Telecom Switches (Appnote 65)

Introduction

As a companion to this document, please refer to the respective telecom switch data sheets for more information.

The LH1529 and LH1549 Telecom Switches consist of an optically isolated solid state relay (SSR) and autopolarity optocoupler in a single 8-pin package. The LH1529 and LH1549 differ on three parameters, SSR load voltage, SSR ON-resistance, and optocoupler LED continuous forward current. The following table illustrates the differences between the two devices:

Device	SSR V_L (V)	SSR R_{ON} (Ω) Max	Optocoupler I_F (mA) Max
LH1529	350	25	50
LH1549	400	33	120

Within the telecom switch, the SSR is ideal for performing on/off-hook control and dial pulse switching. The optocoupler is ideal for ring detection and loop current sensing functions. Both the SSR and the optocoupler provide up to 5300 V_{RMS} of input-to-output isolation to satisfy worldwide telecom safety requirements.

Figure 1 shows the LH1529 SSR being used for on/off-hook control and dial pulsing, and the optocoupler being used for ring detection in a modem circuit. A discussion of this application follows.

On/Off-Hook Control

For on/off-hook control, the function of the SSR is that of a switchhook, to make a connection to the telephone loop. The SSR has a 1 Form A contact (SPST-NO) between pins 7 and 8, which is actuated by an LED between pins 1 and 2. An appropriate LED drive current (I_{FON}) can be derived from Figure 2. Drive current is dependent upon ambient and junction temperature. Elevated ambient temperatures and electrical self-heating from high-load currents mandate a higher LED drive current. Figure 2 utilizes a worst-case parameter analysis and takes into account manufacturing tolerances in order to ensure SSR turn-on. For the circuit in Figure 1, a minimum of 5 mA drive current is provided.

This drive current can easily be sinked from TTL logic or sourced or sinked from modem chip set CMOS. The 5 mA was selected from Figure 2 as a value that guarantees hook control up to 85 °C ambient temperature with loop current potentials better than 80 mA. The input resistor value (R_{IN}) was calculated assuming a minimum supply voltage of 4.75 V and a maximum LED voltage drop of 1.45 V at 0 °C.

$$\frac{V_{CC(min)} - V_{F(max)}}{I_{F(min)}} = R_{IN(max)}$$

Where $V_{CC(min)}$ is the minimum supply voltage, $V_{F(max)}$ is the maximum forward voltage drop of the LED at the coldest ambient temperature, and $I_{F(min)}$ is the minimum desired LED forward current. The maximum value for R_{IN} equates to 660 Ω. The next lowest common resistor value of 620 Ω is used. For a more in-depth discussion, refer to the *Input Resistor Selection* Application Note.

The output of the SSR is a source-coupled MOSFET switch pair (Figure 1 of the data sheet), which functions as the relay's contact. In its off-state (on-hook), a typical SSR provides an extremely high off-resistance (5000 GΩ). The SSRs are tested for an off-resistance minimum of 500 MΩ at 100 V_{DC}. This far exceeds worldwide on-hook dc impedance requirements. For instance, the U.S. requires 5 MΩ, and Canada 2 MΩ off-resistance at 100 V. Japan requires 1 MΩ at 250 V, and the U.S., 30 kΩ at 200 V [1]. Test minimums of 350 MΩ at 350 V for the LH1529 and 400 MΩ at 400 V for the LH1549 guarantee these requirements.
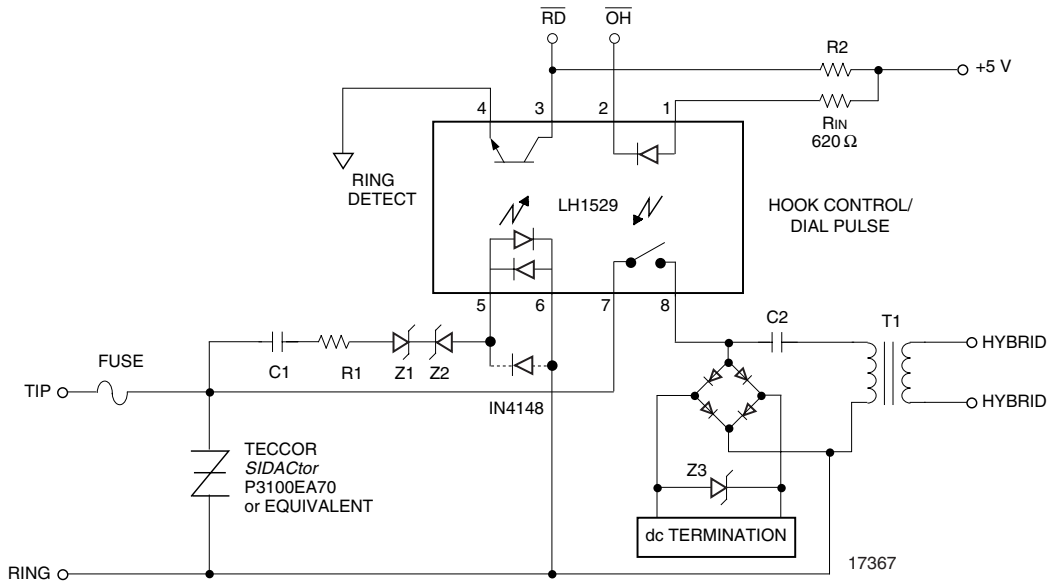
Figure 1. Telecom switch modem application

Some countries also specify a minimum on-hook ac impedance. The ac impedance of the SSR is dependent upon the contact capacitance, which is a function of the applied voltage. For these requirements, the SSR provides 32 MΩ of capacitance reactance at 500 Hz. Canada requires that the ac impedance be greater than16 kΩ at 500 Hz.

Most countries also specify impedance from Tip and Ring to ground. The telecom switch provides a minimum of 450 MΩ from input to output tested at 4500 V_{RMS}. Here again, this far exceeds typical on-hook regulatory requirements of 5 MΩ or less. It also easily complies with FCC 68.304 leakage current limitations (>100 kΩ at 1000 V_{DC}).

Off-hook impedance for the SSR is in the 12 Ω to 33 Ω region depending on the telecom switch selected. Overall dc off-hook impedance requirements of less than 200 Ω or 300 Ω are easily achieved using the SSR and a transformer or dc loop holding circuit. For off-hook return loss and longitudinal balance requirements, the contribution of a typical SSR at room temperature is a flat 0.28 dB for an LH1529 or 0.35 dB for an LH1549 across the entire frequency range.

The final consideration with the on/off-hook control SSR is contact protection under fault conditions. Built-in current-limiting circuitry to the SSR protects the contacts from repetitive off-hook transients or ac

over-current stresses. Overvoltage protection is required to prevent the SSR from going into avalanche breakdown during on-hook faults. Quite often, the same protector that is used to protect voltage-sensitive components in the ring-detect circuit or dc loop holding circuit will serve as adequate protection for the telecom switch.

There are many performance and safety requirements that specify longitudinal and metallic lightning surges. There are also documents like UL 1459 which specify power line inductions. For any longitudinal requirement, the I/O isolation of the telecom switch is 100% tested to ensure a minimum sustaining voltage at 5300 V_{RMS} for 1 minute. For metallic requirements, a transient voltage suppressor is required.

The circuit of Figure 1 uses a solid state *SIDACtor** to limit the potential between Tip and Ring to 350 V. If a metal oxide varistor (MOV) is used in lieu of the crow-bar *SIDACtor* device, use the LH1549 Telecom Switch. The SSR in the LH1549 provides a load voltage of 400 V which provides additional margin for the MOV's clamp voltage during lightning surges. In addition, the dc termination zener (Z3) protects an off-hook SSR from transformer inductive flyback by free-wheeling when the SSR current-limit circuitry interrupts current during a transient. For a more in-depth

discussion of SSR overvoltage protection and current-limit performance during transient operation, refer to the appropriate application notes.

Dial Pulsing

The SSR in the circuit of Figure 1 can also be used for dial pulsing in the U.S. and other countries. For countries that specify pulse dial rise and fall times like the U.K., an additional SSR should be used. A separate relay for dial pulse eliminates electronic inductor interaction in dry transformer designs by placing a direct short across the telephone loop for a dial pulse make period.

For dial pulsing, EIA/TIA-496-A specifies a minimum ac on-hook impedance with $1\ V_{RMS}$ to $10\ V_{RMS}$ across the device. The worst-case capacitance of the SSR would be at the lower $1\ V_{RMS}$ requirement. The ac impedance of the SSR under this condition is in the hundreds of megohms, well above the kilohms specification. On-hook and off-hook impedance to ground requirements are also compliant as described previously.

EIA/TIA-496-A allows 3 ms for contact bounce. The SSR will switch cleanly, well within 2.5 ms without any contact bounce when driven with at least 5 mA of LED drive current.

Note:

*SIDACtor is a registered trademark of TECCOR Electronics Inc.

Ring Detection

The optoisolator portion of the telecom switch is used for ring detection in Figure 1. With proper selection of an external zener and RC network, isolated ring detection can be implemented.

Capacitor C1 blocks dc loop current from entering the ring detection path. The value of C1 must be low enough to pass the lowest-frequency ring signal. The upper value limit is set by Telco impedance regulations like FCC Part 68.312 (generally $1600\ \Omega$ to $40\ k\Omega$). Values between $0.33\ \mu F$ to $0.56\ \mu F$ are common for ringer equivalence numbers (REN) less than 1.

The working voltage of C1 should be higher than the breakover voltage of the transient voltage suppressor. Resistor R1 limits the ring current flowing through the ring detect path. R1 and C1 values set up the overall ring-detect impedance and REN value. This impedance value will dictate the current transfer ratio (CTR) of the optoisolator and select the sensitivity of the ring-detect network. Values from $7.2\ k\Omega$ through $22\ k\Omega$ are common for R1. The power rating should

be between 0.5 W and 1 W, chosen to safely dissipate the worst-case ring signal (example, $150\ V_{RMS}$, 68 Hz).

The back-to-back zener diodes, Z1 and Z2, set the minimum amplitude threshold for the incoming ring signal. The value of the zener depends on the combined impedance of (R1+C1) in the range of 15.3 Hz to 68 Hz together with the V-I specifications of the LED of the optoisolator.

The optoisolator crosses the dielectric barrier and therefore is subject to the on-hook impedance tests. Like the SSR, the optoisolator provides $450\ M\Omega$ of isolation resistance tested at $4500\ V_{RMS}$. This exceeds worldwide on-hook impedance requirements [1]. The optoisolator contains two antiparallel LEDs. For ring detection, the antiparallel LEDs provide symmetry by conducting on both halves of the ac ring signal. The forward-biased LED also protects the other LED from exceeding its reverse breakdown voltage. Upon ring detection, the phototransistor outputs a full-wave rectified ring signal. For half-wave rectification, place a 1N4148 diode across the internal diodes as shown with the dotted lines in Figure 1. This will clamp the voltage to 0.7 V, keeping the forward-biased parallel diode from conducting during its half of the ring waveform.

R2 is the collector pull-up resistor. The value of R2 is dependent upon REN, CTR, dark current leakage, and trickle current leakage parameters. REN determines how much current will be flowing through the LEDs. CTR determines how much of that current will be coupled to the optotransistor. From dark current leakage (I_{CEO}), one can determine how resistive the optotransistor will be with 5 V across it and no LED input. Figure 3 provides I_{CEO} versus temperature information. Trickle current leakage specifies collector current when a small amount of current is flowing through the LED input. For a given V_{CC}, the phototransistor must swing down to a logic level low when the lowest LED current is sourced. For a given REN, a range of LED currents can be determined. The optoisolator collector currents can then be determined from the CTR (allow some design margin). With known collector currents, a range of values for R2 can be determined.

There are drawbacks to extreme values on either side of such range. If R2 is chosen close to the lower limit, logic and phototransistor leakage current are more tolerable but the saturation voltage of the logic low state increases. If R2 is chosen close to the upper limit, a low REN can be realized but sensitivity to line

disturbances and leakage current fluctuations becomes more of a concern. Values of R2 between 10 kΩ to 20 kΩ are common.

Having considered parameter interactions, manufacturing tolerances, and temperature variations (up to 50 °C), component values for a U.S. ring-detect circuit implementation are shown in Figure 4. Vary these values accordingly when designing for other countries or to achieve better performance.

In any design, remember to consider parameter shifts with temperature. Zener voltage increases with elevated temperature, while capacitance and CTR decreases. CTR of the telecom switch varies by approximately –0.4 %/°C with an increase in temperature. The average CTR value runs about 150 %.

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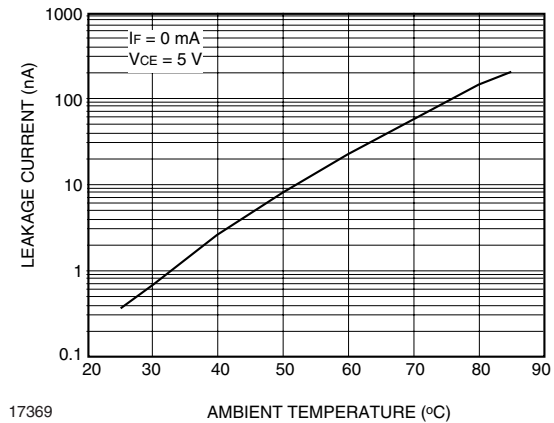
Figure 3. Typical ICEO vs. temperature
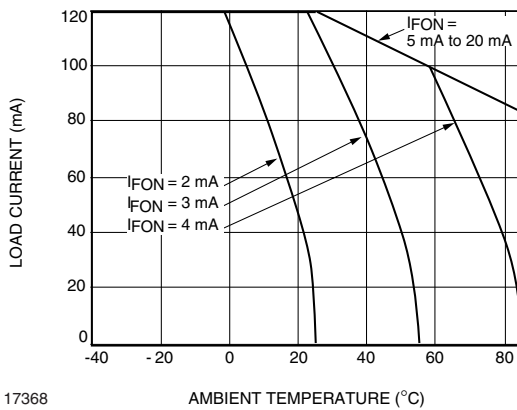

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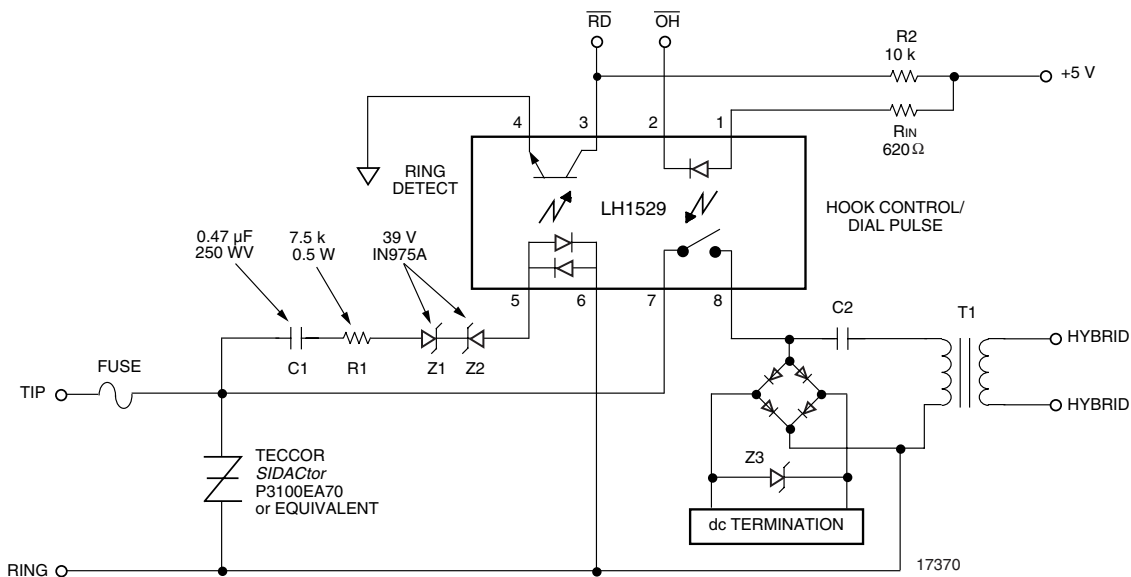Figure 2. SSR recommended operating conditions

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Figure 4. Typical telecom switch modem application

Loop Current Detection

Another application for the telecom switch is loop current detection. The optoisolator in the telecom switch can be placed in series with a telephone line to detect presence of loop current. The autopolarity input allows current detection even under polarity reversal conditions.

Loop current detection can be used for a variety of reasons. One common application is in FAX machines and answering machines. If the far-end party hangs up after a call has been established, many central offices will momentarily interrupt the loop current to the local end of the connection. If this disconnect signal can be detected, the FAX or answering machine can immediately go on-hook, rather than waiting 20 seconds or more to detect that the far-end party is no longer on the line. This prevents the FAX or answering machine from tying up the phone line unnecessarily.

To set up a threshold trip current, a resistor shunt can be used as shown in Figure 5. To trip at a given threshold current, simply divide the lowest anticipated LED forward voltage by the desired threshold current to determine the resistor shunt value.
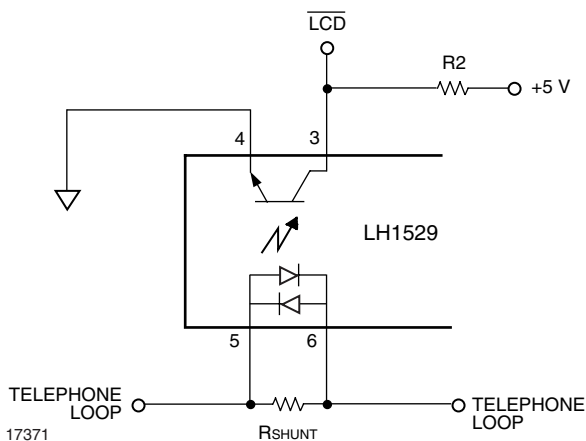

Figure 5. Loop current detection

To determine the lowest LED forward voltage, start with the manufacturing minimum value of 0.9 V @ 10 mA and vary it accordingly to compensate for threshold current and temperature using Figure 6 as a guide. For selecting the value of R2, the same considerations as those discussed in the Ring Detection section apply. Of course here, loop current would take the place of REN.
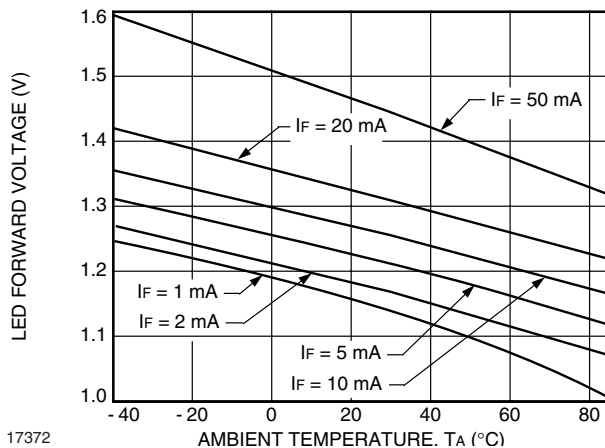

Figure 6. Typical LED forward voltage vs. temperature

Another consideration is LED protection against lightning. Here, the current-limited SSR can be beneficial if used in series with the loop current detector. For circuits where this is not possible, a set of external shunting diodes and another sense resistor may be required to protect the antiparallel LEDs from excessive current (see Figure 7).

An alternative loop current detector circuit is shown in Figure 8. This circuit senses loop current as it flows through the dc termination circuit. Positive and negative connections are derived from the dc termination's diode bridge. The forward-biased diode of the telecom switch supplies base current to Q1. Q1 shunts excess loop current around the telecom switch. Loop threshold current is set by the value of R1. In this circuit, lightning protection is provided by the zener protecting the electronic inductor.

In loop current detection applications, potentially high-loop currents can flow through the telecom switch LEDs which can degrade an LED's light output over time. The LH1529 Telecom Switch can reliably handle up to 50 mA of loop current. The LH1549 has larger LEDs in the optocoupler which can reliably handle 120 mA. Be leery of products that do not use an adequately sized LED to handle higher currents.
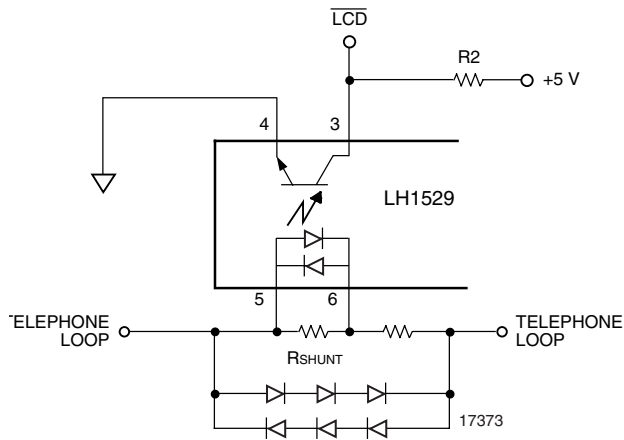
References:

1.*Trade and Telecom: Direct Connection Overseas*, by Glen Dash, Compliance Engineering, page 278, 1988.

2.*TIA Telecommunications Systems Bulletin No.31, Part 68 Rationale and Measurement Guidelines*, by EIA/TIA TR-41 Committee on Telephone Terminals, Washington D.C. 1990.

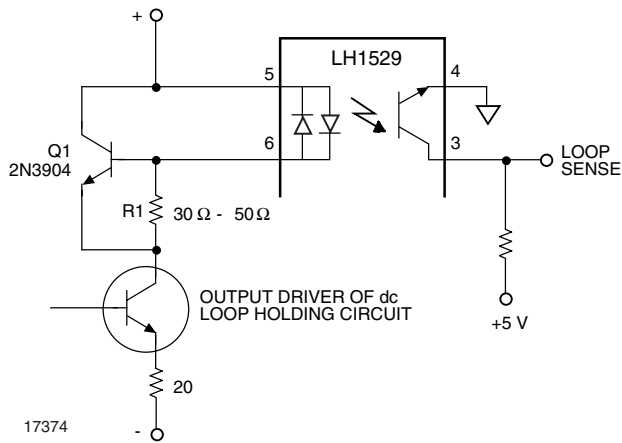Figure 7. Loop current detection with parallel protection network

Figure 8. Loop current detection within the electronic inductor of a dc loop holding circuit