ-Z-363.
5. PHOSPHOR BRONZE PER QQ-B-750.
6. BRASS PER ASTM-B-453.
7. BRASS PER ASTM-B-16.
8. NICKEL PLATE PER QQ-N-290, 3.81 µm [.000150] MINIMUM THICK.
9. TIN PLATE PER ASTM-B-545. 3.81 µm [.000150] MINIMUM THICK.
10. GOLD PLATE PER MIL-G-45204, 0.76 µm [.000030] MINIMUM THICK.
11. GOLD PLATE PER MIL-G-45204, 1.27 µm [.000050] MINIMUM THICK.
12. SEE INSTRUCTION SHEET 408-2769.



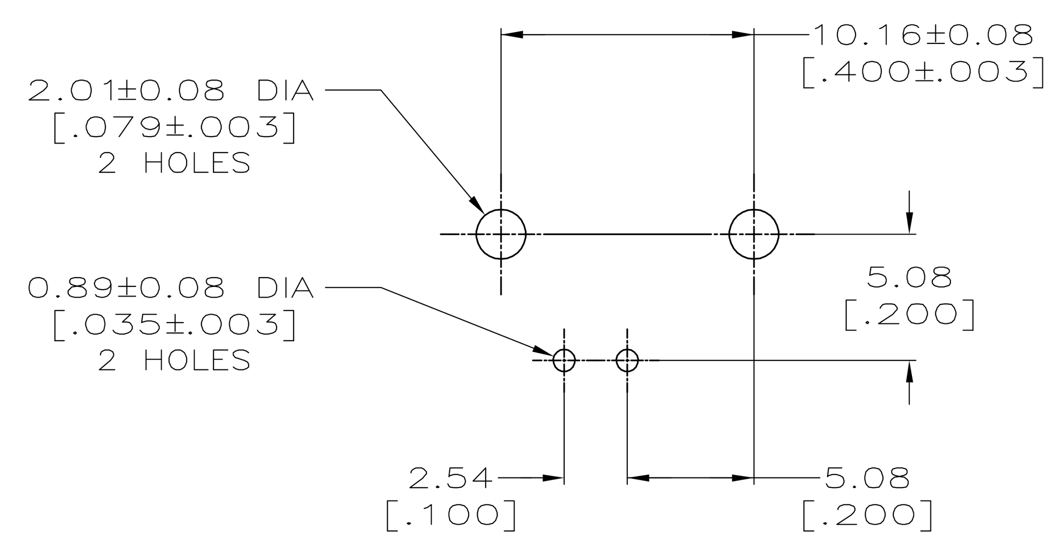
VIEW A



RECOMMENDED PANEL CUTOUT



VIEW B



PCB CONFIGURATION

CONTACT FINISH	HOUSING MATERIAL	VIEW	(3) LOCKWASHER	(2) JAM NUT QTY=1	(1) ASSEMBLY QTY=1	PART NUMBER
-	-	B	1-329632-2	1-329631-2	5227161-9	1-5227161-7
-	-	B	1-329632-2	1-329631-2	5227161-6	1-5227161-6
10	2	C	-	-	-	1-5227161-5
10	2	C	-	-	-	5227161-9
10	1	C	-	-	-	5227161-7
10	2	A	-	-	-	5227161-6
10	1	A	-	-	-	5227161-3
9	2	A	-	-	-	5227161-2
9	1	A	-	-	-	5227161-1

THIS DRAWING IS A CONTROLLED DOCUMENT.

DIMENSIONS: mm[INCHES]

TOLERANCES UNLESS OTHERWISE SPECIFIED:
0 PLC ± -
1 PLC ± -
2 PLC ± 0.05 [.002]
3 PLC ± -
4 PLC ± -
ANGLES ± -

MATERIAL: 1 2 3 4 5 6 7
FINISH: 8 9 10 11

DWN L. VARELA - DOCK5 20APR2005
CHK J. HAVENER 20APR2005
APVD S. BURKHOLDER 20APR2005
PRODUCT SPEC 108-12078
APPLICATION SPEC -
WEIGHT -

Tyco Electronics Corporation
Harrisburg, Pa 17105-3608

NAME: JACK, RIGHT ANGLE, 50 OHM, PCB, BNC

SIZE A1 | CAGE CODE 00779 | DRAWING NO C-5227161 | RESTRICTED TO -

CUSTOMER DRAWING | SCALE 4:1 | SHEET 1 OF 1 | REV A

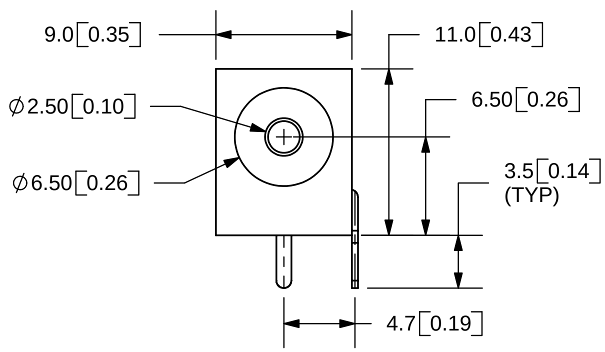
13. PJ-102BH: DC Power Jack

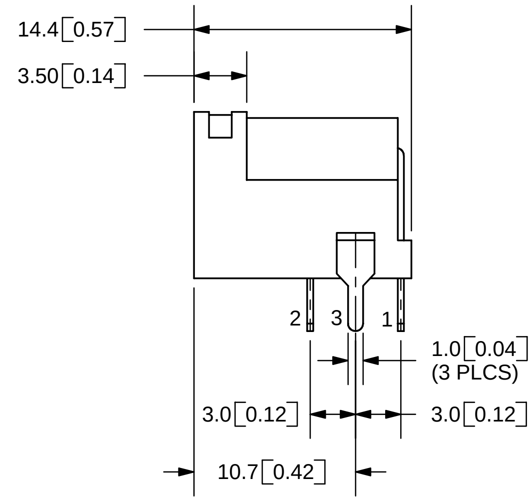
CUI Inc

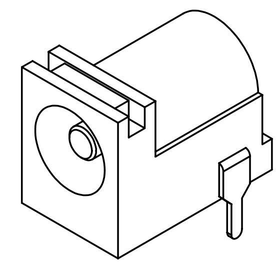
DC Power Jack

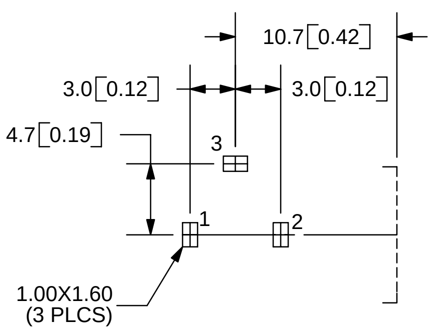
PJ-102BH

REV.	DESCRIPTION	DATE
A	NEW DRAWING	11/17/2005





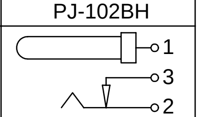




PCB LAYOUT
TOP VIEW

TOLERANCE:
X.X ±0.2mm
X.XX ±0.1mm
X.XXX ±0.05mm

SPECIFICATIONS:
RATING: 24V DC @ 5A
CONTACT RESISTANCE: 50m OHMS MAX
INSULATION RESISTANCE: 50M OHMS MIN: 100V DC
VOLTAGE WITHSTAND: 500V AC R.M.S. FOR 1 MINUTE
LIFE: 5,000 CYCLES

MODEL NO.	PJ-102BH
SCHEMATIC	

CENTER PIN DIAMETER 2.5mm Dia.

	MATERIAL	PLATING
CENTER PIN	Copper	Nickel
TERMINAL 1	Brass	Silver
TERMINAL 2	Copper Alloy	Silver
TERMINAL 3	Brass	Silver
HOUSING	PBT	

CUI INC
9615 SW Allen Blvd., Ste. 103
Beaverton, OR 97005
Phone: 503-643-4899
800-275-4899
Fax: 503-372-1266
Website: www.cui.com

TITLE: DC POWER JACK			REV: A
PART NO. PJ-102BH		UNITS: MM [INCHES]	
DRAWN BY: ZRJ	APPROVED BY:		SCALE: 2:1

PC FILE NAME: PJ-102BH