Building a Probe for an HP4815A Vector Impedance Meter

What is the HP4815A?

This meter measures the magnitude and phase of any impedance from 1 ohm to 100 Kohms and the phase from 0 to 360 degrees. HP built these meters back in the sixties, with entirely analog discretes. This makes them valuable in a mostly digital world. It also makes them quite fixable if something goes wrong. However, most of the machines are missing there detachable probes. HP does not sell replacement probes, and to buy one professionally made, you will have to spend around US$1000. So, the question is, how hard is it to make a replacement probe? This is what we set out to do. And, no, it is not easy, but can be done by those who have professional experience in the field of electrical engineering. The hope of this paper is to guide one through the process and hopefully eliminate many of the pitfalls associated with their construction.

Overview of the HP4815A Operation

The HP4815A probe has a voltage sampling section and a current sampling section, which uses a current sense
Building a Probe for an HP4815A Vector Impedance Meter

transformer. There are two main signals sent through the test load: an oscillator frequency, set by the user from .5 MHz to 108 MHz, and five nanosecond sampling pulses spaced 1.1 microseconds apart. The below pictures show what would be seen looking at the load with an oscilloscope if the two signals are separated:

Scope of the project

Most of the design work is making the current transformer work over the broad 0.5 MHz - 108 MHz Frequency range. The magnitude needs to be constant and the phase must be linear with frequency. Other problems are dealing with HPs proprietary connector for the probe. Our solution was to hard wire back into the machine. This is a long and tedious job, since the length must not vary by more than a few millimeters. Isolation and parasitics are also an issue, so good grounding and separate housings for the current and voltage senses must be carefully done. Also, many of the meters haven't been used for a while, and are out of calibration. This can be tough, because you need to test whether your probe is the problem, or if something needs to be calibrated internally. Other potential problems include burned out transistors or capacitors.

More information on individual sections of the probe:

Current Transformer Design
Board Design
Ballun Design
Routing the Coaxial cable into the machine
Probe Housing
Calibration issues
Delay Line for Voltage Sense
Parts used/data sheets
HP4815A Manual
Results and Pictures
Schematic of Probe

Rev. 1
March 18, 2004
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Current Transformer

The current transformer is the most difficult part of the design. The operating frequency is between 0.5 MHz to 108 MHz. The attached magnitude and phase plot shows what was used in the design.

For cores, we tried nanocrystalline, powdered iron, and ferrite. Ferrite produced the best results for a broad frequency range. Nanocrystalline cores were excellent at low frequencies, but at the higher frequencies they were not linear enough. Powdered iron cores did not go low enough in frequency.

Ferrite beads worked the best. The data for our core is as follows:
Material: #43
Part: #2643021801
Inside Diameter: 1.45 mm
Outside Diameter: 4.83 mm
Length: 10.72 mm
μ: 3000 max

Fewer turns improved the frequency response considerably. Two turns seemed to be a good compromise. Cascading two cores in series also made the response better. Below is a picture of the core we used:

Notice that the voltage sense wire runs right through the cores. The other two turns are for the current sensing.

Here is the magnitude and phase response of our current transformer:
Board Design

The board design is very critical. There are nine coaxial cables that must be connected to the probe, four on the current sense and five on the voltage sense. The shielding needs to be well connected to ground, and good use of ground planes will help to prevent noise. The traces should also have a characteristic impedance of around 50 ohms, especially for the sampling pulse traces (lines 2, 3, 6, and 9). Surface mount components should be used as much as possible.

A picture of our current board:

And our voltage board:
**Ballun Design**

The ballun goes across the two balanced input lines for the sampling pulses. It insures that the lines are truly balanced. This is one of the easiest parts to build. Only a few turns are needed, and any ferrite core will work fine. A picture of our ballun is below:

![Ballun Design Image](image)

Here is a list of the specs on the core we used:

- $\mu_i = 250$
- $\mu = 3000$
- #43 Material, type 6
- Ferrite
- two turns of 30 gauge wirewrap
Routing the Coaxial cable into the machine

For connecting the probe to the meter, we couldn't just use the connector on the front, because HP used a proprietary connector. Therefore, we routed the cable back to the origin inside the meter. This takes some time, and must be done carefully. All but one of the cables goes to the same part of the meter, and there is plenty of room to solder the coax directly to the boards. Each coax should be cut to precisely the same length as what was in it. After removing all the old coax, we measured each line, and added five feet to it. This should be done to within a millimeter or two (see equation below). Also, the coax should have a characteristic impedance of around 50 ohms, and a velocity factor of 0.66.

Here is a picture of where the coax goes:
\[
\Delta \phi = \frac{360^\circ}{f_o} \Delta t
\]
\[
\Delta t = \Delta \phi \frac{1}{360^\circ f_o} = 1^\circ \frac{1}{360^\circ \cdot 108 \text{MHz}} = 25.7 \text{ps}
\]
\[
\Delta l = .66 \cdot c \cdot \Delta t = 5.1 \text{mm}
\]
Probe Housing

A good housing for the probe must be constructed. A conducting metal tube works best, with a good connection to ground. We divided the tube into two sections, with the top being the voltage board, and the bottom for the current board, with a grounding plane between. This provides excellent isolation, which we need for the phase measurements.

Here is a picture of our boards on the grounding plane separating them:

Current board

Voltage board
Calibration issues

Calibration is probably the most difficult part of the project. The magnitude should be done first, then the phase.

The magnitude can be calibrated in several ways. One is to change the number of turns on the current transformer, the other by internally calibrating the meter. The phase can be adjusted by changing the length of the delay line on the voltage board (discussed later).
The Delay Line for the Voltage Board

The pulses sent to the voltage board lead the sampling pulses to the current board by approximately 1.55 ns. This must be measured, as each instrument varies slightly. The best way to make a delay line is to cut a piece of coax to about 15”, then connecting it to a TDR (Time Domain Reflectometer) to determine the exact length. One can assume a velocity of approximately .66c to get close to the right length.

A picture of our delay line:

[Image of delay line]

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March 18, 2004
WALLA WALLA COLLEGE
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Parts used/data sheets

Most of the parts used in our design are readily available. However, here is a list of what we used:

T1 = Current Transformer:
#43 Material, Type 6 Ferrite Core Bead
µ = 3000 max
Inside Diameter = 1.45mm
Outside Diameter = 4.83mm
Length = 10.72mm

T2 and T3 = Ballun:
#43 Material, Type 6 Ferrite Ballun

Capacitors and Resistors:
All 1/10 watt surface mount

Diodes:
HSMS-282x Quad Bridge Schottky Diodes
Data Sheet

Q1 and Q2 = J-Fet:
MMBF5461
Data Sheet

PCB:
permitivity = 4.0

Rev. 1
March 18, 2004
WALLA WALLA COLLEGE
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Surface Mount RF Schottky Barrier Diodes

Technical Data

Features

- Low Turn-On Voltage (As Low as 0.34 V at 1 mA)
- Low FIT (Failure in Time) Rate*
- Six-sigma Quality Level
- Single, Dual and Quad Versions
- Unique Configurations in Surface Mount SOT-363 Package
  - increase flexibility
  - save board space
  - reduce cost
- HSMS-282K Grounded Center Leads Provide up to 10 dB Higher Isolation
- Matched Diodes for Consistent Performance
- Better Thermal Conductivity for Higher Power Dissipation

* For more information see the Surface Mount Schottky Reliability Data Sheet.

Description/Applications

These Schottky diodes are specifically designed for both analog and digital applications. This series offers a wide range of specifications and package configurations to give the designer wide flexibility. Typical applications of these Schottky diodes are mixing, detecting, switching, sampling, clamping, and wave shaping. The HSMS-282x series of diodes is the best all-around choice for most applications, featuring low series resistance, low forward voltage at all current levels and good RF characteristics.

Note that Agilent's manufacturing techniques assure that dice found in pairs and quads are taken from adjacent sites on the wafer, assuring the highest degree of match.
Pin Connections and Package Marking

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>2820</td>
<td>C0[3] Single</td>
</tr>
<tr>
<td>2822</td>
<td>C2[3] Series</td>
</tr>
<tr>
<td>2823</td>
<td>C3[3] Common Anode</td>
</tr>
<tr>
<td>2824</td>
<td>C4[3] Common Cathode</td>
</tr>
<tr>
<td>2825</td>
<td>C5[3] Unconnected Pair</td>
</tr>
<tr>
<td>2829</td>
<td>C9[3] Cross-over Quad</td>
</tr>
<tr>
<td>282C</td>
<td>C Series</td>
</tr>
<tr>
<td>282E</td>
<td>C3[7] Common Anode</td>
</tr>
<tr>
<td>282F</td>
<td>C4[7] Common Cathode</td>
</tr>
<tr>
<td>282K</td>
<td>CX[7] Unconnected Pair</td>
</tr>
<tr>
<td>282L</td>
<td>CL[7] Unconnected Trio</td>
</tr>
<tr>
<td>282M</td>
<td>KH[7] Common Cathode Quad</td>
</tr>
<tr>
<td>282N</td>
<td>NN[7] Common Anode Quad</td>
</tr>
<tr>
<td>282P</td>
<td>CP[7] Bridge Quad</td>
</tr>
<tr>
<td>282R</td>
<td>OR[7] Ring Quad</td>
</tr>
</tbody>
</table>

Notes:
1. Package marking provides orientation and identification.
2. See “Electrical Specifications” for appropriate package marking.

Absolute Maximum Ratings[1] TC = 25°C

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Unit</th>
<th>SOT-23/SOT-143</th>
<th>SOT-323/SOT-363</th>
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<tr>
<td>If</td>
<td>Forward Current (1 μs Pulse)</td>
<td>Amp</td>
<td>1</td>
<td>1</td>
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<tr>
<td>PIV</td>
<td>Peak Inverse Voltage</td>
<td>V</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>TJ</td>
<td>Junction Temperature</td>
<td>°C</td>
<td>150</td>
<td>150</td>
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<tr>
<td>Tstg</td>
<td>Storage Temperature</td>
<td>°C</td>
<td>-65 to 150</td>
<td>-65 to 150</td>
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<tr>
<td>θjc</td>
<td>Thermal Resistance</td>
<td>°C/W</td>
<td>500</td>
<td>150</td>
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</table>

Notes:
1. Operation in excess of any one of these conditions may result in permanent damage to the device.
2. TC = +25°C, where TC is defined to be the temperature at the package pins where contact is made to the circuit board.


<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package Marking Code</th>
<th>Lead Code</th>
<th>Configuration</th>
<th>Minimum Breakdown Voltage VBR (V)</th>
<th>Maximum Forward Voltage VF (mV)</th>
<th>Maximum Reverse Leakage IR (nA) @ VR (V)</th>
<th>Maximum Capacitance CT (pF)</th>
<th>Typical Dynamic Resistance RD (Ω)</th>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2824</td>
<td>C4[3]</td>
<td>4</td>
<td>Common Cathode</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2825</td>
<td>C5[3]</td>
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<td>Unconnected Pair</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2829</td>
<td>C9[3]</td>
<td>9</td>
<td>Cross-over Quad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>282C</td>
<td>C Series</td>
<td>C</td>
<td>Series</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>282E</td>
<td>C3[7]</td>
<td>E</td>
<td>Common Anode</td>
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</tr>
<tr>
<td>282L</td>
<td>CL[7]</td>
<td>L</td>
<td>Unconnected Trio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>282P</td>
<td>CP[7]</td>
<td>P</td>
<td>Bridge Quad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>282R</td>
<td>OR[7]</td>
<td>R</td>
<td>Ring Quad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test Conditions

I R = 100 μA  I F = 1 mA[4]

Notes:
1. ΔVF for diodes in pairs and quads is 15 mV maximum at 1 mA.
2. AC τ For diodes in pairs and quads is 0.2 ps maximum.
3. Package marking code is in white.
4. Effective Carrier Lifetime (τ) for all these diodes is 100 ps maximum measured with Krakauer method at 5 mA.
5. See section titled “Quad Capacitance.”
6. R D = R S + 5.2 Ω at 25°C and I F = 5 mA.
7. Package marking code is laser marked.
Quad Capacitance

Capacitance of Schottky diode quads is measured using an HP4271 LCR meter. This instrument effectively isolates individual diode branches from the others, allowing accurate capacitance measurement of each branch or each diode. The conditions are: 20 mV R.M.S. voltage at 1 MHz. Agilent defines this measurement as “CM”, and it is equivalent to the capacitance of the diode by itself. The equivalent diagonal and adjacent capacitances can then be calculated by the formulas given below.

In a quad, the diagonal capacitance is the capacitance between points A and B as shown in the figure below. The diagonal capacitance is calculated using the following formula

\[ C_{\text{DIAGONAL}} = \frac{C_1 \times C_2}{C_1 + C_2} + \frac{C_3 \times C_4}{C_3 + C_4} \]

The equivalent adjacent capacitance is the capacitance between points A and C in the figure below. This capacitance is calculated using the following formula

\[ C_{\text{ADJACENT}} = C_1 + \frac{1}{\frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}} \]

This information does not apply to cross-over quad diodes.

Linear Equivalent Circuit Model

Diode Chip

\[ R_S = \text{series resistance (see Table of SPICE parameters)} \]
\[ C_j = \text{junction capacitance (see Table of SPICE parameters)} \]
\[ R_j = \frac{8.33 \times 10^{-6}}{I_b + I_s} \text{nT} \]

where
\[ I_b = \text{externally applied bias current in amps} \]
\[ I_s = \text{saturation current (see table of SPICE parameters)} \]
\[ T = \text{temperature, °K} \]
\[ n = \text{ideality factor (see table of SPICE parameters)} \]

Note:
To effectively model the packaged HSMS-282x product, please refer to Application Note AN1124.

ESD WARNING:
Handling Precautions Should Be Taken To Avoid Static Discharge.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>HSMS-282x</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B_V)</td>
<td>V</td>
<td>5</td>
</tr>
<tr>
<td>(C_{j0})</td>
<td>pF</td>
<td>0.7</td>
</tr>
<tr>
<td>(E_G)</td>
<td>eV</td>
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</tr>
<tr>
<td>(I_{BV})</td>
<td>A</td>
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<td>(I_S)</td>
<td>A</td>
<td>2.2E-8</td>
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<tr>
<td>(N)</td>
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<tr>
<td>(R_S)</td>
<td>(\Omega)</td>
<td>6.0</td>
</tr>
<tr>
<td>(P_B)</td>
<td>V</td>
<td>0.65</td>
</tr>
<tr>
<td>(P_T)</td>
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<td>2</td>
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<tr>
<td>(M)</td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>
Typical Performance, $T_C = 25^\circ C$ (unless otherwise noted), Single Diode

Figure 1. Forward Current vs. Forward Voltage at Temperatures.

Figure 2. Reverse Current vs. Reverse Voltage at Temperatures.

Figure 3. Total Capacitance vs. Reverse Voltage.

Figure 4. Dynamic Resistance vs. Forward Current.

Figure 5. Typical $V_F$ Match, Series Pairs and Quads at Mixer Bias Levels.

Figure 6. Typical $V_F$ Match, Series Pairs at Detector Bias Levels.

Figure 7. Typical Output Voltage vs. Input Power, Small Signal Detector Operating at 850 MHz.

Figure 8. Typical Output Voltage vs. Input Power, Large Signal Detector Operating at 915 MHz.

Figure 9. Typical Conversion Loss vs. L.O. Drive, 2.0 GHz (Ref AN997).
Applications Information 
Product Selection

Agilent’s family of surface mount Schottky diodes provide unique solutions to many design problems. Each is optimized for certain applications.

The first step in choosing the right product is to select the diode type. All of the products in the HSMS-282x family use the same diode chip—they differ only in package configuration. The same is true of the HSMS-280x, -281x, 285x, -286x and -270x families. Each family has a different set of characteristics, which can be compared most easily by consulting the SPICE parameters given on each data sheet.

The HSMS-282x family has been optimized for use in RF applications, such as

- DC biased small signal detectors to 1.5 GHz.
- Biased or unbiased large signal detectors (AGC or power monitors) to 4 GHz.
- Mixers and frequency multipliers to 6 GHz.

The other feature of the HSMS-282x family is its unit-to-unit and lot-to-lot consistency. The silicon chip used in this series has been designed to use the fewest possible processing steps to minimize variations in diode characteristics. Statistical data on the consistency of this product, in terms of SPICE parameters, is available from Agilent.

For those applications requiring very high breakdown voltage, use the HSMS-280x family of diodes. Turn to the HSMS-281x when you need very low flicker noise. The HSMS-285x is a family of zero bias detector diodes for small signal applications. For high frequency detector or mixer applications, use the HSMS-286x family. The HSMS-270x is a series of specialty diodes for ultra high speed clipping and clamping in digital circuits.

Schottky Barrier Diode Characteristics

Stripped of its package, a Schottky barrier diode chip consists of a metal-semiconductor barrier formed by deposition of a metal layer on a semiconductor. The most common of several different types, the passivated diode, is shown in Figure 10, along with its equivalent circuit.

Rs is the parasitic series resistance of the diode, the sum of the bondwire and leadframe resistance, the resistance of the bulk layer of silicon, etc. RF energy coupled into Rs is lost as heat—it does not contribute to the rectified output of the diode. Cj is parasitic junction capacitance of the diode, controlled by the thickness of the epilayer and the diameter of the Schottky contact. Rj is the junction resistance of the diode, a function of the total current flowing through it.

\[
R_j = \frac{8.33 \times 10^5 n T}{T} = R_v - R_s
\]

where

\[
R_s = \frac{n IS + I_b}{0.026} \approx \frac{1}{T}
\]

where

- \( n \) = ideality factor (see table of SPICE parameters)
- \( T \) = temperature in °K
- \( I_s \) = saturation current (see table of SPICE parameters)
- \( I_b \) = externally applied bias current in amps
- \( R_v \) = sum of junction and series resistance, the slope of the V-I curve

\( I_s \) is a function of diode barrier height, and can range from picoamps for high barrier diodes to as much as 5 µA for very low barrier diodes.

The Height of the Schottky Barrier

The current-voltage characteristic of a Schottky barrier diode at room temperature is described by the following equation:

\[
V = I R_s + I_s (e^{0.026} - 1)
\]

On a semi-log plot (as shown in the Agilent catalog) the current graph will be a straight line with inverse slope 2.3 X 0.026 = 0.060 volts per cycle (until the effect of...
RS is seen in a curve that droops at high current). All Schottky diode curves have the same slope, but not necessarily the same value of current for a given voltage. This is determined by the saturation current, IS, and is related to the barrier height of the diode.

Through the choice of p-type or n-type silicon, and the selection of metal, one can tailor the characteristics of a Schottky diode. Barrier height will be altered, and at the same time Cj and Rs will be changed. In general, very low barrier height diodes (with high values of IS, suitable for zero bias applications) are realized on p-type silicon. Such diodes suffer from higher values of Rs than do the n-type. Thus, p-type diodes are generally reserved for detector applications (where very high values of Rv swamp out high Rs) and n-type diodes such as the HSMS-282x are used for mixer applications (where high L.O. drive levels keep Rv low). DC biased detectors and self-biased detectors used in gain or power control circuits.

Detector Applications
Detector circuits can be divided into two types, large signal (P_in > -20 dBm) and small signal (P_in < -20 dBm). In general, the former use resistive impedance matching at the input to improve flatness over frequency — this is possible since the input signal levels are high enough to produce adequate output voltages without the need for a high Q reactive input matching network. These circuits are self-biased (no external DC bias) and are used for gain and power control of amplifiers.

Small signal detectors are used as very low cost receivers, and require a reactive input impedance matching network to achieve adequate sensitivity and output voltage. Those operating with zero bias utilize the HSMS-285x family of detector diodes. However, superior performance over temperature can be achieved with the use of 3 to 30 μA of DC bias. Such circuits will use the HSMS-282x family of diodes if the operating frequency is 1.5 GHz or lower.

Typical performance of single diode detectors (using HSMS-2820 or HSMS-282B) can be seen in the transfer curves given in Figures 7 and 8. Such detectors can be realized either as series or shunt circuits, as shown in Figure 11.

The two diodes are in parallel in the RF circuit, lowering the input impedance and making the design of the RF matching network easier.

The two diodes are in series in the output (video) circuit, doubling the output voltage.

Some cancellation of even-order harmonics takes place at the input.

Typical performance of single diode detectors (using HSMS-2820 or HSMS-282B) can be seen in the transfer curves given in Figures 7 and 8. Such detectors can be realized either as series or shunt circuits, as shown in Figure 11.

The series and shunt circuits can be combined into a voltage doubler[1], as shown in Figure 12. The doubler offers three advantages over the single diode circuit.

1. The two diodes are in parallel in the RF circuit, lowering the input impedance and making the design of the RF matching network easier.
2. The two diodes are in series in the output (video) circuit, doubling the output voltage.
3. Some cancellation of even-order harmonics takes place at the input.

Figure 12. Voltage Doubler.

The most compact and lowest cost form of the doubler is achieved when the HSMS-2822 or HSMS-282C series pair is used.

Both the detection sensitivity and the DC forward voltage of a biased Schottky detector are temperature sensitive. Where both must be compensated over a wide range of temperatures, the differential detector[2] is often used. Such a circuit requires that the detector diode and the reference diode exhibit identical characteristics at all DC bias levels and at all temperatures. This is accomplished through the use of two diodes in one package, for example the HSMS-2825 in Figure 13. In the Agilent assembly facility, the two dice in a surface mount package are taken from adjacent sites on the wafer (as illustrated in Figure 14). This

---


assures that the characteristics of the two diodes are more highly matched than would be possible through individual testing and hand matching.

In high power applications, coupling of RF energy from the detector diode to the reference diode can introduce error in the differential detector. The HSMS-282K diode pair, in the six lead SOT-363 package, has a copper bar between the diodes that adds 10 dB of additional isolation between them. As this part is manufactured in the SOT-363 package it also provides the benefit of being 40% smaller than larger SOT-143 devices. The HSMS-282K is illustrated in Figure 15 — note that the ground connections must be made as close to the package as possible to minimize stray inductance to ground.

While the differential detector works well over temperature, another design approach[3] works well for large signal detectors. See Figure 18 for the schematic and a physical layout of the circuit. In this design, the two 4.7 KΩ resistors and diode D2 act as a variable power divider, assuring constant output voltage over temperature and improving output linearity.

lower cost solution is available\cite{ref4}. Illustrated schematically in Figure 19, this circuit uses diode D2 and its associated passive components to cancel all even order harmonics at the detector’s RF input. Diodes D3 and D4 provide temperature compensation as described above. All four diodes are contained in a single HSMS-282R package, as illustrated in the layout shown in Figure 20.

**Mixer applications**

The HSMS-282x family, with its wide variety of packaging, can be used to make excellent mixers at frequencies up to 6 GHz.

The HSMS-2827 ring quad of matched diodes (in the SOT-143 package) has been designed for double balanced mixers. The smaller (SOT-363) HSMS-282R ring quad can similarly be used, if the quad is closed with external connections as shown in Figure 21.

A review of Figure 21 may lead to the question as to why the HSMS-282R ring quad is open on the ends. Distortion in double balanced mixers can be reduced if LO drive is increased, up to the point where the Schottky diodes are driven into saturation. Above this point, increased LO drive will not result in improvements in distortion. The use of expensive high barrier diodes (such as those fabricated on GaAs) can take advantage of higher LO drive power, but a lower cost solution is to use a eight (or twelve) diode ring quad. The open design of the HSMS-282R permits this to easily be done, as shown in Figure 23.

Both of these networks require a crossover or a three dimensional circuit. A planar mixer can be made using the SOT-143 crossover quad, HSMS-2829, as shown in Figure 22. In this product, a special lead frame permits the crossover to be placed inside the plastic package itself, eliminating the need for via holes (or other measures) in the RF portion of the circuit itself.

This same technique can be used in the single-balanced mixer. Figure 24 shows such a mixer, with two diodes in each spot normally occupied by one. This mixer, with a sufficiently high LO drive level, will display low distortion.

\[\text{\cite{ref4} Alan Rixon and Raymond W. Waugh, “A Suppressed Harmonic Power Detector for Dual Band ‘Phones,” to be published.}\]
Sampling Applications

The six lead HSMS-282P can be used in a sampling circuit, as shown in Figure 25. As was the case with the six lead HSMS-282R in the mixer, the open bridge quad is closed with traces on the circuit board. The quad was not closed internally so that it could be used in other applications, such as illustrated in Figure 17.

![Sampling Circuit](image)

**Figure 25. Sampling Circuit.**

Thermal Considerations

The obvious advantage of the SOT-323 and SOT-363 over the SOT-23 and SOT-142 is combination of smaller size and extra leads. However, the copper leadframe in the SOT-3x3 has a thermal conductivity four times higher than the Alloy 42 leadframe of the SOT-23 and SOT-143, which enables the smaller packages to dissipate more power.

The maximum junction temperature for these three families of Schottky diodes is 150°C under all operating conditions. The following equation applies to the thermal analysis of diodes:

\[
T_j = (V_f I_f + P_{RF}) \theta_{jc} + T_a
\]  

where

- \( T_j \) = junction temperature
- \( T_a \) = diode case temperature
- \( \theta_{jc} \) = thermal resistance
- \( V_f I_f \) = DC power dissipated
- \( P_{RF} \) = RF power dissipated

Note that \( \theta_{jc} \), the thermal resistance from diode junction to the foot of the leads, is the sum of two component resistances,

\[
\theta_{jc} = \theta_{pkg} + \theta_{chip}
\]  

Package thermal resistance for the SOT-3x3 package is approximately 100°C/W, and the chip thermal resistance for the HSMS-282x family of diodes is approximately 40°C/W. The designer will have to add in the thermal resistance from diode case to ambient — a poor choice of circuit board material or heat sink design can make this number very high.

Equation (1) would be straightforward to solve but for the fact that diode forward voltage is a function of temperature as well as forward current. The equation for \( V_f \) is:

\[
I_f = I_S \left( \frac{11600 (V_f - R_s)}{e^{nT} - 1} \right)
\]

where

- \( n \) = ideality factor
- \( T \) = temperature in °K
- \( R_s \) = diode series resistance
- \( I_S \) = diode saturation current

and \( I_S \) (diode saturation current) is given by

\[
I_s = I_0 \left( \frac{T}{298} \right)^{\frac{2}{n}} e^{-4060 \left( \frac{1}{T} - \frac{1}{298} \right)}
\]

Equation (4) is substituted into equation (3), and equations (1) and (3) are solved simultaneously to obtain the value of junction temperature for given values of diode case temperature, DC power dissipation and RF power dissipation.

Diode Burnout

Any Schottky junction, be it an RF diode or the gate of a MESFET, is relatively delicate and can be burned out with excessive RF power. Many crystal video receivers used in RFID (tag) applications find themselves in poorly controlled environments where high power sources may be present. Examples are the areas around airport and FAA radars, nearby ham radio operators, the vicinity of a broadcast band transmitter, etc. In such environments, the Schottky diodes of the receiver can be protected by a device known as a limiter diode.[5] Formerly available only in radar warning receivers and other high cost electronic warfare applications, these diodes have been adapted to commercial and consumer circuits.

Agilent offers a complete line of surface mountable PIN limiter diodes. Most notably, our HSMP-4820 (SOT-23) can act as a very fast (nanosecond) power-sensitive switch when placed between the antenna and the Schottky diode, shorting out the RF circuit temporarily and reflecting the excessive RF energy back out the antenna.

Assembly Instructions
SOT-3x3 PCB Footprint
Recommended PCB pad layouts for the miniature SOT-3x3 (SC-70) packages are shown in Figures 26 and 27 (dimensions are in inches). These layouts provide ample allowance for package placement by automated assembly equipment without adding parasitics that could impair the performance.

Figure 26. PCB Pad Layout, SOT-323 (dimensions in inches).

Figure 27. PCB Pad Layout, SOT-363 (dimensions in inches).

SMT Assembly
Reliable assembly of surface mount components is a complex process that involves many material, process, and equipment factors, including: method of heating (e.g., IR or vapor phase reflow, wave soldering, etc.) circuit board material, conductor thickness and pattern, type of solder alloy, and the thermal conductivity and thermal mass of components. Components with a low mass, such as the SOT packages, will reach solder reflow temperatures faster than those with a greater mass.

Agilent’s diodes have been qualified to the time-temperature profile shown in Figure 28. This profile is representative of an IR reflow type of surface mount assembly process.

After ramping up from room temperature, the circuit board with components attached to it (held in place with solder paste) passes through one or more preheat zones. The preheat zones increase the temperature of the board and components to prevent thermal shock and begin evaporating solvents from the solder paste. The reflow zone briefly elevates the temperature sufficiently to produce a reflow of the solder.

The rates of change of temperature for the ramp-up and cool-down zones are chosen to be low enough to not cause deformation of the board or damage to components due to thermal shock. The maximum temperature in the reflow zone ($T_{MAX}$) should not exceed 235°C.

These parameters are typical for a surface mount assembly process for Agilent diodes. As a general guideline, the circuit board and components should be exposed only to the minimum temperatures and times necessary to achieve a uniform reflow of solder.

Figure 28. Surface Mount Assembly Profile.
### Part Number Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>No. of Devices</th>
<th>Container</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSMS-282x-TR2*</td>
<td>10000</td>
<td>13” Reel</td>
</tr>
<tr>
<td>HSMS-282x-TR1*</td>
<td>3000</td>
<td>7” Reel</td>
</tr>
<tr>
<td>HSMS-282x-BLK</td>
<td>100</td>
<td>antistatic bag</td>
</tr>
</tbody>
</table>

x = 0, 2, 3, 4, 5, 7, 8, 9, B, C, E, F, K, L, M, N, P or R

---

### Package Dimensions

#### Outline 23 (SOT-23)

**Top View**
- 0.92 (0.036)
- 0.89 (0.035)
- 1.02 (0.040)
- 0.76 (0.030)
- 0.69 (0.027)

**Side View**
- 0.15 (0.006)
- 0.10 (0.004)
- 0.013 (0.0005)

**End View**
- 0.15 (0.006)
- 0.09 (0.003)

* THESE DIMENSIONS FOR HSMS-280X AND -281X FAMILIES ONLY.

DIMENSIONS ARE IN MILLIMETERS (INCHES)

---

#### Outline SOT-323 (SC-70 3 Lead)

**Top View**
- 0.135 (0.053)
- 0.115 (0.045)
- 0.65 (0.026)
- 0.3 (0.012)
- 0.20 (0.008)

**Side View**
- 0.1 (0.004)
- 0.00 (0.00)

**End View**
- 0.1 (0.004)
- 0.00 (0.00)

DIMENSIONS ARE IN MILLIMETERS (INCHES)

---

#### Outline 143 (SOT-143)

**Top View**
- 0.92 (0.036)
- 0.76 (0.030)
- 0.69 (0.027)

**Side View**
- 0.15 (0.006)
- 0.10 (0.004)
- 0.013 (0.0005)

**End View**
- 0.15 (0.006)
- 0.09 (0.003)

DIMENSIONS ARE IN MILLIMETERS (INCHES)

---

#### Outline SOT-363 (SC-70 6 Lead)

**Top View**
- 0.135 (0.053)
- 0.115 (0.045)
- 0.65 (0.026)
- 0.3 (0.012)
- 0.20 (0.008)

**Side View**
- 0.1 (0.004)
- 0.00 (0.00)

**End View**
- 0.1 (0.004)
- 0.00 (0.00)

DIMENSIONS ARE IN MILLIMETERS (INCHES)
### Tape Dimensions and Product Orientation

**For Outline SOT-323 (SC-70 3 Lead)**

**Device Orientation**

- **USER FEED DIRECTION**
- **COVER TAPE**
- **REEL**

#### Tape Dimensions

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SYMBOL</th>
<th>SIZE (mm)</th>
<th>SIZE (INCHES)</th>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LENGTH</td>
<td>A₀</td>
<td>2.24 ± 0.10</td>
<td>0.088 ± 0.004</td>
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<tr>
<td>WIDTH</td>
<td>B₀</td>
<td>2.34 ± 0.10</td>
<td>0.092 ± 0.004</td>
</tr>
<tr>
<td>DEPTH</td>
<td>P₀</td>
<td>1.22 ± 0.10</td>
<td>0.048 ± 0.004</td>
</tr>
<tr>
<td>PITCH</td>
<td>P₁</td>
<td>4.00 ± 0.10</td>
<td>0.157 ± 0.004</td>
</tr>
<tr>
<td>BOTTOM HOLE DIAMETER</td>
<td>D₁</td>
<td>1.00 ± 0.25</td>
<td>0.039 ± 0.010</td>
</tr>
<tr>
<td><strong>PERFORATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIAMETER</td>
<td>D</td>
<td>1.55 ± 0.05</td>
<td>0.061 ± 0.002</td>
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<tr>
<td>PITCH</td>
<td>P₀</td>
<td>4.00 ± 0.10</td>
<td>0.157 ± 0.004</td>
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<tr>
<td>POSITION</td>
<td>E</td>
<td>1.75 ± 0.10</td>
<td>0.069 ± 0.004</td>
</tr>
<tr>
<td><strong>CARRIER TAPE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIDTH</td>
<td>W₁</td>
<td>8.00 ± 0.30</td>
<td>0.315 ± 0.012</td>
</tr>
<tr>
<td>THICKNESS</td>
<td>T₁₁</td>
<td>0.255 ± 0.013</td>
<td>0.010 ± 0.0005</td>
</tr>
<tr>
<td><strong>COVER TAPE</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>WIDTH</td>
<td>C₁</td>
<td>5.4 ± 0.10</td>
<td>0.205 ± 0.004</td>
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<td>TAPE THICKNESS</td>
<td>T₁₂</td>
<td>0.062 ± 0.001</td>
<td>0.0025 ± 0.00004</td>
</tr>
<tr>
<td><strong>DISTANCE</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CAVITY TO PERFORATION (WIDTH)</td>
<td>F₁</td>
<td>3.50 ± 0.05</td>
<td>0.138 ± 0.002</td>
</tr>
<tr>
<td>(LENGTH DIRECTION)</td>
<td>P₁₂</td>
<td>2.00 ± 0.05</td>
<td>0.079 ± 0.002</td>
</tr>
</tbody>
</table>

**Note:**

- "###" represents Package Marking Code.
- Package marking is right side up with carrier tape perforations at top. Conforms to Electronic Industries RS-481, "Taping of Surface Mounted Components for Automated Placement."
- Standard quantity is 3,000 devices per reel.
P-Channel General Purpose Amplifier

This device is designed primarily for low level audio and general purpose applications with high impedance signal sources. Sourced from Process 89.

Absolute Maximum Ratings* TA = 25°C unless otherwise noted

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>Drain-Gate Voltage</td>
<td>-40</td>
<td>V</td>
</tr>
<tr>
<td>VGS</td>
<td>Gate-Source Voltage</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td>IDF</td>
<td>Forward Gate Current</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>TＪ, Tstg</td>
<td>Operating and Storage Junction Temperature Range</td>
<td>-55 to +150</td>
<td>°C</td>
</tr>
</tbody>
</table>

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 150 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics TA = 25°C unless otherwise noted

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Characteristic</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD</td>
<td>Total Device Dissipation</td>
<td>350 / 225</td>
<td>mW</td>
</tr>
<tr>
<td></td>
<td>Derate above 25°C</td>
<td>2.8 / 1.8</td>
<td>mW/°C</td>
</tr>
<tr>
<td>RJC</td>
<td>Thermal Resistance, Junction to Case</td>
<td>125 / *C/W</td>
<td></td>
</tr>
<tr>
<td>RJA</td>
<td>Thermal Resistance, Junction to Ambient</td>
<td>357 / 556 *C/W</td>
<td></td>
</tr>
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</table>

*Device mounted on FR-4 PCB 1.6” X 1.6” X 0.06.”
### Electrical Characteristics

**TA = 25°C unless otherwise noted**

#### OFF CHARACTERISTICS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{(BR)GS}$</td>
<td>Gate-Source Breakdown Voltage</td>
<td>$I_D = 10 \mu A, V_{DS} = 0$</td>
<td>40</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{GS}$</td>
<td>Gate Reverse Current</td>
<td>$V_{GS} = 20 , V, V_{DS} = 0$</td>
<td>5.0</td>
<td>1.0</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{GS} = 20 , V, V_{DS} = 0, T_A = 100^\circ C$</td>
<td>0.75</td>
<td>1.0</td>
<td>6.0</td>
<td>V</td>
</tr>
<tr>
<td>$V_{GS(off)}$</td>
<td>Gate-Source Cutoff Voltage</td>
<td>$V_{DS} = 15 , V, I_D = 1.0 \mu A$</td>
<td>5460</td>
<td></td>
<td>0.5</td>
<td>V</td>
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<tr>
<td></td>
<td></td>
<td>$V_{DS} = 15 , V, I_D = 0.1 , mA$</td>
<td>5461</td>
<td></td>
<td>0.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{DS} = 15 , V, I_D = 0.4 , mA$</td>
<td>5462</td>
<td></td>
<td>1.5</td>
<td>V</td>
</tr>
</tbody>
</table>

#### ON CHARACTERISTICS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{DSS}$</td>
<td>Zero-Gate Voltage Drain Current*</td>
<td>$V_{DS} = 15 , V, V_{GS} = 0$</td>
<td>5460</td>
<td>-1.0</td>
<td>-5.0</td>
<td>mA</td>
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<tr>
<td></td>
<td></td>
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<td>5461</td>
<td>-2.0</td>
<td>-9.0</td>
<td>mA</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>5462</td>
<td>-4.0</td>
<td>-16</td>
<td>mA</td>
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#### SMALL SIGNAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g_{fs}$</td>
<td>Forward Transfer Conductance</td>
<td>$V_{DS} = 15 , V, V_{GS} = 0, f = 1.0 , kHz$</td>
<td>5460</td>
<td>1000</td>
<td>4000</td>
<td>μmhos</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5461</td>
<td>1500</td>
<td></td>
<td>μmhos</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5462</td>
<td>2000</td>
<td></td>
<td>μmhos</td>
</tr>
<tr>
<td>$g_{os}$</td>
<td>Output Conductance</td>
<td>$V_{DS} = 15 , V, V_{GS} = 0, f = 1.0 , kHz$</td>
<td>5460</td>
<td></td>
<td>75</td>
<td>μmhos</td>
</tr>
<tr>
<td>$C_{iss}$</td>
<td>Input Capacitance</td>
<td>$V_{DS} = 15 , V, V_{GS} = 0, f = 1.0 , MHz$</td>
<td>5460</td>
<td></td>
<td>5.0</td>
<td>pF</td>
</tr>
<tr>
<td>$C_{rss}$</td>
<td>Reverse Transfer Capacitance</td>
<td>$V_{DS} = 15 , V, V_{GS} = 0, f = 1.0 , MHz$</td>
<td>5460</td>
<td></td>
<td>1.0</td>
<td>pF</td>
</tr>
<tr>
<td>NF</td>
<td>Noise Figure</td>
<td>$V_{DS} = 15 , V, V_{GS} = 0, R_G = 1.0 , \text{megohm}, f = 100 , Hz, \text{BW} = 1.0 , Hz$</td>
<td>5460</td>
<td>1.0</td>
<td>1.0</td>
<td>dB</td>
</tr>
<tr>
<td>$\theta_n$</td>
<td>Equivalent Short-Circuit Input Noise Voltage</td>
<td>$V_{DS} = 15 , V, V_{GS} = 0, f = 100 , Hz, \text{BW} = 1.0 , Hz$</td>
<td>5460</td>
<td>60</td>
<td>115</td>
<td>nV/√Hz</td>
</tr>
</tbody>
</table>

*Pulse Test: Pulse Width ≤ 300 ms, Duty Cycle ≤ 2%
P-Channel General Purpose Amplifier

Typical Characteristics (continued)

**Transfer Characteristics**
- $V_{DS} = -15V$
- $V_{GS(Off)}$, TYP = 4.0V
- $T_A = -55^\circ C$
- $T_A = +25^\circ C$
- $T_A = +125^\circ C$
- $V_{GS(Off)} = 1.8V$
- $T_A = -55^\circ C$
- $T_A = +25^\circ C$
- $T_A = +125^\circ C$

**Common Drain-Source**
- $T_A = 25^\circ C$
- TYP $V_{GS(Off)} = 1.8V$
- $V_{DS} = 0V$
- $I_D = $ DRAIN CURRENT (mA)
- $V_{DS} = $ DRAIN SOURCE VOLTAGE (V)

**Leakage Current vs. Voltage**
- $V_{DS} = -100 mV$
- $V_{DS} = 0$
- $V_{GS(Off)} = 1.0V$
- $V_{GS(Off)} = 1.8V$
- $V_{GS(Off)} = 5.0V$

**Channel Resistance vs. Temperature**
- $V_{DS} = -100 mV$
- $V_{DS} = 0$
- $V_{GS(Off)} = 1.0V$
- $V_{GS(Off)} = 1.8V$
- $V_{GS(Off)} = 5.0V$
P-Channel General Purpose Amplifier

Typical Characteristics

- **Output Conductance vs. Drain Current**
- **Transconductance vs. Drain Current**
- **Noise Voltage vs. Frequency**
- **Capacitance vs. Voltage**
- **Power Dissipation vs. Ambient Temperature**
TRADEMARKS

The following are registered and unregistered trademarks Fairchild Semiconductor owns or is authorized to use and is not intended to be an exhaustive list of all such trademarks.

<table>
<thead>
<tr>
<th>Trademark</th>
<th>Description</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>ACEx™</td>
<td>Fast®</td>
<td>Preliminary</td>
</tr>
<tr>
<td>Bottomless™</td>
<td>FastTr™</td>
<td>No Identification Needed</td>
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<tr>
<td>CoolFET™</td>
<td>FRFET™</td>
<td>Preliminary</td>
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<td>CROSSVOLT™</td>
<td>GlobalOptoisolator™</td>
<td>No Identification Needed</td>
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<tr>
<td>DenseTrench™</td>
<td>GTO™</td>
<td>Full Production</td>
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<tr>
<td>DOME™</td>
<td>HiSeC™</td>
<td>Formative or In Design</td>
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<tr>
<td>EcoSPARK™</td>
<td>ISOPLANAR™</td>
<td>Full Production</td>
</tr>
<tr>
<td>E²CMOS™</td>
<td>LittleFET™</td>
<td>First Production</td>
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<td>EnSigna™</td>
<td>MicroFET™</td>
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<td>OPTOLOGIC™</td>
<td>Full Production</td>
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<td>OPTOPLANAR™</td>
<td>POP™</td>
<td>Full Production</td>
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<td>PowerTrench®</td>
<td>QT Optoelectronics™</td>
<td>Full Production</td>
</tr>
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<td>SILENT SWITCHER®</td>
<td>Full Production</td>
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<td>SMART START™</td>
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<td>Full Production</td>
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<td>SuperSOT™-3</td>
<td></td>
<td>Full Production</td>
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<tr>
<td>SuperSOT™-6</td>
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<td>Full Production</td>
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<tr>
<td>VCX™</td>
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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

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<th>Datasheet Identification</th>
<th>Product Status</th>
<th>Definition</th>
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<td>Advance Information</td>
<td>Formative or In Design</td>
<td>This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.</td>
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<td>First Production</td>
<td>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.</td>
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Building a Probe for an HP4815A Vector Impedance Meter

HP 4815A Manual

HP has a good manual, which can be downloaded in PDF format here:

HP 4815A Manual
HP4815A-probe section

Rev. 1
March 18, 2004
WALLA WALLA COLLEGE
KittDa@wwc.edu
### Table 1-1. Specifications

**FREQUENCY**
- **Range:** 500 kHz to 108 MHz in five bands: 500 kHz to 1.5 MHz, 1.5 to 4.5 MHz, 4.5 to 14 MHz, 14 to 35 MHz, 35 to 108 MHz.
- **Accuracy:** ±2% of reading, ±1% of reading at 1.592 and 15.92 MHz.
- **RF monitor output:** 150 mV minimum into 50 ohms.

**IMPEDANCE MAGNITUDE MEASUREMENT**
- **Range:** 1 ohm to 100K ohms; full-scale ranges: 10, 30, 100, 300, 1K, 3K, 10K, 30K, 100K ohms.
- **Accuracy:** ±4% of full scale ± \((\frac{f}{30 \text{ MHz}} + \frac{Z}{25 \text{ k}\Omega})\)% of reading, where \(f\) = frequency in MHz and \(Z\) in ohms; reading includes probe residual impedance.
- **Calibration:** linear meter scale with increments 2% of full scale.

**PHASE ANGLE MEASUREMENT**
- **Range:** 0 to 360° in two ranges: 0 ± 90°, 180° ± 90°.
- **Accuracy:** ±(3 ± \(\frac{f}{30 \text{ MHz}} + \frac{Z}{25 \text{ k}\Omega}\)) degrees; where \(f\) = frequency in MHz and \(Z\) is in ohms.
- **Calibration:** increments of 90°.
- **Adjustments:** front panel screwdriver adjustments for Magnitude and Phase Zero.

**RECORDER OUTPUTS**
- **Frequency:** 0 to 1 volt from 0 to 1K ohm source, proportional to dial rotation.
- **Impedance magnitude:** 0 to 1 volt from 1K ohm source.
- **Phase angle:** 0 ± 0.9 volt from 1K ohm source.

**ACCESSORIES FURNISHED:**
1. 00600A Accessory Kit.
2. Rack Mounting Kit.
3. Plugin board extender.

**DIMENSIONS:**

**WEIGHT:** net 39 lbs. (17.6 kg), shipping 50 lbs. (22.5 kg).

**POWER:** 105 to 125 v or 210 to 250 v, 50 to 400 Hz, 50 w.

### Table 1-2. Additional Information

**MEASURING TERMINAL CHARACTERISTICS**
- **Configuration:** Both excitation and measuring circuits are contained in a single sampling probe attached to instrument by a cable. Measurement is made between probe center pin and ground pin on probe case.
- **Residuals:** indicated impedance includes approximately 0.5 ohm resistance and 8 nF inductance in series with the unknown, and 0.3 pF capacitance in parallel with the unknown.
- **Impedance:** 25 ohms in series with 0.01 μF, looking into probe. Probe is constant-current driving source to circuit being measured.

**TEST SIGNAL CHARACTERISTICS**
- **Waveshape:** sinusoidal.
- **Level:** approximately 4 μA on all ranges except 10-ohm scale where it is approximately 13 μA.

**External oscillator input:** Rear BNC connector accepts excitation signal, 100 mV ±10% into 50 ohms; maximum instantaneous rate of change 1 MHz/s.

**RFI CHARACTERISTICS**
Conducted and radiated leakage limits are below those specified for MIL-I-6181D, except for RF excitation and sampling pulses emitted from probe. The sampling pulses are approximately 75 mV peak to peak, from 25-ohm source, with a duration of 3 ns occurring at a maximum repetition rate of 1 MHz. Probe may be stored in front panel probe check socket to obtain full compliance with MIL-I-6181D.

**SELF-CONTAINED CALIBRATION**
- **Probe check:** 100 ohms ±.5% at phase angle of 90° ± 2°.
SECTION I
GENERAL INFORMATION

1-1. DESCRIPTION.

1-2. The Model 4815A RF Vector Impedance Meter (Figure 1-1) is a general purpose, self-contained instrument for measuring complex impedance in a wide variety of laboratory applications as well as production testing of circuits and components. The frequency range is 0.5 to 108 MHz; impedance magnitude is measured in 9 ranges from 10Ω to 100 kΩ full scale; and phase angle between 0° and 360° is indicated on two ranges.

1-3. Impedance measurement is made at the tip of a probe that is at the end of a 5 ft. cable, with rf test signal and measuring circuits brought close to the probe tip to reduce residual impedances.

1-4. An internal rf oscillator, 0.5 to 108 MHz supplies a test signal to the unknown impedance, 12.6 μA on the 10 Ω range and 4 μA on all other ranges. Provision is made for using an external rf source, particularly useful when measuring quartz crystals and other high Q devices.

1-5. Dc voltages proportional to magnitude, phase and frequency are available at the rear panel for recording equipment.

1-6. Complete specifications are given in Table 1-1.

1-7. Additional information on the Model 4815A is given in Table 1-2. The characteristics are general design parameters that are useful in the application of the Impedance Meter.

1-8. ACCESSORIES FURNISHED.

1-9. Accessory kit number 00600A is supplied with the 4815A. The kit consists of adapters for probe to BNC and Type N connectors, a probe socket for use on circuit boards, a component mounting adapter, probe holder, probe ground assembly and center pins. The probe accessories are described in detail in Paragraphs 1-9 to 1-16 and shown in Figure 1-1 and 1-2. Also supplied is a rack mounting kit with hardware (-hp- Stock No. 5060-0776) and a circuit board extender for servicing.

Figure 1-1. Model 4815A RF Vector Impedance Meter with 00600A Probe Accessory Kit
Section I
Paragraphs 1-10 to 1-21

1-10. PROBE ADAPTER. This adapter converts the probe tip to a male type N connector and is available under accessory number 10206A.

1-11. PROBE TO BNC ADAPTER. With the use of the 10206A accessory, this adapter converts the probe tip to a male BNC connector and is available under accessory number 10207A.

1-12. PROBE SOCKET. This socket supports the probe and guides the center pin to the test point. An excellent ground return is obtained with the socket, which is available under accessory number 10210A.

1-13. COMPONENT MOUNTING ADAPTER. This adapter allows many types of components to be measured with minimum addition of residual impedance to affect measurements, and is separately available as accessory number 00601A.

1-14. PROBE GROUND ASSEMBLY is a grounding device that may be positioned at a convenient point on the probe barrel. A spring-loaded pin makes ground contact. This accessory is available as -hp- Stock No. 187B-21A-8.

1-15. PROBE CENTER PINS. Six additional center pins are supplied against possible damage or loss. The small-diameter end of the center pin is inserted into the mating jack in the probe tip.

1-16. PROBE HOLDER. This accessory clips onto the front handle of the 4815A to hold the probe when not in use, and is available separately as -hp- Stock No. 5040-0404

1-17. ACCESSORIES AVAILABLE.

1-18. SHIELDED BANANA PLUGS TO FEMALE BNC. This adapter converts banana post inputs to shielded BNC, and is available as accessory 10111A. The adapter has approximately 10 pf shunt capacity.

1-19. INSTRUMENT IDENTIFICATION.

1-20. Each Model 4815A is identified by an eight-digit (000-00000) serial number on the rear panel. The five digit number is an identification number unique to each instrument and the three digit number is a serial prefix number used to document changes.

1-21. All instruments with the same serial prefix are the same. The group of instruments to which this manual applies directly is identified on the title page. For instruments with serial numbers higher than those listed on the title page, a Manual Change sheet describing the changes is included with the manual.

The manual for an instrument having special electrical modifications will include an insert sheet describing that modification. If a change sheet or special information sheet is missing, the information can be supplied by any Hewlett-Packard Sales and Service Office listed at the back of this manual.

Figure 1-2. Probe Accessories

00601A
Component Mounting Adapter

10207A
Probe to BNC Adapter

5040-0404
Probe Holder

10206A
Probe Adapter

04815-200770
Probe Center Pins

10210A
Probe Socket
Figure 4-1. Simplified Overall Block Diagram.
Sampling gate A16CR1-4 is normally reverse-biased by ac. A positive pulse to A16CR1-2 junction and a simultaneous negative pulse at A16CR3-4 junction let the diodes conduct briefly (about one nano-second). A16C1 charges toward the instantaneous rf voltage across A16R1 during this time. The pulses are so short that A16C1 can only charge about 25%. Positive feedback from A13AIQ3 raises the overall efficiency to between 80% and 100%. The A16C1 charge and A13AI output voltage are maintained until the next sample is taken.

Sampling gate A16CR5-8 is normally reverse-biased by ac. A positive pulse to A16CR5-6 junction and a simultaneous negative pulse to A16CR7-8 junction let the diodes conduct briefly (about one nano-second). A16C4 charges toward the instantaneous rf voltage at the output of A16DL1 during this time. The pulses are so short that A16C4 can only charge about 25%. Positive feedback from A13A2Q3 raises the overall sampling efficiency to between 80% and 100%. The A16C4 charge and A13A2 output voltage are maintained until the next sample is taken. A16DL1 allows sampling of both voltage and current at the same point of the rf waveform without interaction between samplers.

For all the sampling diodes to conduct simultaneously the reverse bias on each sampling diode must be equal and the gating pulses must be of the same amplitude but of opposite polarity. Balun A13AIQ1T2 develops, and A13AIQ1T1 maintains equal but opposite polarity pulses. A13AIQ1-3 provides the gain to improve overall sampling efficiency. A voltage divider network develops two volts of dc to reverse bias the sampling gate diodes.

For all the sampling diodes to conduct simultaneously the reverse bias on each sampling diode must be equal and the gating pulses must be of the same amplitude but of opposite polarity. Balun A13A5T2 develops, and A13A5T1 maintains equal but opposite polarity pulses. A13A2Q1-3 provides the gain to improve overall sampling efficiency. A voltage divider network develops two volts of dc to reverse bias the sampling gate diodes.
Results

We didn't complete the project, but we did get some promising results from our work. Our magnitude measurements came out fairly well, being off by a constant. Our phase was also quite constant, being off by 60 degrees.

The magnitude and phase, as output by the HP4815A were:
At 0.5 MHz:

<table>
<thead>
<tr>
<th>Resistor Value</th>
<th>Meter Reading</th>
<th>Phase</th>
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<tbody>
<tr>
<td>100 kohms</td>
<td>21 kohms</td>
<td>-60 °</td>
</tr>
<tr>
<td>10 kohms</td>
<td>2.1 kohms</td>
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<td>1 kohms</td>
<td>200 ohms</td>
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</tr>
<tr>
<td>100 ohms</td>
<td>21 ohms</td>
<td>-60 °</td>
</tr>
</tbody>
</table>

Here are some pictures of our output through the load:

Oscillator Output
Building a Probe for an HP4815A Vector Impedance Meter

Sampling Pulses

Current sampling board

Voltage sampling board

Notice the significant number of coax coming off the board
Advice: make a bigger board with better connections

Rev. 1
March 18, 2004