Operation of the HC5523, HC5515 Evaluation Board

Application Note | December 1996 | AN9632

Features

- Includes the Ringing Relay
- Toggle Switch Programming for Logic States
- Convenient Monitoring of $\overline{DET}$ Via LED or Banana Jack Output
- Logic Terminal Port for Easy Evaluation in Existing Systems
- Includes On-Board Op Amp for Evaluation of Transhybrid Balance
- Pulse Metering Capability

Applications

- Solid State Line Interface for Digital and Analog Telephone Line Cards

Functional Description

The HC5523/15EVAL Subscriber Line Interface Circuit (SLIC) evaluation board has provisions for full evaluation of the voice and DC feeding characteristics of the HC5523 and the HC5515, including the ringing function.

SLIC functional control is provided using the toggle switches E0, E1, C1 and C2. The logic truth tables for the HC5523 and the HC5515 are shown in Table 2 and Table 3 respectively. $\overline{DET}$ is available at both a banana jack for monitoring with test instrumentation, as well as an LED for visual verification.

Applying Power to the HC5523/15EVAL

Power Supply Connections

The HC5523/15EVAL requires three external power supplies for operation. The supply voltages are labeled on the HC5523/15EVAL as V_{CC} +5V, V_{EE} -5V and V_{BAT}. The typical supply currents, when the SLIC is in the Active mode and terminated with a 600Ω load, are given in Table 1.

TABLE 1. POWER SUPPLY INFORMATION

SUPPLY	TYP (V)	TYP (mA)
V_{CC} +5V	+5	11
V_{EE} -5V	-5	1
V_{BAT}, R_{SG} is Open Circuit	-28	27
V_{BAT}, R_{SG} is 4.0kΩ	-48	30

Ground Connections

The HC5523/15EVAL has two separate grounds designated as AGND and BGND. AGND is the analog ground reference for the SLIC. BGND is the battery ground reference, and is to be connected to zero potential. All loop current and longitudinal current flow from this ground. For proper SLIC operation, AGND and BGND must be connected to a common ground, with a potential difference not exceeding ±100mV.

HC5523/15EVAL Board SLIC Controls

The design of the HC5523/15EVAL board incorporates five SPDT switches. Four of the switches control the functional state of the SLIC and the fifth controls the DET output.

Mode Control Switches

The four switches labeled E0, E1, C1 and C2 are used to set the operational mode of the HC5523. Three switches labeled E0, C1 and C2 are used to set the operational mode of the HC5515. Each switch is a Single Pole Double Throw (SPDT) switch with a center open position.

The two inputs labeled E0 and E1 are enable pins. The two pins labeled C1 and C2 are used to select 1 of 4 operating states of the SLIC. Refer to the HC5523 or the HC5515 data sheet for a full description of the functionality of each pin.

If off-board mode control of the SLIC is desired, the four switches can be set to center open position and driven by logic at the logic terminal port. The logic terminal port is located just below the toggle switches at the bottom of the board. A common ground must exist between the HC5523/15EVAL evaluation board and the off board logic. A differential ground voltage may result in erroneous logic states at the SLIC inputs.

$\overline{DET}$ Select Switch

A switch is provided on the evaluation board to direct the $\overline{DET}$ signal to one of two outputs. With the switch positioned to the right, $\overline{DET}$ will illuminate the LED, when positioned to the left, $\overline{DET}$ may be monitored at the banana jack using an oscilloscope.

Verifying the HC5523/15EVAL Operation

The operation of the HC5523/15EVAL and the sample part can be verified by performing six tests:

1. Power Supply Current Verification.
2. Active Mode Verification.
3. Standby Mode Verification.
4. SLIC Gain Verification.
5. Ring Trip Detector Verification.
6. Transhybrid Balance Verification.

The first four tests require a 600Ω load, an AC volt meter and an oscilloscope. The last test requires a telephone and a battery backed AC source. All of the tests require three external supplies, one each for V_{CC}, V_{EE}, and V_{BAT}.

Verify that the sample HC5523 or the HC5515 included with the evaluation board is oriented in its socket correctly. Correct orientation is with pin 1 pointing towards the bottom of the board.

Application Tip: When terminating tip and ring on the HC5523/15EVAL, it is handy to assemble terminators using a Pomona MDP dual banana plug connector as the terminating resistor receptacle. Refer to Figure 1 for details.

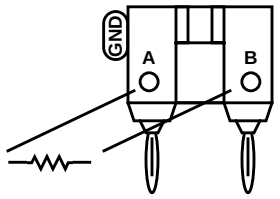


FIGURE 1. TERMINATION ADAPTER

Using the termination shown in Figure 1 provides an unobtrusive technique for terminating tip and ring while still providing access to both signals using the banana jack feature of the MDP connector. Posts are also available that fit into holes A and B, providing a solderable connection for the terminating resistor.

Test No. 1 - Power Supply Current Verification

A quick check of evaluation board and the sample is to measure the currents of each supply voltage. The readings should be similar to the values listed in Table 1. The measurements can be made using a series ammeter on each supply, or power supplies with current displays.

SETUP:

1. Connect the power supplies to the HC5523/15EVAL.
2. Set V_{BAT} to -48V.
3. Connect AGND and BGND to common ground point.
4. Connect V-REC pin to common ground point.
5. Terminate the HC5523 or the HC5515 with 600Ω load across Tip and Ring.
6. Set the mode switches to E0 = 0, E1 = 1, C1 = 0, C2 = 1.

DISCUSSION:

Once setup is complete, apply power to the HC5523/15EVAL and verify the supply currents listed in Table 1. Note that special power supply sequencing is not required for either the HC5523 or the HC5515.

Test No. 2 - Active Mode Verification

This test verifies loop current operation and loop current detection in the Active mode via the onboard LED.

SETUP:

1. Connect the power supplies to the HC5523/15EVAL.
2. Set V_{BAT} to -48V.
3. Connect AGND and BGND to common ground point.
4. Connect V-REC pin to common ground point.
5. Terminate the HC5523 or the HC5515 with 600Ω load across Tip and Ring.
6. Set the mode switches to E0 = 0, E1 = 1, C1 = 0, C2 = 1.
7. Position the $\overline{DET}$ select switch to the right.

DISCUSSION:

When power is applied to the SLIC a loop current will flow from tip to ring through the 600Ω load. This loop current triggers an internal detector that pulls the output of $\overline{DET}$ low, illuminating the LED through the +5V supply. Once the LED illuminates, remove the 600Ω termination and verify that the LED turns off.

VERIFICATION:

1. LED is on when tip and ring are terminated with 600Ω.
2. LED is off when tip and ring are open circuit.

Test No. 3 - Standby Mode Verification

This test verifies loop current operation and loop current detection in the Standby state via the banana jack interface.

SETUP:

1. Connect the power supplies to the HC5523/15EVAL.
2. Set V_{BAT} to -48V.
3. Connect AGND and BGND to common ground point.
4. Connect V-REC pin to common ground point.
5. Terminate the HC5523 or the HC5515 with 600Ω load across Tip and Ring.
6. Set the mode switches to E0 = 0, E1 = 1, C1 = 1, C2 = 1.
7. Position the $\overline{DET}$ select switch to the left.
8. Connect an oscilloscope or DC voltmeter to the $\overline{DET}$ jack.
9. Monitor the V_{BAT} supply current.

DISCUSSION:

When power is applied to the SLIC, loop current will flow from tip to ring through the 600Ω load. This loop current triggers an internal detector that pulls the output of $\overline{DET}$ near zero volts. Disconnecting the 600Ω termination will cause $\overline{DET}$ to be pulled to the V_{CC} rail. In Standby mode, the V_{BAT} current should be approximately 16.4mA with the 600Ω termination and 0.8mA without the 600Ω termination.

VERIFICATION:

1. $\overline{DET}$ is near 0V when terminated with 600Ω.
2. $\overline{DET}$ is near the V_{CC} rail when not terminated with 600Ω.
3. V_{BAT} current is near 16.4mA when terminated.
4. V_{BAT} current is near 0.8mA when not terminated.

Test No. 4 - SLIC Gain Verification

This test will verify that SLIC is operating properly and that the SLIC is exhibiting unity gain. Unity gain will only exist if the SLIC is properly terminated with 600Ω.

SETUP:

1. Connect the power supplies to the HC5523/15EVAL.
2. Set V_{BAT} to- 48V.
3. Connect AGND and BGND to common ground point.
4. Terminate the HC5523 or the HC5515 with 600Ω load across Tip and Ring.
5. Set the mode switches to E0 = 0, E1 = 1, C1 = 0, C2 = 1.
6. Connect a sine wave generator to the V-REC input.
7. Set the generator for $0.775V_{RMS}$ and 1kHz.
8. Connect an AC voltmeter across tip and ring.

DISCUSSION:

When terminated with 600Ω, the SLIC will exhibit unity gain from the V-REC input pin to across tip and ring. The unity gain results from the matched impedance that the 600Ω termination represents to the internally synthesized 600Ω of the SLIC. When an open circuit exists, a mismatch occurs and the gain of the SLIC will double.

VERIFICATION:

1. Tip to ring AC voltage of $0.775V_{RMS}$ when terminated.
2. Tip to ring AC voltage of $1.55V_{RMS}$ when not terminated.

Test No. 5 - Ring Trip Detector Verification

This test will verify the ringing function of the SLIC. A telephone and an AC signal source are the only additional hardware required to complete the test.

SETUP:

1. Connect the power supplies to the HC5523/15EVAL.
2. Set V_{BAT} to -28V.
3. Connect AGND and BGND to common ground point.
4. Connect V-REC pin to common ground point.
5. Set the mode switches to E0 = 0, E1 = 1, C1 = 1, C2 = 0.
6. Connect the telephone across tip and ring.
7. Connect battery backed AC (20 Hz oscillator) to RINGING (V_{BAT} + $90V_{RMS}$) banana jack.
8. Position $\overline{DET}$ select switch to the right (for LED).

DISCUSSION:

The 600Ω termination is not necessary for this test since the phone provides this nominal impedance when off-hook. Setting the mode switches as shown above will cause the RINGRLY pin of the SLIC to energize the relay that is on the evaluation board. The D_T and D_R comparator inputs will sense the flow of DC loop current, causing the Ring Trip comparator to sense when the phone is either on-hook or off-hook. Refer to the HC5523 or the HC5515 data sheet for a full description of the functionality of the Ring Trip Detector.

VERIFICATION:

1. Phone starts ringing when power applied to test setup.
2. While ringing and on-hook, $\overline{DET}$ LED is not illuminated.
3. While ringing, going off-hook will illuminate the LED.
   - CAUTION: Short time durations of off-hook should be maintained to protect R_{RT}. In systems, the ring relay is software controlled to turn off milliseconds after off-hook is detected, hence limiting power dissipated in R_{RT}.
4. When phone is returned to on-hook, LED will turn off.
5. Configure SLIC in Active mode to stop phone from ringing. Set mode switches to E0 = 0, E1 = 1, C1 = 0, C2 = 1.

Test No. 6 - Transhybrid Balance Verification

This test will verify the transhybrid balance circuitry for both the voice path and the pulse metering (TELETAX) path. A low distortion AC signal and a voltmeter are the only additional hardware required to complete this test.

VOICE PATH

SETUP:

1. Connect the power supplies to the HC5523/15EVAL.
2. Set V_{BAT} to -48V.
3. Connect AGND and BGND to common ground point.
4. Terminate the HC5523 or the HC5515 with 600Ω load across Tip and Ring.
5. Set the mode switches to E0 = 0, E1 = 1, C1 = 0, C2 = 1.
6. Set the AC source to $1V_{RMS}$, 1kHz and apply to the V-REC input.
7. Connect an AC voltmeter between the V-XMIT and GND.

DISCUSSION:

Transhybrid balance is a measure of how well the input signal is canceled (that being received by the SLIC) from the transmit signal (that being transmitted from the SLIC). Without this function, voice communication would be difficult because of the echo.

VERIFICATION:

1. Measure the AC voltage at V-XMIT output.
2. Calculate the Transhybrid balance using Equation 1.

$$\text{Transhybrid(dB)} = 20 \times \log \frac{\text{V - XMIT}}{1V_{RMS}} \quad \text{(EQ. 1)}$$

3. The value should be approximately -40dB.

PULSE METERING OPTION

SETUP:

1. Connect the power supplies to the HC5523/15EVAL.
2. Set V_{BAT} to -48V.
3. Connect AGND and BGND to common ground point.
4. Terminate the HC5523 or the HC5515 with 600Ω load across Tip and Ring.
5. Set the mode switches to E0 = 0, E1 = 1, C1 = 0, C2 = 1.
6. Set the AC source to $1V_{RMS}$, 12kHz or 16kHz and apply to the V-PM input.
7. Connect an AC voltmeter between the V-XMIT and GND.

DISCUSSION:

The pulse metering signal is a 12kHz or 16kHz signal that is injected on to the tip and ring lines. This signal is monitored by a counter (non-U.S. markets) inside the pay phone, which tallies up the cost of the call.

VERIFICATION:

1. Measure the AC voltage at V-XMIT output.
2. Calculate the Transhybrid balance using Equation 1.
3. The value should be approximately -25dB.

Passive Components

The HC5523/15EVAL design incorporates all of the external components necessary for using the HC5523 or the HC5515 in normal applications. A brief description of each component is provided below. The components will be grouped by function to provide further insight to the operation of the HC5523/15EVAL board.

TWO WIRE SIDE, TIP AND RING

Relay	Allows injection of ringing signal.
PTC	Provides thermal protection for relay to ground path during extended periods of use. The PTC is not provided with HC5523/15EVAL board.
R_{F1}, R_{F2}	Feed resistors that limit the current into the tip and ring inputs of the SLIC.
D_1, D_4	Provide transient protection on the tip and ring inputs.
C_{TC}, C_{RC}	Provide immunity against high frequency noise on tip and ring respectively.

The Two Wire Side components are typical telephone values. Design equations are not used for these components.

RING TRIP DETECTOR

R_1, R_2	Generate a bias voltage from V_{BAT} to drive the RD pin.
R_3, R_4, R_{RT}	Combine to sense off-hook condition and drive the RT pin.
C_{RT}	Provides attenuation of the ring signal for stability of DT pin.

The component values for the Ring Trip Detector circuit do not require design equations. For information concerning the functionality of this supervisory function refer to the “Supervisory Function” section of the HC5523 or the HC5515 Data Sheet.

LOOP CURRENT DETECTOR

R_D	Sets the loop current detect threshold for the SLIC’s internal comparator function.

The value of R_D programs the loop current detect threshold for the SLIC. Since the internal comparator has hysteresis, there are two equations that apply to the value of R_D. One equation is for on-hook to off-hook threshold, and the other is for off-hook to on-hook threshold. The equations for each condition are as follows:

On-Hook to Off-Hook Threshold

$$R_D = \frac{465}{I_{ON-HOOK\ to\ OFF-HOOK}} \quad \text{(EQ. 2)}$$

Off-Hook to On-Hook Threshold

$$R_D = \frac{375}{I_{OFF-HOOK\ to\ ON-HOOK}} \quad \text{(EQ. 3)}$$

For details concerning the design equations refer to the “Supervisory Function” section of the HC5523 or the HC5515 Data Sheet. As delivered, the HC5523/15EVAL is configured for a loop current detect level of 11.9mA for on-hook to off-hook, and 9.6mA for off-hook to on-hook.

SATURATION GUARD RESISTOR

R_{SG}	Sets the saturation guard for the SLIC.

When operating in systems with a -28V battery, R_{SG} needs to be an open circuit. When operating in systems with a -48V battery, R_{SG} needs to be 4.0kΩ as per the following equation:

$$R_{SG} = \frac{5 \bullet 10^5}{|V_{BAT}| - V_{MAR} - 16.66V} - 17300 \quad \text{(EQ. 4)}$$

For details concerning the design equations refer to the “Constant Loop Current (DC) Path” section of the HC5523 or the HC5515 Data Sheet. As delivered, the HC5523/15EVAL is configured for a saturation guard of 4V on both the tip side and ring side, resulting in a V_{MARGIN} of 8V for V_{BAT} of -48V.

FOUR WIRE SIDE, SLIC IMPEDANCE MATCHING

R_T	Sets the synthesized impedance across the tip and ring terminals.
R_{RX}	Performs a voltage to current conversion of the receive signal. Selected to maintain unity gain from 4-wire to 2-wire side when SLIC is terminated with 600Ω.

The values of R_T and R_{RX} have been selected for a 600Ω system. These values can be modified for different impedances. Also, complex impedance matching is possible using these components. For information on impedance matching of the SLIC, refer to the “(AC) 2-Wire Impedance” section of the HC5523 or the HC5515 Data Sheet.

CONSTANT FEED CURRENT PROGRAMMING

R_{DC1}, R_{DC2}	Sets the constant feed current that flows from tip to ring when a DC path is present during off-hook conditions. Resistance is split to allow capacitor for filtering (C_{DC}).
C_{DC}	Filter capacitor to attenuate high frequency noise that is fed back from tip and ring.

The constant feed current is programmed using the sum of R_{DC1} and R_{DC2}. The design equation used to set the loop current is shown below.

$$I_L = \frac{2.5V}{R_{DC1} + R_{DC2}} \times 1000 \quad \text{(EQ. 5)}$$

For details concerning the design equations for loop current as well as the selection of C_{DC} refer to the “Constant Loop Current (DC) Path” section of the HC5523 or the HC5515 Data Sheet. As delivered, the constant feed current is set at 30mA.

TRANSHYBRID BALANCE

U2	Op-amp used for transhybrid balance.
R_{TX}, R_B, FB, RPM	Used as part of transhybrid balance circuitry that is located off board.

Transhybrid balance is accomplished by using an external op amp (U2, usually part of the CODEC) and by the inversion of the signal from the 4-wire receive port (RSN) to the 4-wire transmit port (V_{TX}). The input signal will be subtracted from the output signal if I_1 equals I_2 (Figure 2). Node analysis yields the following equation:

$$\frac{V_{TX}}{R_{TX}} + \frac{V_{RX}}{Z_B} = 0 \quad \text{(EQ. 6)}$$

The value of Z_B is then

$$Z_B = -R_{TX} \bullet \frac{V_{RX}}{V_{TX}} \quad \text{(EQ. 7)}$$

Where V_{RX}/V_{TX} equals 1/ A_{4-4}.

Therefore,

$$Z_B = R_{TX} \bullet \frac{Z_{RX}}{Z_T} \bullet \frac{\frac{Z_T}{1000} + 2R_F + Z_L}{Z_L + 2R_F} \quad \text{(EQ. 8)}$$

Example:

Given: R_{TX} = 20kΩ, Z_{RX} = 280kΩ, Z_T = 562kΩ and Z_L = 600Ω and R_F = 20Ω.

The value of Z_B = 18.7kΩ 1%.

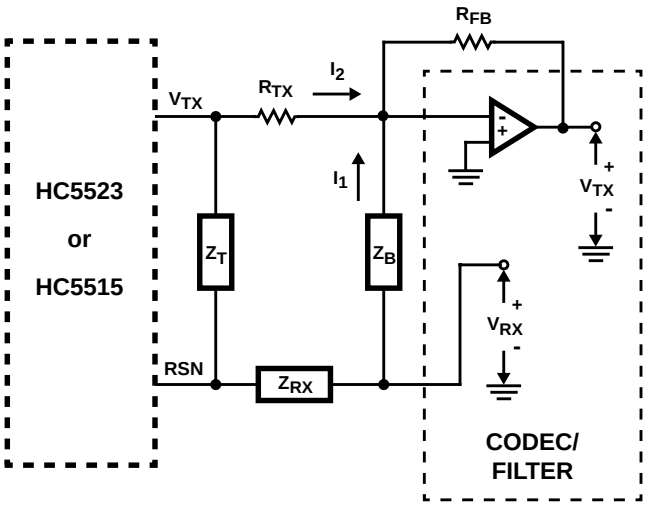


FIGURE 2. TRANSHYBRID CIRCUIT

Logic Truth Table

The logic truth tables for the HC5523 and the HC5515 are shown in Table 2 and Table 3 respectively. The SLIC has four operating states. The states are Open Circuit, Active, Ringing and Standby. Each state, except Open Circuit, has options available selecting the supervisory signal that drives the $\overline{DET}$ pin. The supervisory signals are Ground Key Detect (HC5523 only), Loop Current Detect and Ring Trip Detect.

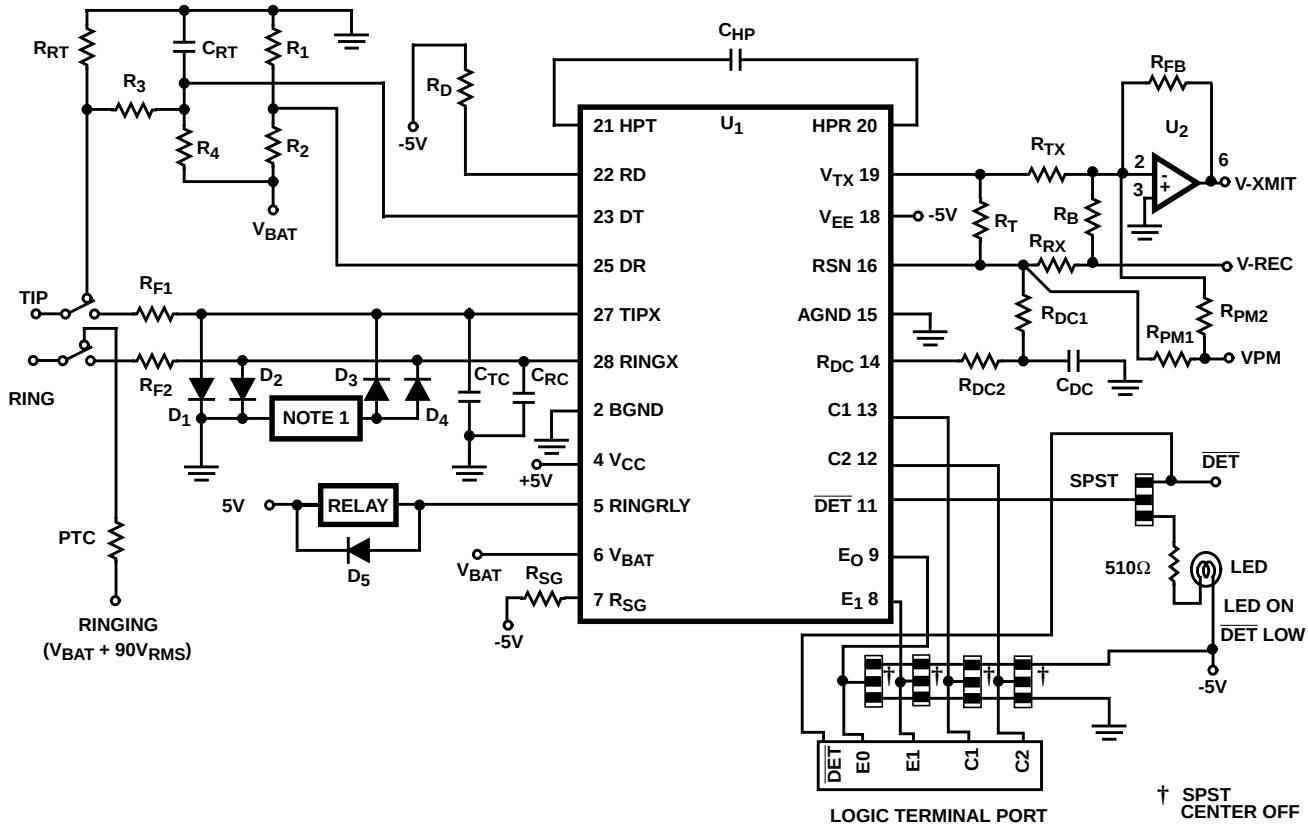
HC5523/15 SLIC Operating States

TABLE 2. HC5523 LOGIC TRUTH TABLE

E0	E1	C1	C2	SLIC OPERATING STATE	ACTIVE DETECTOR	$\overline{DET}$ OUTPUT
0	0	0	0	Open Circuit	No Active Detector	Logic Level High
0	0	0	1	Active	Ground Key Detector	Ground Key Status
0	0	1	0	Ringing	No Active Detector	Logic Level High
0	0	1	1	Standby	Ground Key Detector	Ground Key Status
0	1	0	0	Open Circuit	No Active Detector	Logic Level High
0	1	0	1	Active	Loop Current Detector	Loop Current Status
0	1	1	0	Ringing	Ring Trip Detector	Ring Trip Status
0	1	1	1	Standby	Loop Current Detector	Loop Current Status
1	0	0	0	Open Circuit	No Active Detector	Logic Level High
1	0	0	1	Active	Ground Key Detector	
1	0	1	0	Ringing	No Active Detector	
1	0	1	1	Standby	Ground Key Detector	
1	1	0	0	Open Circuit	No Active Detector	
1	1	0	1	Active	Loop Current Detector	
1	1	1	0	Ringing	Ring Trip Detector	
1	1	1	1	Standby	Loop Current Detector	

TABLE 3. HC5515 LOGIC TRUTH TABLE

E0	C1	C2	SLIC OPERATING STATE	ACTIVE DETECTOR	$\overline{DET}$ OUTPUT
0	0	0	Open Circuit	No Active Detector	Logic Level High
0	0	1	Active	Loop Current Detector	Loop Current Status
0	1	0	Ringing	Ring Trip Detector	Ring Trip Status
0	1	1	Standby	Loop Current Detector	Loop Current Status
1	0	0	Open Circuit	No Active Detector	Logic Level High
1	0	1	Active	Loop Current Detector	
1	1	0	Ringing	Ring Trip Detector	
1	1	1	Standby	Loop Current Detector	



NOTE:

1. The anodes of D_3 and D_4 may be connected directly to the V_{BAT} supply if the application is exposed to only low energy transients. For harsher environments it is recommended that the anodes of D_3 and D_4 be shorted to ground through a transzorb or surgector.

FIGURE 3. DEMO BOARD SCHEMATIC

HC5523/15EVAL Evaluation Board Parts List

TABLE 4. EVALUATION BOARD PARTS LIST

COMPONENT	VALUE	TOLERANCE	RATING	COMPONENT	VALUE	TOLERANCE	RATING
U1 - SLIC	HC5523 or HC5515			R_{PM2}	18.7kΩ	1%	1/4W
U2	CA741C Op Amp			R_{RT}	150Ω	5%	2W
R_{F1}, R_{F2}	20Ω	1% match	1/2W	R_{SG}, V_{BAT} = -48V	4.0kΩ	1%	1/4W
R_1, R_3	200kΩ	5%	1/4W	R_{DC1}, R_{DC2}	41.2kΩF	5%	1/4W
R_2	910kΩ	5%	1/4W	C_{DC}	1.5µF	20%	63V, (npo)
R_4	1.2MΩ	5%	1/4W	C_{HP}	10nF	20%	100V, (npo)
R_B	18.7kΩ	1%	1/4W	C_{RT}	0.39µF	20%	100V, (npo)
R_D	39kΩ	5%	1/4W	C_{TC}, C_{RC}	2200pF	20%	100V, (npo)
R_{FB}	20.0kΩ	1%	1/4W	D_1 - D_4	1N4007 or Equivalent		100V, 3A
R_{RX}	280kΩ	1%	1/4W	D_5	1N914	N/A	N/A
R_T	562kΩ	1%	1/4W	PTC	Shorted	N/A	N/A
R_{TX}	20kΩ	1%	1/4W	K_R	2C Contacts, 12V Coil		N/A
R_{LED}	510Ω	10%	1/4W	Textool Socket	228-5523		
R_{PM1}	280kΩ	1%	1/4W				

HC5523/15EVAL Evaluation Board Layout

FIGURE 4. SILK SCREEN

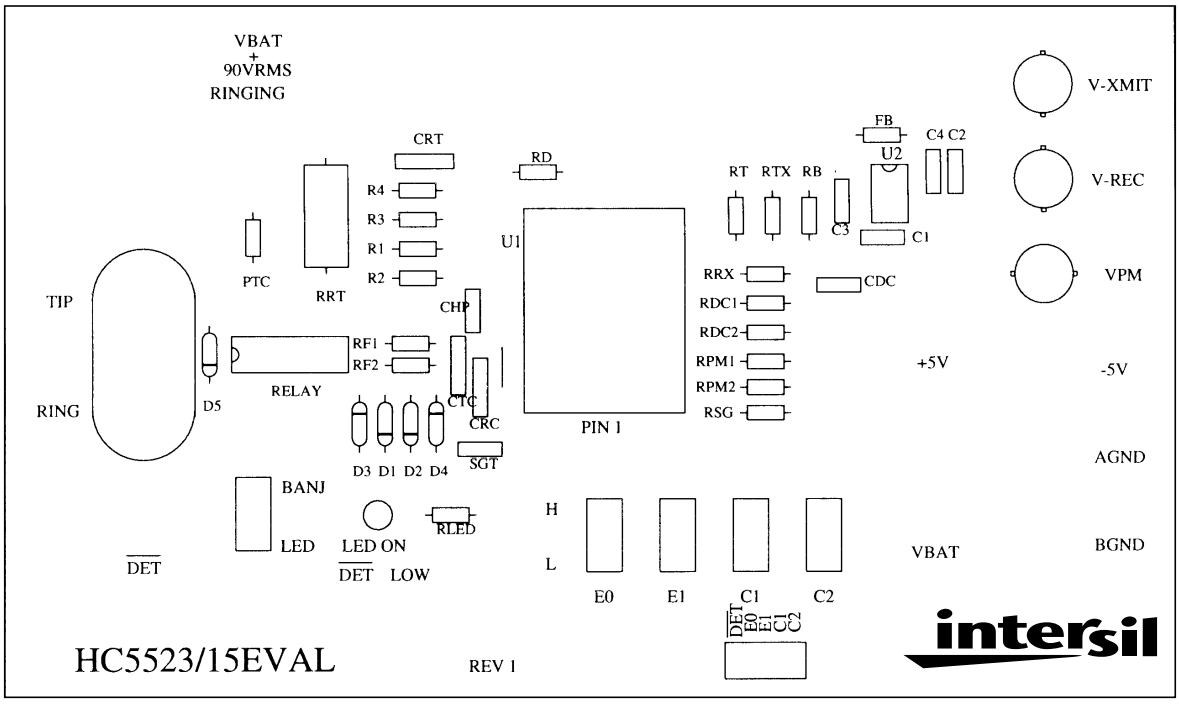
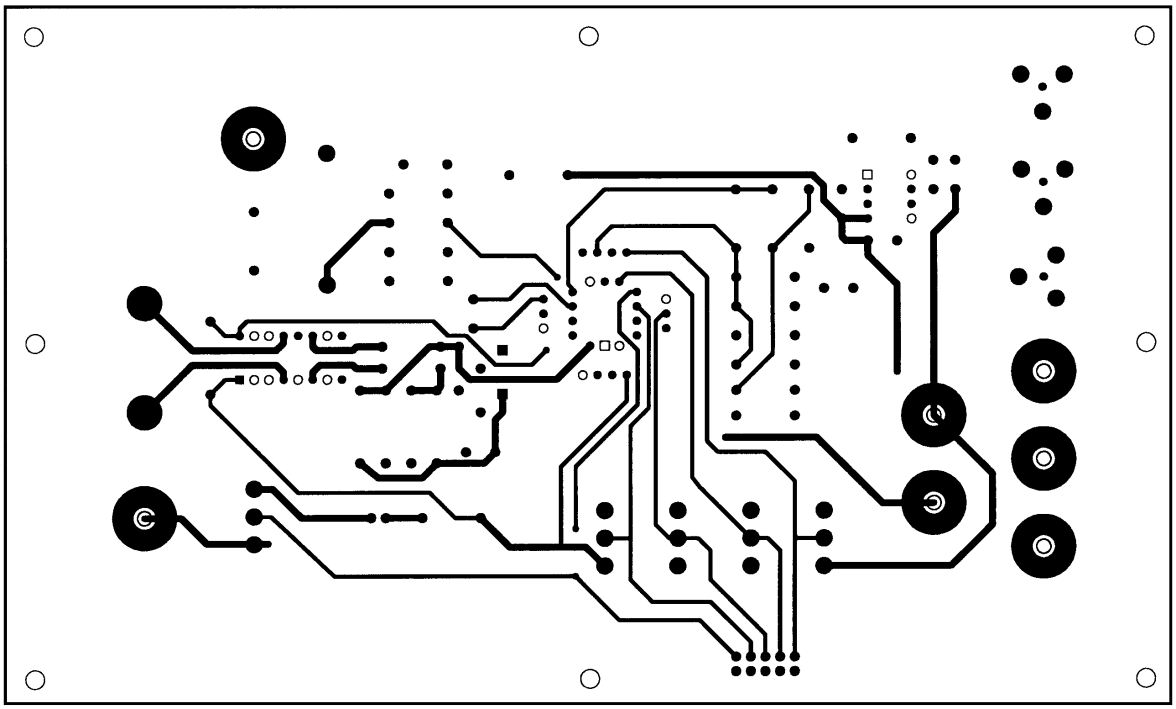


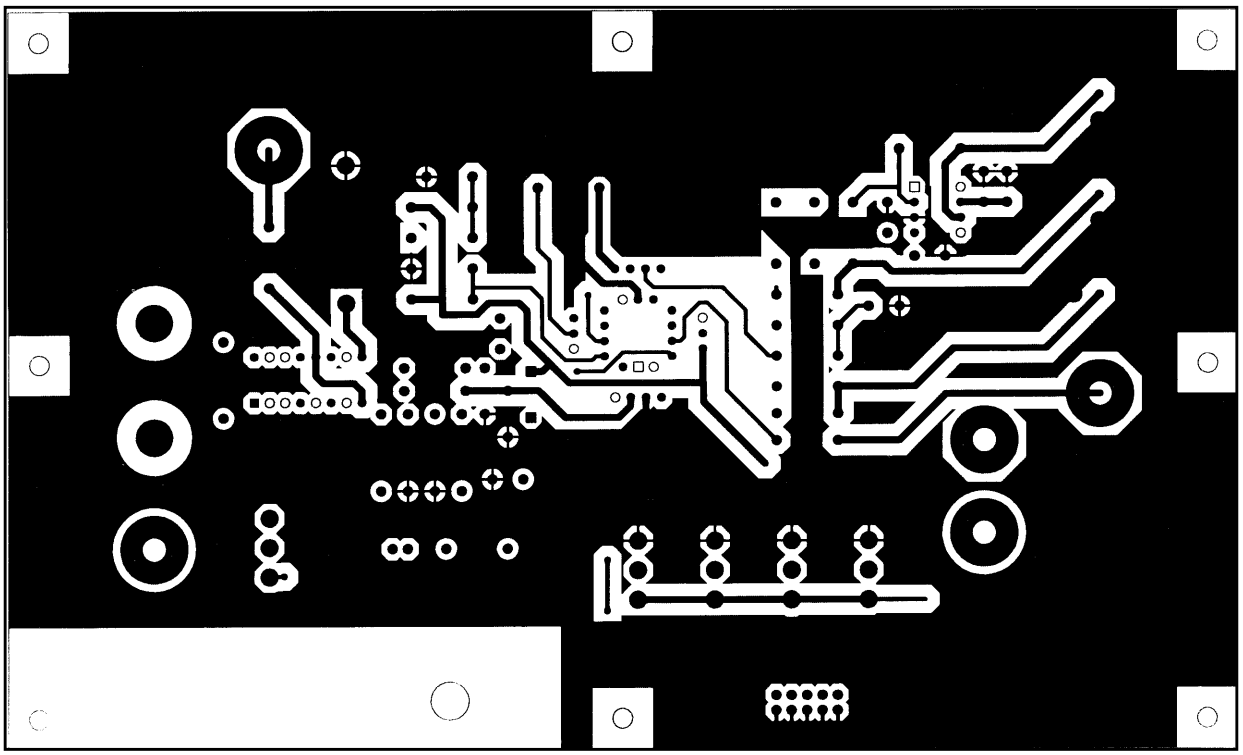
FIGURE 5. TOP SIDE



NOTE: Board dimensions not actual size.

HC5523/15EVAL Evaluation Board Layout (Continued)

FIGURE 6. BOTTOM SIDE



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