Using Hermetic Optocouplers in Military and Space Electronics

By Jamshed N. Khan
Optocoupler Applications Engineer
Avago Technologies

Abstract

Sensitive and high reliability applications such as Space, Aeronautics, Military, and Naval will continue to rely on high reliability Hermetic Components. The risks associated with using plastic electronic components in harsh and rugged environments, where components may be subjected to extremes of temperature, humidity, radiation, and shock/acceleration are just too great. Optically isolated (Optocoupler/Optoisolator) technology to provide noise free data transmission capabilities and to provide safe galvanic isolation has been around for over twenty years. Latest advances in design and processing of transmitter and receiver technologies have allowed for greater functionality, integration and sophistication of Hermetic Optocouplers for various electronic design and application purposes. Hermetic Optocouplers are now available for high speed digital data transmission applications, Analog optocouplers for sensing voltages and current, Intelligent Power Module (IPM) drivers for motor control applications, and AC/DC threshold voltage detectors for various high power detection purposes. Also, available are Hermetic power MOSFET Optocouplers (HSSR-7111) for switching applications. Depending on end applications, these high reliability hermetic optocouplers are available as commercial grade, Class H (high reliability) and Class K (highest reliability). Most product families are available in various package styles (8 and 16 pin DIP, 16 lead Flat Pack, and 20 terminal LCC) and lead configurations for through hole or surface mount applications.

Why Use Hermetic Optocouplers?

Safe Optical Isolation using optocouplers or optoisolators is now a well-proven, well-established, and most reliable technology. Modern state of the art optocouplers are available for high-speed digital data transmission applications (upto 20 Mbit/s), analog current and voltage sensing, feedback and control electronics. Application specific optocouplers are also available for Inverter (IGBT/MOSFET, and IPM) gate drivers, and AC/DC high voltage threshold sensing requirements.

Traditionally, optocouplers have been extensively used to safely isolate low power, delicate, and expensive electronic components from high power circuits. In addition, optocouplers provide excellent means of interfacing circuits with high ground potential differences, protect circuits from large common mode voltages, and eliminate noise and interference due to undesirable ground loop currents. Optocouplers are also used to provide amplification of signals, provide ON/OFF switching, and insulate humans from electric shock or hazards of high voltage power sources, or patients from high power medical instruments. Advances in optocoupler design and processing technologies have allowed new optocoupler designs for application specific areas, and provide increasing functionality and sophistication.

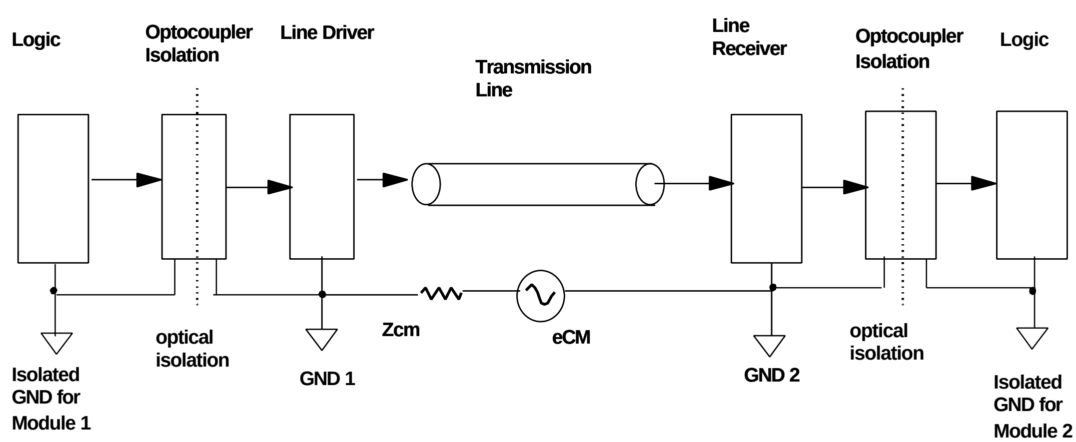
Historically, digital data transmission applications were the first to realize the common mode noise elimination and surge protection benefits of Optocouplers. Today, variable speed motor control electronics is one area where optocouplers are finding increasing applications. Also available are optocouplers optimized to provide high output sourcing and sinking capabilities to drive inverters (IGBTs / MOSFETs) or Intelligent Power Modules (IPM). Similarly, sophisticated analog optoisolators are increasingly replacing Hall effect sensors for measuring and monitoring AC Phase currents, DC rail /bus currents, and measuring bus voltages or monitoring temperatures.

In addition, Hermetic Optocouplers provides benefits of being able to be used in wide temperature range (–55 to +125) ^{o}C applications, high humidity such as found in naval and marine environments, and where parts are invariably subjected to high mechanical shock such as aeronautics or satellites, and adverse radiation conditions such as space. The primary benefits of using Hermetic optocouplers can be summarized as follows:

- High reliability , high quality, and long life
- Variable speed and frequency capability
- Ease and simplicity of design
- Relatively Small size and footprint area
- Relatively Low power dissipation
- Safe Optical Isolation (galvanic isolation)
- Rugged and will withstand thermal or mechanical shocks
- Immunity to Ground Loop Current Noise Interference
- Higher Temperature Operation
- Radiation Tolerant for Space applications
- Isolate different Voltage levels and level shifting
- Amplify or Attenuate Digital or Analog signals
- Insulate human operators from power circuits and shock hazards
- Prevent noise or interference between control and power circuits
- Provide high voltage transient protection for expensive digital circuits

Digital Applications of Hermetic Optocouplers

Modern communications relies on transmitting digital data. Technologies such as computers, satellites, telemetry, electronics and integrated circuits have paved the way for generating and transmitting enormous amount of data. Figure (1) shows the basic elements of an optocoupler-isolated transmission system and consists of optocouplers, transmitter or line driver, transmission line or medium, receiver, and digital control logic at either end.



Note: Zcm represents the impedance associated with the source of the common mode interference and eCM represents Common Mode Voltage

Figure 1. Basic Optically Isolated Transmission Line

The ground loop currents circulating between the two grounds of the transmission line often induce offsets and noise degrading the integrity of the data. The use of the optocoupler as shown in Figure 1 breaks this ground loop current between the transmission line and the control logic, which is often times the CPU of a remote computer. The common mode interference associated with shifts in the ground potentials is another problem. Both of these effects, ground loop currents and common mode noise, can be eliminated when using the optocouplers.

A common misunderstanding regarding optocouplers in digital data transmission applications is that optocouplers can be used directly either as line drivers or as line receivers. Generally speaking, the optocoupler's input stages or the output stages are TTL and/or CMOS logic compatible. These stages are not optimized to function directly as line receivers or line drivers. Although with a careful understanding of the digital data transmission standard and a careful design of the optocoupler drive circuitry in some cases optocouplers can be made to act as line receivers. But invariably, optocouplers can not drive the transmission line directly, as the output stages do not have the power capability to drive the transmission line directly. Thus, for a safe and optimum design, it is highly recommended that a designer use an appropriate transceiver of the transmission standard under consideration in conjunction with the right optocoupler.

Summarized in Table 1 are the technical requirements for some common digital communication standards. The simplest standard is the RS-232, and requires a single transmitter and a receiver on the line. The transmit levels for the RS-232 are ±5V to ±15V, and the typical data rate is 20 kbit/sec. Whereas the RS-484 is a multi drop standard with possibly 32 transmitters and 32 receivers connected to the transmission line. The maximum operating speed is 10 Mbit/sec at a maximum cable length of 1200m.

For example, if the optocoupler were to act as a line receiver for the RS-232 line, it should be able to respond to the receive sensitivity signal of as low as ± 3V, with an impedance presented to the transmission line of minimum 3KΩ and maximum 7kΩ. Additionally, the transmission line driver requirements are 500mA for the RS-232 transmission line. It is because of the diverse and stringent power sensitivity and drive requirements that it is essential that one uses the transceiver pertinent for the transmission standard of interest and use an appropriate optocoupler that meets the speed requirements of the transmission standard selected.

Table 1. Some Common Digital Data Transmission Standards

Mode	RS-232C/D single -ended	RS-423A single-ended	RS-422A differential	RS-485 differential	20MA Current Loop 20mA current
Maximum number drivers/transmitter	1	1	1	32	≥1
receivers	1	10	10	32	≥1
Maximum cable length	15m	1200m	1200m	1200m	10km
Maximum data rate (bits/s)	20k	100k	10M	10M	20kbd
Transmit levels	± 5V min ± 5V max	±3.6V min ±6.0 max	±2V min (diff'l)	±1.5V min (diff'l)	≥12mA (H) ≤3mA (L)
Receive sensitivity	± 3V	±0.2V (diff'l)	±0.2V (diff'l)	±0.2V (diff'l)	≥12mA (H) ≤3mA (L)
Load impedance	3k to 7k	450 min	100 min	60 min	-
Output current limit	500mA to V or gnd	150mA to gnd	150mA to gnd	150mA to gnd 250mA to -8V or +12V	-
Driver Z min (pwr off)	300	60k	60k	120k	-

This is not to imply that in all cases the optocouplers can not be used as line receivers. For the RS-232 line with a careful input drive current circuitry, it is possible to use an optocoupler such as the 6N140A to act as the line receiver. In addition, there are some optocouplers that are designed and optimized to be direct line receivers. One such example of the application specific line receiver is the HCPL-1931.

For Line driver applications, one would need to provide external buffer current amplifiers that can drive the transmission line. However, if one selects the appropriate line transceivers, then one can obviate the need to design both the input driver circuitry that is compatible with the line receiver requirements, and also the external current amplifier stage design. It is for design simplicity and direct availability of line transceivers that it is recommended to go the transceiver route in transmission line applications.

Table 2 shows the basic digital Hermetic optocoupler families. Most of these optocouplers are available in a variety of packages such as LCCC, Flat Packs, Ceramic Dips, with multiple channel counts. All of these devices are available as commercial grade, Class H (high reliability) and class K (highest reliability).

Table 2. Digital Hermetic Optocouplers Available from Avago Technologies

Note: This summary does not reflect all the different packages or lead form options available. Consult the web site to download the data sheets at: [http:// www.avagotech.com]

PRODUCT FAMILY	MIN I F (mA)	MAX VCC (V)	Max PROP DELAY tPHL(us)	Max PROP DELAY tPLH (us)	CMR (kV/us) (min)
6N140A HCPL-5701 HCPL-5731 (100 kBd)	1.5	18	100	60	0.5
4N55 HCPL-5501 HCPL-5531 (700 KBd)	12	18	2	6	1
HCPL-5201 HCPL-5231 (5MBd)	2	20	0.350	0.350	1
6N134 (10 MBd)	10	20	0.120	0.140	1
HCPL-5401 HCPL-5431 (20 MBd)	6	5.25	0.06	0.06	0.5

The maximum data rate that can be transmitted through the optocoupler can be calculated from the propagation delay parameter of the optocoupler. Propagation delay defines how quickly a logic signal propagates through the optocoupler. The simplest way to calculate the worst case speed response is to take the reciprocal of the maximum propagation delay. Optocoupler data sheets indicate the propagation delay low to high (t_{PLH}) as well as propagation delay high to low (t_{PHL}). Thus, taking the reciprocal of the higher of the two propagation delay numbers indicates what the maximum data rate through the optocoupler can be:

Data Rate Maximum = $1/(t_{PHL})$ or $1/(t_{PLH})$ whichever is lower (bits/s)

The pulse width distortion (PWD) is defined as the difference between the t_{PHL} and the t_{PLH}. Using the PWD parameter if it is given is another way to calculate the speed of the optocoupler. Typically, (20 to 30) percent PWD is considered acceptable in the industry. The maximum speed at this particular distortion level can be calculated as:

Data Rate Maximum = (1/PWD) • (30%) (Maximum speed at 30% distortion level)

The two methods may give slightly different data rate numbers. Thus, knowing the speed requirements of the digital data transmission standard one is working with, it is easy to pick the right optocoupler with the correct speed that will work in the transmission standard. Once again, the optocoupler will be used in conjunction with the appropriate transceiver of the particular transmission standard chosen.

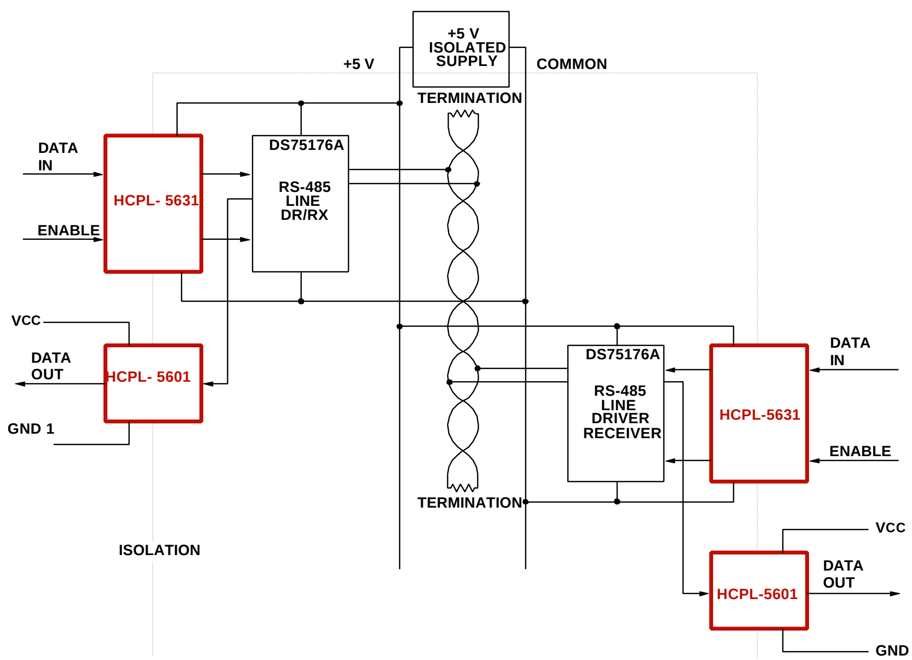


Figure 2. Optocoupler Isolation for RS-485 Digital Data Transmission Standard

Shown in Figure 2 are HCPL-5631 and HCPL-5601 being used in the RS-485 data transmission standard. One channel of the dual HCPL-5631 can be used as an enable, which is needed in this multi drop (32 receivers and 32 transmitters) standard. As mentioned before, an appropriate line transceiver must be used as line driver and line receiver. In this case DS75176A is a transceiver for the RS-485 line, and the maximum data rate for the RS-485 digital transmission data standard is 10 MBit/sec. The optocouplers selected should have a speed of 10 Mbit/sec, matching the speed requirements of the transmission line. Note, above is a conceptual simplified schematic, and does not show the actual output pull up resistor required on the output of this open collector stage optocoupler, or the actual input drive current circuitry at the inputs of the optocouplers.

Another example of digital data transmission application for Hermetic Optocouplers is that of Controller Area Network (CAN). CAN is a serial bus protocol similar to DeviceNet^{TM}, and is primarily intended for transmission of control data between a number of bus nodes for in-vehicle high-speed digital data communication. A typical application circuit is shown in Figure 3.

The galvanic isolation is provided by the HCPL-5601 placed between the CAN controller and the transceiver. The HCPL-5601 are high-speed 10 MBd optocouplers having a maximum propagation delay of 140 nsec. When data is transmitted or received at a typical 500 kbit/sec in the CAN protocol, the delay introduced by these high-speed optocouplers impacts the maximum achievable bus length minimally.

The transceivers shown are Philips semiconductor PCA 82C250/251. A protocol controller (e.g. PCx82C200) is connected to the transceiver via the HCPL-5601. The serial data output line (TX) from the controller initiates the transmit function, and the serial data input line (RX) receives the data. The transceiver is attached to CAN Bus Line through the two bus terminal CANH and CANL. The data is transmitted and received through differential transmit and receive capability.

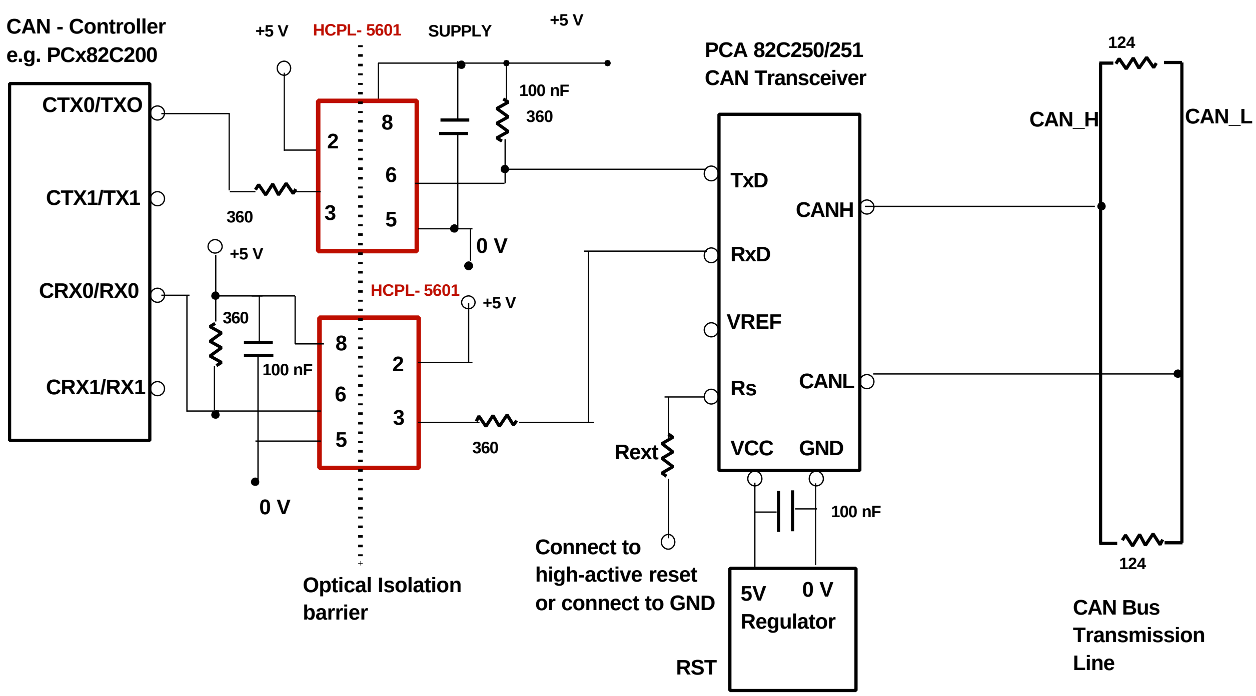


Figure 3. Optocoupler Isolation for CAN Digital Data Transmission Standard

In addition to data communication applications, Digital optocouplers are used in many other industrial, commercial, and high reliability applications for diverse purposes such as switching power supplies, motor control, un-interruptible power supplies, sports / exercise equipment, and medical applications. Figure 4 shows an example of a switch mode power supply application.

Virtually every piece of electronic equipment, whether High Reliability, Industrial, or Commercial requires some sort of power supply to work. These power supplies could be AC to DC converters or DC to DC converters. High Speed digital optocouplers are very often used as a part of the isolated feedback control loop such as in pulse width modulated switching power supplies.

Figure 4 shows an example of a push-pull switching power supply that utilizes the HCPL-5201 to provide the isolated feedback drive to the switching power MOSFET s. The silicon unilateral switch (SUS) bootstrap starts the power supply when the AC power is first applied. Once the PWM has started, a peak detector disables the SUS.

The enable function of the HCPL-5201 has been used to good advantage in this application. The enable voltages provides a common mode conduction interlock function that will not allow both power MOSFET switching transistors to turn ON at the same time, but allowing high efficiency at a high switching rate.

In a switching power supply, the switching transistors are driven at some PWM frequency, generated by the PWM control circuit. This control circuit monitors the isolated output voltage of the power supply and generates the PWM frequency as a function of the voltage sensed. The optocouplers are driven at the PWM generated frequency to drive the power MOSFETs. The power MOSFETs drive the primary side of the transformer at the PWM frequency, thereby achieving a very high efficiency for which the switched mode power supplies are correctly valued.

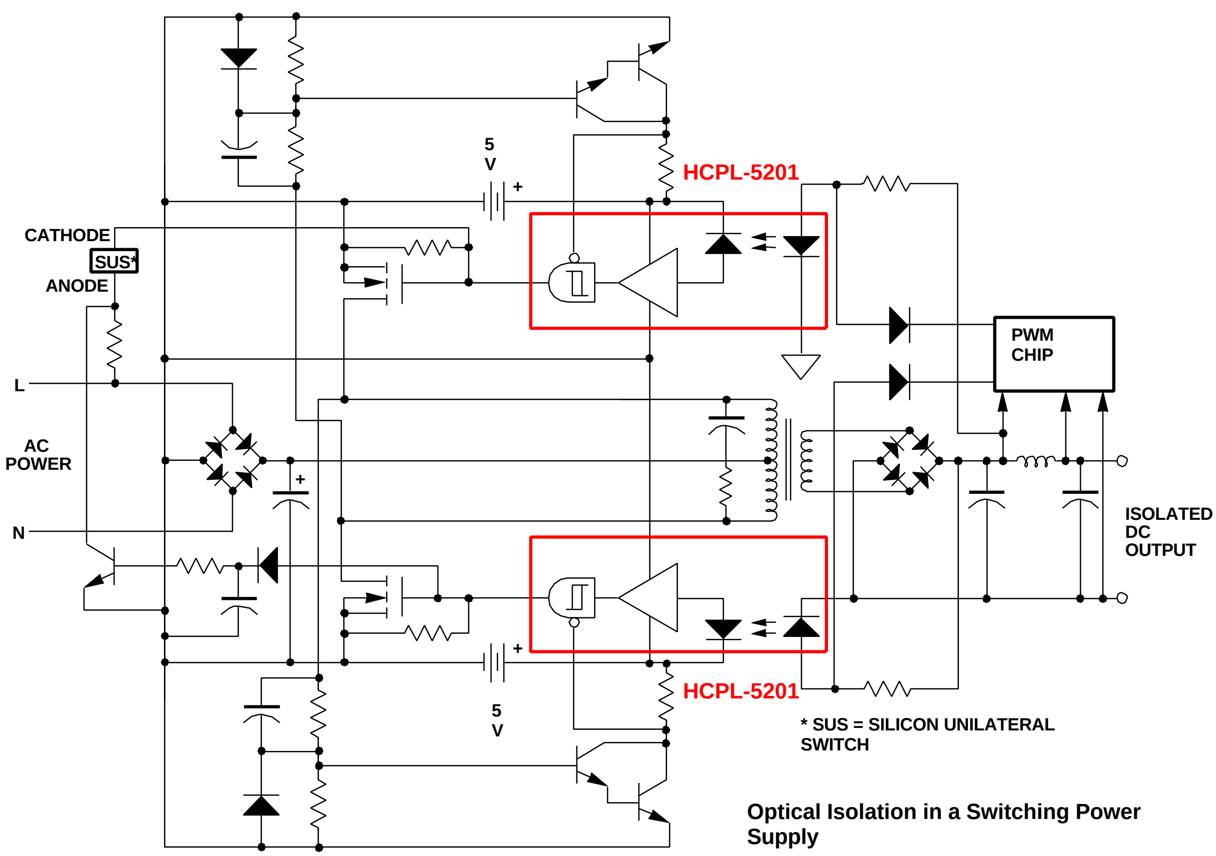


Figure 4. Hermetic Optocoupler Isolation in Feedback Control in Switched Mode Power Supply

IPM Gate Driver Optocoupler for Motor Control Applications

In motor control applications, driving the gate of an IGBT, MOSFET, or Intelligent Power Module (IPM), or analog current and voltage sensing is another major area where optocouplers are used. Figure 5 shows a typical variable speed hex bridge motor control circuit topology. In this topology ac three phase input voltage is converted to a dc bus voltage through an ac rectifier bridge at the input. Power MOSFET inverters or IGBT inverters are driven in an appropriate three phase pulse width modulated sequence to turn the inverters on and off. These power inverters generate the high amperage ac currents needed to turn or drive the motor.

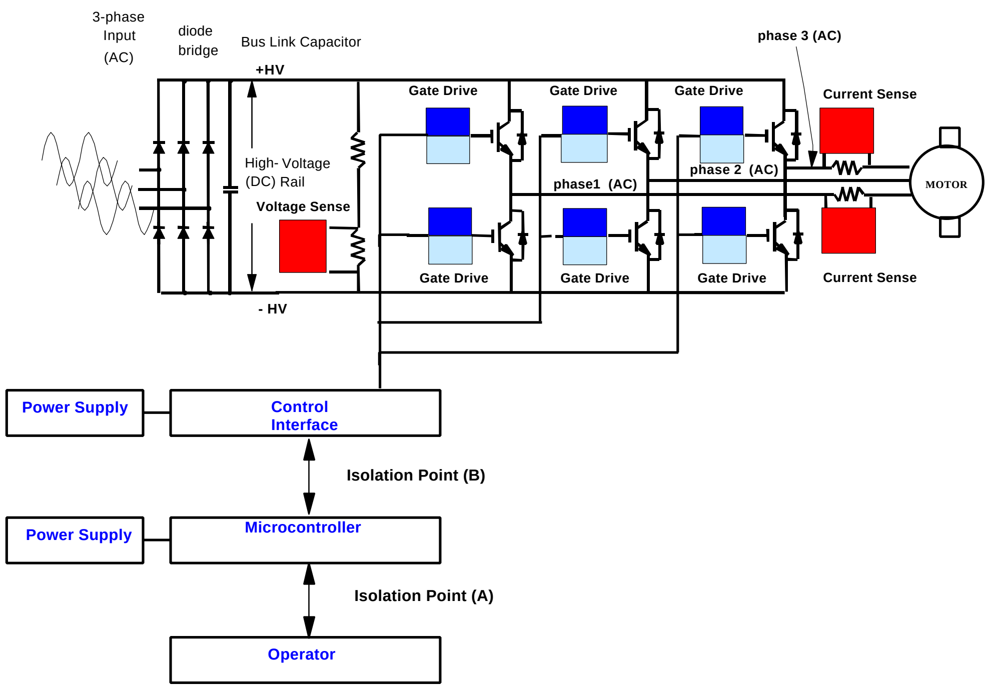


Figure 5. Typical Variable Speed Motor Control Topology

Typically, in a 3-phase motor, 7 drivers would be needed. Six to drive the IGBT inverter gates, and one for the motor brake IGBT inverter gate. For speed, position, and phase control of a motor, numerous analog motor parameters are measured or monitored. Invariably, these monitored analog parameters are fed back to the micro-controller for system control. Since, a microcontroller unit is typically referenced to earth ground, any high power parameters fed back from the motor to the controller need to be isolated for protection and safety purposes. Depending on the type and cost of the motor drive, various numbers of these analog parameters are monitored and fed back to the micro-controller.

Figures 6 and 7 shows the HCPL-5300 optocoupler being used in an inverter gate drive application. The HCPL-5300 is optimized for IPM driver and gate driver applications, and can drive a 100 pF load at a typical speed of 300 nsec. An internal pull up resistor of 20kΩ is provided at pin 7, giving one flexibility to use either this internal pull up resistor, or an external pull up resistor of a different value if desired.

When the HCPL-5300 is used in these inverter gate driver applications, one would need an external current amplifier buffer to provide the high peak currents necessary to drive the gates of the MOSFETs or IGBTs. The resistors R_{G1} and R_{G2} shown allow optimization of the charging and discharging times of the inverter gate capacitance. The NPN/PNP buffer amplifier should be appropriately selected to provide the minimum peak currents required to switch the inverters.

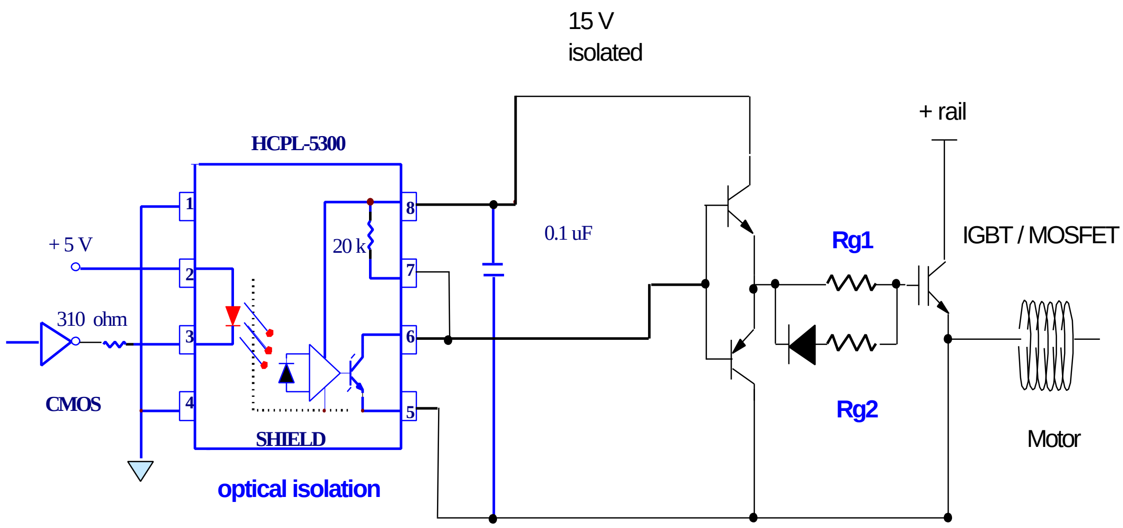


Figure 6. HCPL-5300 Driving a Buffer Current Amplifier to Drive a Motor [Splitting Gate Resistance for Fast Turn-Off (method One)]

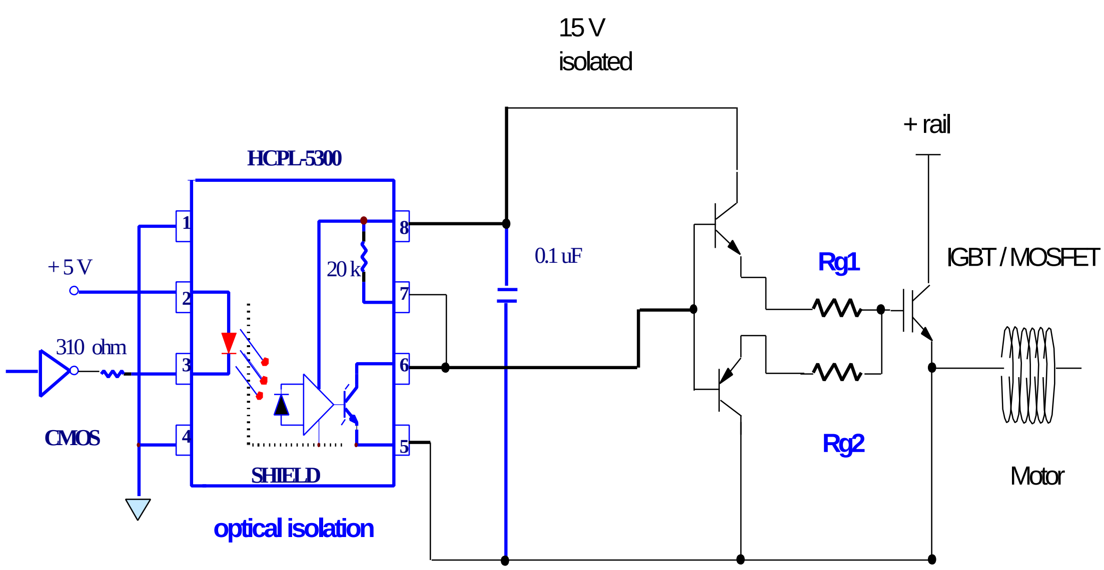


Figure 7. HCPL-5300 Driving a Buffer Current Amplifier to Drive a Motor [Splitting Gate Resistance for Fast Turn-Off (method two)]

For driving an Intelligent Power Module (IPM) as shown in Figure 8, one does not need to use the external high output drive current buffers. Since an IPM has a built in current amplifier driver and IGBT in a single modular package, one can use a transistor output optocoupler such as HCPL- 5501 or HCPL-5300. Such an optocoupler would only require a pull-up resistor to interface with the input of an IPM.

Shown in Figure 8 is an IPM interface using the HCPL-5300. This optocoupler has a built-in pull up resistor available at pin 7, and is optimized and ideal for IPM driver applications. The HCPL-5300 can drive a 100 pF load capacitance at 500-nsec maximum propagation delay. In a noisy common mode environment, it is recommended that the unconnected pins 1 and 4 of the HCPL-5300 be grounded.

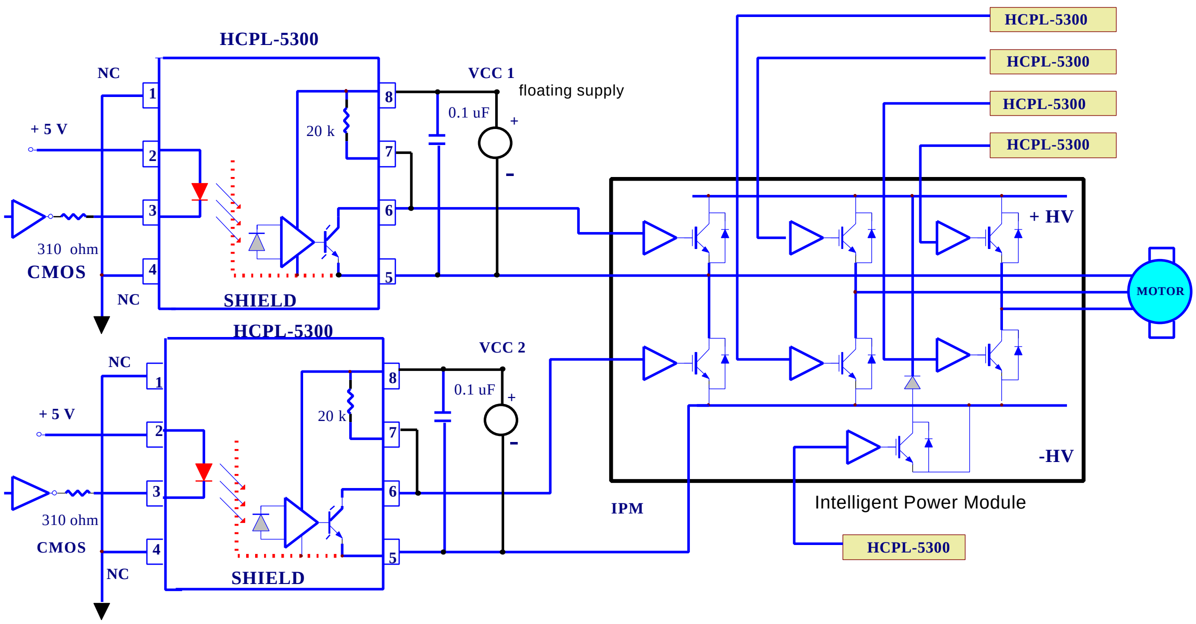


Figure 8. Typical IPM driver Application Circuit using the HCPL-5300

Current Sensing Using Optically Isolated Analog Isolation Amplifier

After the inverter gate driver requirements, the second big challenge in motor control applications is how to measure motor phase current, bus currents, and other analog parameters like temperature or voltage. Typically, all these measurements need to be made through some type of safe isolation barrier. At the present time there are three main methods that are used that all incorporate some type of isolation technique. These three methods are:

(1) Current transformers
(2) Hall Effect current Sensors
(3) Optically Isolated Analog Sensors

Each of the above methods offers some advantages and disadvantages. Thus, a designer will again pick the solution that best reduces overall cost, optimizes performance and reliability, minimizes board space, and meets the accuracy and linearity requirements.

The HCPL-7850 Analog isolation amplifier is based on sigma-delta (ΣΔ) analog-to-digital converter which is optically coupled to an integrated output digital to analog converters. The analog isolation amplifiers have very high common mode transient rejection capability (CMR), which is often necessary in modern fast switching motor control electronics in addition to providing high isolation voltages through optical transmission of the signal from the input to the output. The voltage is sensed by the isolation amplifier inputs over a low value resistor connected in parallel with the input pins. The analog linearity is guaranteed over the maximum input range of 200 mV. The output voltage of the isolation amplifier is an analog output voltage proportional to the input voltage.

The block diagram of the isolation amplifier is shown in Figure 9. The input is sampled at a high rate through a chopper stabilized differential amplifier that is a part of the ΣΔ amplifier. The input sensing at a very high rate is accomplished by a sampling rate typically between 6 to 10 MHz. This high speed sensing guarantees that the Nyquist criterion is always met when sensing the input at high frequency signals.

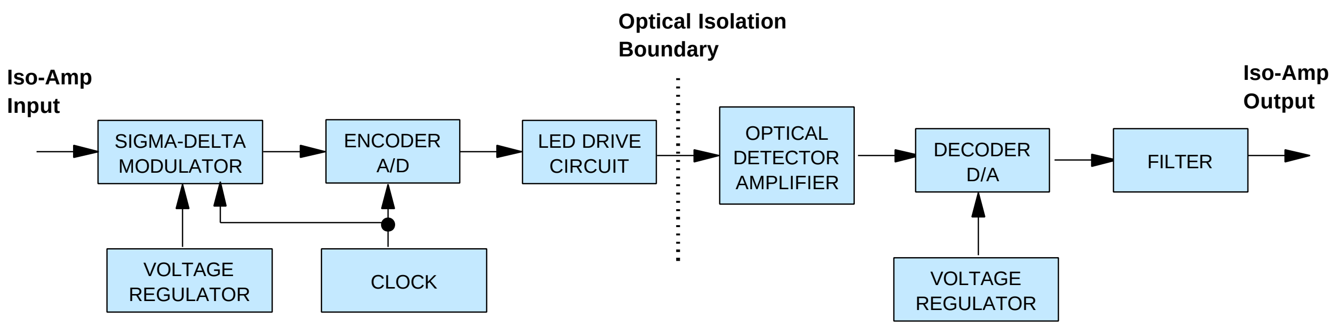


Figure 9. A Block Diagram of the Optically Isolated Analog Isolation Amplifier HCPL-7850

In operation, the sigma-delta modulator converts the analog input signal into high-speed serial bit stream. The time average of this bit stream is directly proportional to the input signal. This stream of digital data is encoded and optically transferred to the detector circuit. The detected signal is decoded and converted back into analog signal, which is filtered to obtain the final output signal. Figure 10 shows a typical application circuit for motor phase current measurements.

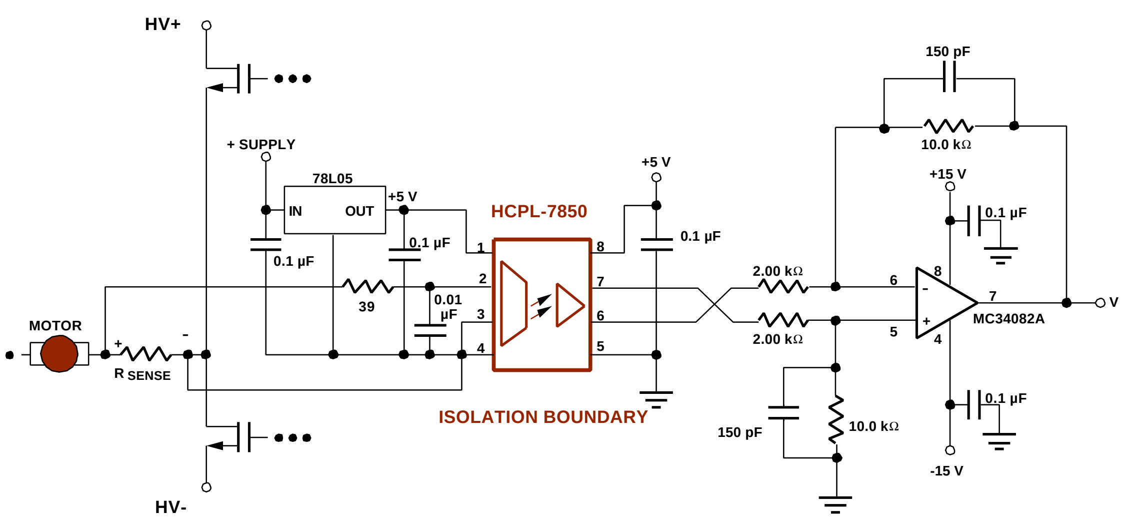


Figure 10. Typical Current Sensing Application Circuit using the HCPL-7850 Amplifier

The input is sensed across a precision, low resistance, low inductance, and low temperature co-efficient shunt resistor. A low pass RC filter at the input (39 Ω resistor and 0.01 µ F capacitor) rejects high frequency noise components and is an anti-aliasing filter. Post differential amplifier converts the differential output signal of the isolation amplifier to a ground referenced voltage compatible with an A/D converter at the microcontroller. The differential amplifier's bandwidth can be adjusted by the R-C filter on the feedback path to reject and to minimize the noise at the output if necessary.

For dc bus current or ac phase current sensing, and voltage sensing for bus voltage, temperature sensing (voltage from temperature sensor of the heat sink of the IGBT or IPM), or counter electromotive voltage sensing of the motor (for brushless dc motors only), one can use the HCPL-7850. Figure 10 had shown the HCPL-7850 in a motor phase current sensing topology. In Figure 11 we show how a suitable voltage divider at the input (such that the sensing voltage is below 200-mV absolute value) can be used to measure the bus voltage or counter emf of brushless dc motors.

In this case, the constraint is that the value of R1 should be kept below 1kΩ, such that input impedance of the HCPL-7850 (280 kΩ) and input current (1 µA typical) do not introduce offsets and inaccuracies in the measurement. An input bypass capacitor of 0.01 µF is still required, although the 39 Ω resistor can be omitted, as the voltage divider resistor will perform the same low pass filter function.

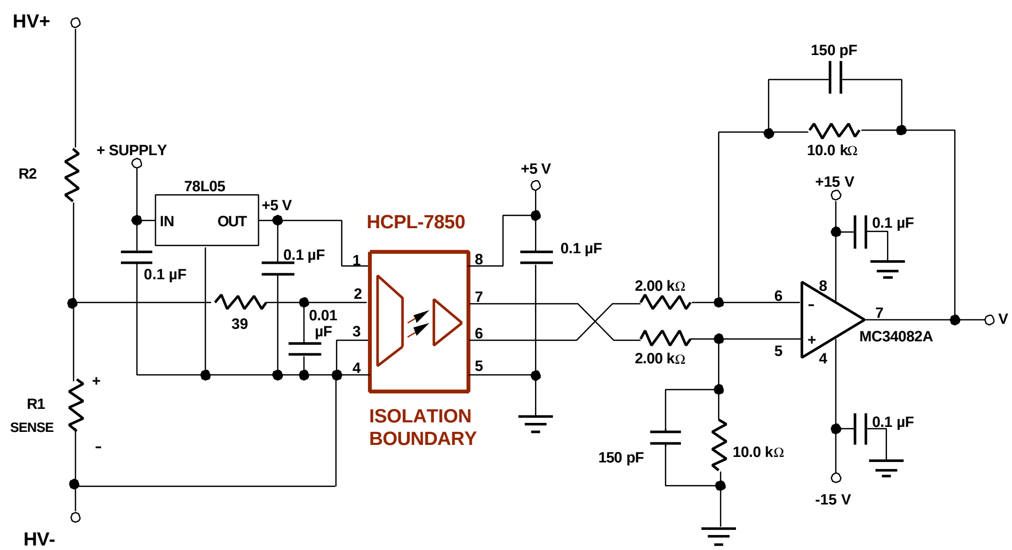


Figure 11.   Typical Voltage Sensing Application Circuit using the HCPL-7850 Amplifier

Threshold Voltage Sensing Using the HCPL-5761 or HCPL-5760

In electronic feedback and control systems, very often situations arises where an interface needs to be established between a high voltage AC/DC such as 110V or 240V AC rms or higher levels and a logic control interface at low voltages such as 5V TTL/CMOS or 3.3V logic levels. When faced with such a situation, first impulse from a designer is to resort to some isolation barrier between the high voltage controlled level and the low voltage logic control level. Traditional methods of isolation generally consisted of transformers, electro-mechanical relays, or capacitors. However, optocoupler isolation offers advantages that are much superior compared to the traditional forms of isolation, such as small size, high reliability, and frequency operation from low frequency or DC levels to much higher frequency or speed capabilities.

In the implementation of an interface it is often desirable to establish a predetermined voltage or current switching point. That is, it is advantageous to establish a precise threshold detection level at which the input signal will be considered true. The HCPL-5761 offers the designer ability to design and select a particular threshold switching level based on a proper selection of just an external resistor. This threshold detection can be either a DC voltage or an AC voltage.

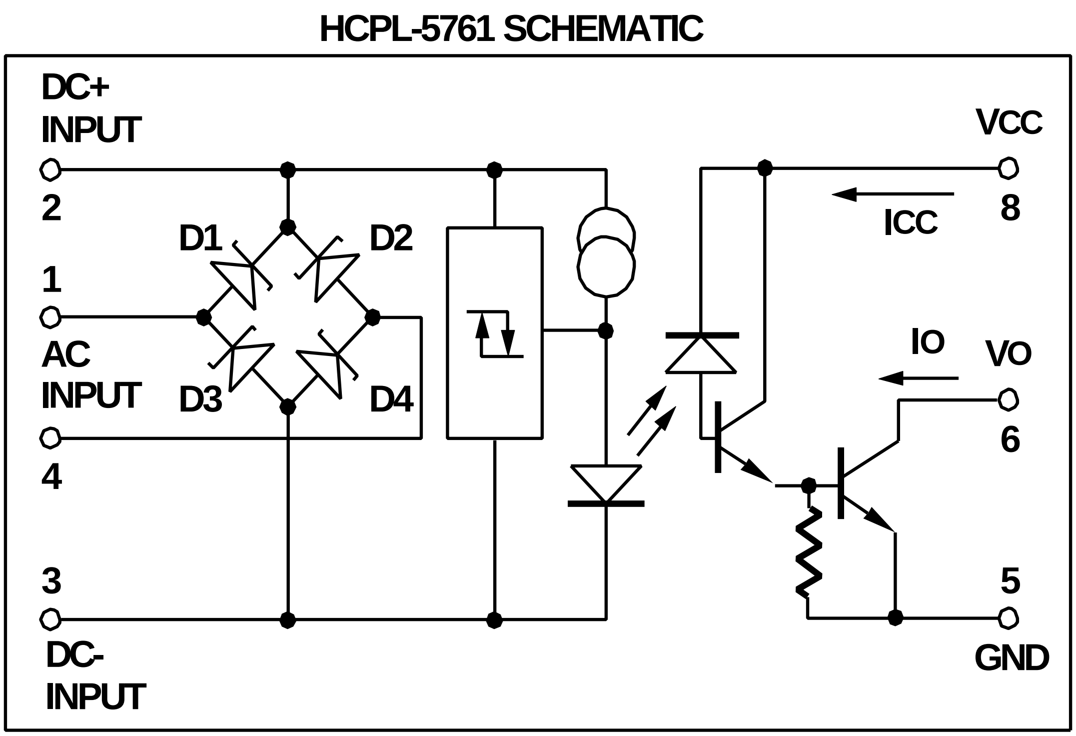


Figure 12. Block Diagram of the HCPL-5761 AC/DC Threshold Detector

The input of the HCPL-5761 consists of a full-wave bridge rectifier and threshold detection integrated circuit with hysteresis for high noise immunity, and a high performance LED, as shown in Figure 12. The detector, or the output stage consists, of an integrated photo-detector diode coupled to a high gain split darlington, open collector amplifier.

The output is compatible with TTL and CMOS logic levels, and will work at V_{CC} levels from 18V to 3V. Minimum Common Mode noise transient immunity level of 1000 V/µs provides excellent noise rejection isolation. Guaranteed Input-Output high voltage insulation (I_{I-O}) is 1500 V dc.

As an example for the use of the HCPL-5761, suppose one wants to monitor a DC bus voltage of 400V dc, and a 360V dc is selected to be the threshold point for detection level when the input is considered true. The HCPL-5761 DC circuit configuration for this dc application is shown in Figure 13.

The data sheet parameters that one would need to consider to set the proper thresholds are shown in the following Table 3.

Table 3: HCPL-5761 Input Threshold Levels (DC)

Parameter	Symbol	Conditions	Min	Typical	Max	Units
Input Threshold Current	I_{TH+}	$V_{IN} = V_{TH+}$; $V_{CC} = 4.5V$ $V_O = 0.4V$; $I_O \geq 2.6mA$	1.75	2.5	3.20	mA
Input Threshold Current	I_{TH-}	$V_{IN} = V_{TH-}$; $V_{CC} = 4.5V$ $V_O = 2.4V$; $I_O \leq 250\mu A$	0.93	1.3	1.62	mA
Input threshold Voltage dc (Pins 2,3)	V_{TH+}	$V_{IN} = V_2 - V_3$; Pins 1 &4 Open $V_{CC} = 4.5V$, $V_O = 0.4V$; $I_O \geq 2.6mA$	3.18	3.6	4.10	V
Input threshold Voltage dc (Pin 2,3)	V_{TH-}	$V_{IN} = V_2 - V_3$; Pins 1 &4 Open $V_{CC} = 4.5V$, $V_O = 2.4V$; $I_O \leq 250\mu A$	1.90	2.5	3.0	V

Let's assume that we are planning to use the HCPL-5761 in a dc bus voltage threshold detection application in a motor control application. The HCPL-5761 will sense the dc high voltage bus of 400V dc, and provide a digital signal to the microcontroller that is controlling the motor.

DC bus voltage to be monitored = 400V dc (Vpeak)
Switching threshold selected V_+ = 360 V dc

Typical HCPL-5761 Input Levels: $V_{TH+} = 3.6$ V
$V_{TH-} = 2.5$ V
$I_{TH+} = 2.5$ mA
$I_{TH-} = 1.3$ mA
(Input Clamp Voltage) $V_{IHC3} = 12V$

Now Calculate the value of the external resistor R_X required to establish the threshold detection level of 36) V dc that we require. The threshold equation is:

$$R_X = (V_- - V_{TH+}) \,/\, (I_{TH+})$$

$$= (360 - 3.6) / (2.5 \text{ mA})$$

$$= 142.56 \text{ k}\Omega$$

It is recommended that to improve common mode noise immunity and to provide equal impedance on the two sides of the input pins (2,3), this impedance of 142.56 kΩ be split in two equal halves, and one half resistor $R_{X/2}$ of 71.28 kΩ be used at each of the two input pins.

The resultant lower threshold level (V_-), because of the hysteresis provided at the input circuit of the HCPL-5761 is calculated as:

$$V_- = (I_{TH-} \bullet R_X) + V_{TH-}$$
$$= 1.3\text{ mA} \bullet 142.56\text{ k}\Omega + 2.5\text{V}$$
$$= 187.8\text{ V}$$

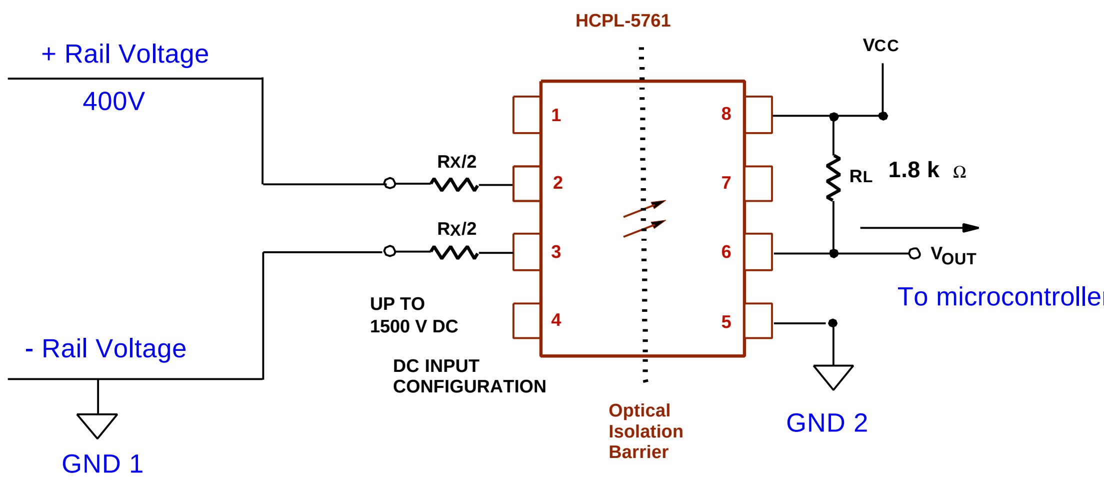


Figure 13. DC Bus Voltage Detection using the HCPL-5761

Now, one must determine what the power rating of the external resistor (R_X) should be. The calculation of the maximum power dissipation in R_X is determined by knowing which of the following inequalities is true, where V_{IHC3} is the input clamp voltage for this dc-input case:

$(V_+) / (V_{peak}) > (V_{TH+}) / (V_{IHC3})$ (V_{IN} will not clamp)

$(V_+) / (V_{peak}) < (V_{TH+}) / (V_{IHC3})$ (V_{IN} will clamp)

Since, 360/400 > 3.6/12, the input will not clamp.

The dc input of the HCPL-5761 appears as a 1000Ω in series with a one volt offset. And if the ac pins (1,4) are left unconnected, as in this example, the dc input voltage can increase to 12V (two Zener diode voltages) before the onset of input voltage clamping occurs (V_{IHC3}). Consequently, a conservative value for the maximum power dissipation in R_X for the unclamped input (ignoring the input offset voltage) can be calculated as:

$$P_{RX} = [V_{peak} (R_X / (R_{RX} + 1\text{k}\Omega)]^2 / R_X$$

$$= [400 (142.56\text{k}\Omega / (142.56\text{k}\Omega + 1\text{k}\ \Omega)]^2 / 142.56\text{k}\Omega$$

$$= 1.1\text{ W}$$

To give some margin for safety, it would be recommended to use a 1.25 W resistor. If the inequality for clamped condition were true, one could easily calculate the power dissipated under that condition through the following equation:

$P_{RX} = [\text{ Vpeak} - V_{IHC}]^2 / R_X$

$= [400 - 12]^2 / 142.56k\Omega$

$= 1.056$ W (again choose 1.25W resistor for some safety margin)

The maximum input current and power must be calculated to ensure the operating conditions are within the absolute maximum ratings of the HCPL-5760.

For the input clamped condition,

$I_{IN} = (\text{Vpeak} - V_{IHC}) / R_X < I_{IN}\text{ (max)}$

$= (400 - 12) / 142.56\ k\Omega$

$= 2.3\text{ mA} < 15\text{ mA (max)}$

$P_{IN} = (V_{IHC} \bullet I_{IN}) < P_{IN}\text{ (max)}$
$= 12\text{ V} \bullet 2.3\text{mA} = 27\text{ mW} < 195\text{ mW (max)}$

Since the output stage of the HCPL-5761 is an open collector stage, a pull up resistor is required to make the optocoupler switch. An output pull up resistor of 1.8kΩ is consistent with the gain and current transfer ratio of the optocoupler when the output V_{CC} is 5V.

If the input voltage is an ac waveform, the threshold detection can be easily achieved by using the ac inputs of the HCPL-5761. Let us assume that ac power line (115 V rms) is to be monitored, and we select a threshold level of 60% of Vpeak. In this case, the threshold voltage level of 60% is selected to provide sufficient noise margin, as the power lines can easily fall within ±15% of nominal values.

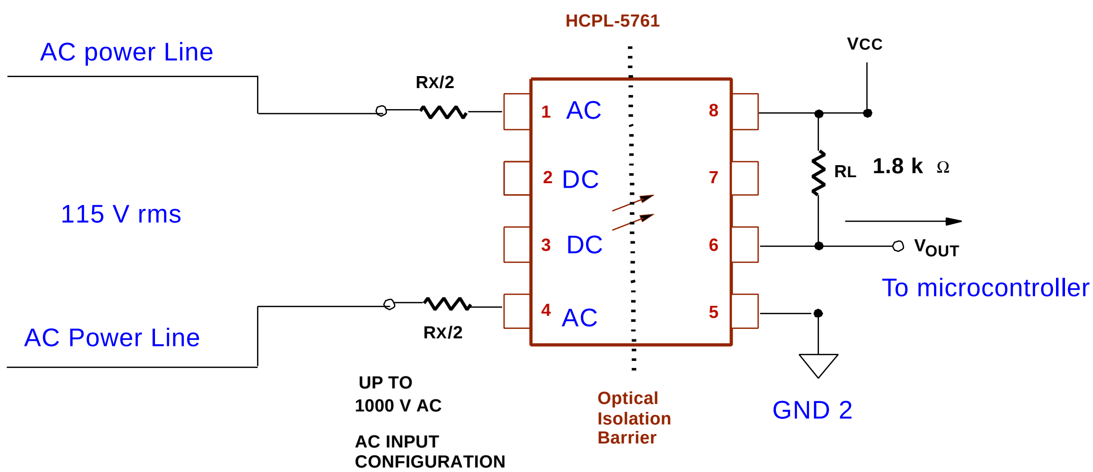


Figure 14. AC Power Line Detection Using the HCPL-5761

For the ac threshold detection case, we have the following:

HCPL-5761 Input thresholds from the data sheet:

V_{TH+} = 5.0V
V_{TH-} = 3.7V
I_{TH+} = 2.5mA
I_{TH-} = 1.3mA
V_{IHC2} = 6.6V

The Nominal AC Voltage = 115 Vrms
Peak ac voltage = 1.414 • 115 = 162.6 V (Vpeak)
Threshold selected (V_{+}) = 60% •162.6 = 97.6 V

As before, the value of the external resistor that we require for the instantaneous 97.6 V ac (peak) voltage detection level is:

$R_X = (V_+ - V_{TH+}) / I_{TH+}$
$= (97.6 - 5.0) / 2.5$ mA
$= 37$ kΩ (use $R_{X/2}$ = 18.5kΩ , 1% resistor for each input lead)

The resulting lower threshold voltage is now found from:
$V_- = I_{TH-} \bullet R_X + V_{TH-}$
= 1.3mA •37kΩ + 2.5
= 50V

Once again, for completion, one needs to calculate the maximum power dissipation in the R_X, and whether the input is clamped or not. One must also ensure that the maximum input current, and maximum input power does not exceed the absolute maximum rating of the HCPL-5761 (as defined in the data sheet).

In this case, V_+ /Vpeak < V_{TH+} / V_{IHC2} [97.6/ 162.6 < 3.6 / 6.6]
And the input will clamp. The input current is now calculated:

I_{IN} = (Vpeak – V_{IHC}) / R_X
= (162.6V – 6.6V) / 37 kΩ
= 4.2 mA (< 15 mA max)

And the input power dissipation is calculated from:
$P_{IN} = V_{IHC} \bullet I_{IN}$
= 6.6 V • 4.2 mA
= 27 .7 mW (< 195 mW max)

And finally the power dissipated in the resistor is calculated:

P_{RX} = [Vpeak – V_{IHC} $]^2$ / R_X (clamped input condition)
= $[162.6 - 6.6]^2$ / 37 kΩ
= 0.66 W

Thus, if one splits the input resistor R_X by half, then one resistor each ($R_{X/2}$ = 18.5 kΩ) of ½ watt should be used at each of the two ac inputs.

Applications Using the Power MOSFET Optocoupler HSSR-7111 or HSSR-7110

The HSSR-7111 is a single-pole, normally open, power MOSFET output stage optocoupler with a very low ON resistance, and operates exactly like a solid-state relay. Two connections are possible, the connection A, where the output is taken across pins 8 and 5, the maximum ON resistance is 1 ohm. This connection is also known as AC/DC connection. In the connection B, where the two outputs are essentially paralleled, with pin 5 connected to pin 8 and ground taken as pin 6 or 7 (pins 6 and 7 are internally shorted), the maximum ON resistance is only ¼ ohm. This connection B is also known as the dc connection. One advantage of the connection B is that the maximum current capability of the optocoupler is twice that of the connection A capability. For instance, the average absolute maximum current in connection A is 0.8A , however, in connection B, this maximum current rating is 1.6A.

This optocoupler provides outstanding benefits when one compares it with the traditional electromechanical relay. Inside this optocoupler there are no mechanical, electromagnetic, or moving parts. Each optocoupler consists of two power MOSFETs on the output, with an array of optical detectors coupled to a FET driver control circuit, which drives the output power MOSFETs. The input of the optocoupler consists of a highly efficient light emitting diode (LED). The optical cavity is filled with a transparent, high dielectric strength silicone material providing the optical isolation between the input and output stage of the optocoupler. Figure 15 shows the schematic diagram of the optocoupler.

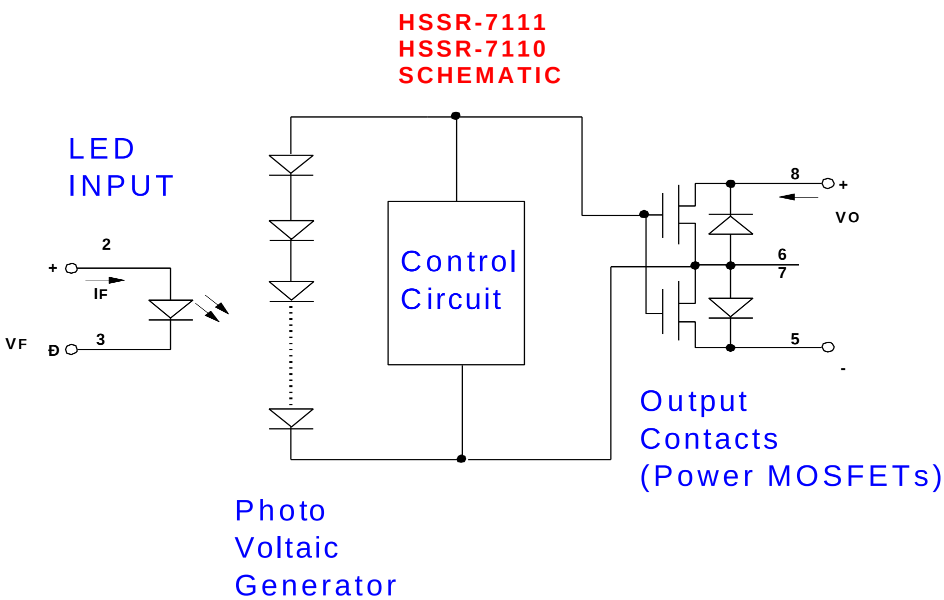


Figure 15. Basic Schematic of the Power MOSFET Optocoupler HSSR-7111

The key advantages of these optocouplers compared to the traditional electromagnetic relay (EMR) can be summarizes as:

- No contact bounce, noise free closures
- No problems with shock, vibration, or mounting position
- No electromagnetic wear out mechanisms
- Unlimited number of contact closures
- Very Long Life and very high reliability
- Very low input current required for turn ON
- No minimum contact “wetting” current required

The HSSR-7111 or HSSR-7110 requires only a 5mA input drive current for the output MOSFETs to close. The LED turn on voltage is 1.7 V maximum. And in the off state, the withstand voltage capability is 90 volts minimum. With a higher input currents (20 mA maximum) somewhat lower switching time can be achieved. The optocoupler has a very low turn-ON threshold, and, thus, to completely turn-OFF will require that the input LED current is zero. One way to guarantee the complete turn-OFF is that the input voltage that the LED is exposed to during the off state should be less than 0.6V maximum. This is because the LED takes around 0.9 V to start conducting, and will conduct zero current at or below 0.6V across it.

When the LED is turned ON, the optical radiation emitted by the LED is detected by the photo-detector diode array indicated as the photovoltaic generator in the Figure 15. This array converts the optical radiation detected to a voltage and current sufficient to operate the FET driver or the control circuit to drive the output power MOSFET stage. All the power to operate the MOSFET switch is generated through the photovoltaic action of the photo-detector, and no external power is needed from the external circuit.

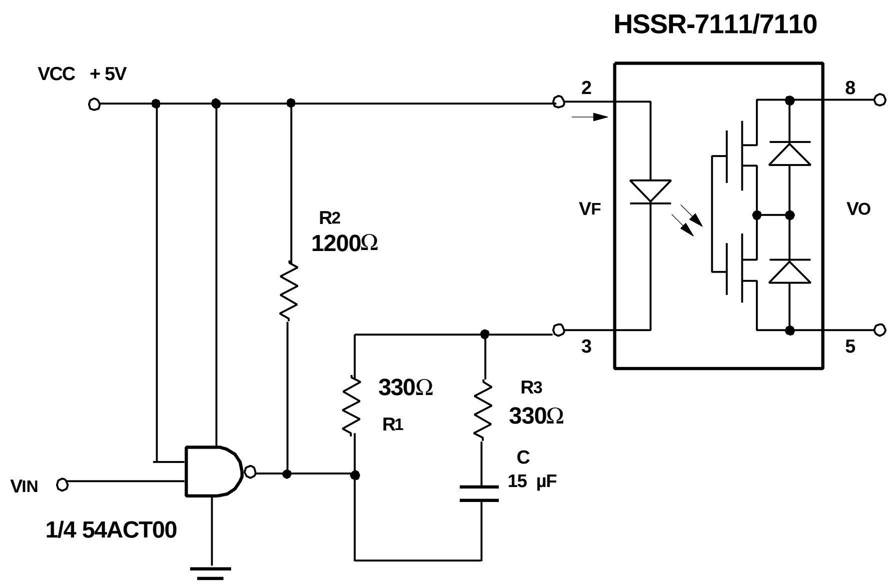


Figure 16. A Recommended Drive Circuit for the HSSR-7111

Figure 16 shows a simple input drive current circuit driven with a 5V CMOS logic gate. Resistor R1 is required to set a steady state input drive current, and a nominal value of 10mA drive current is achieved if R1 is 330 Ω. Resistor R2 is selected at 1200 Ω. One important consideration is that in the OFF state, there should not be more than 0.6V across the LED, otherwise even a small amount of LED current in the µA range can turn the output switch ON. The purpose of R2 is to allow an alternative leakage path for the CMOS gate, and ensures that in the OFF state the voltage across the LED is less than 0.6V. Resistor R3 and capacitor C are only needed if one wants to provide an initial peaking current for faster turn-ON. The value of R3 selected at 330 Ω provides for a peaking current of 20mA that stabilizes down to 10 mA after the time constant provided by the RC value. The steady state value of the current is provided by R1 alone. If a higher peaking current is selected, one may want to use two CMOS gates in parallel for the higher sinking current.

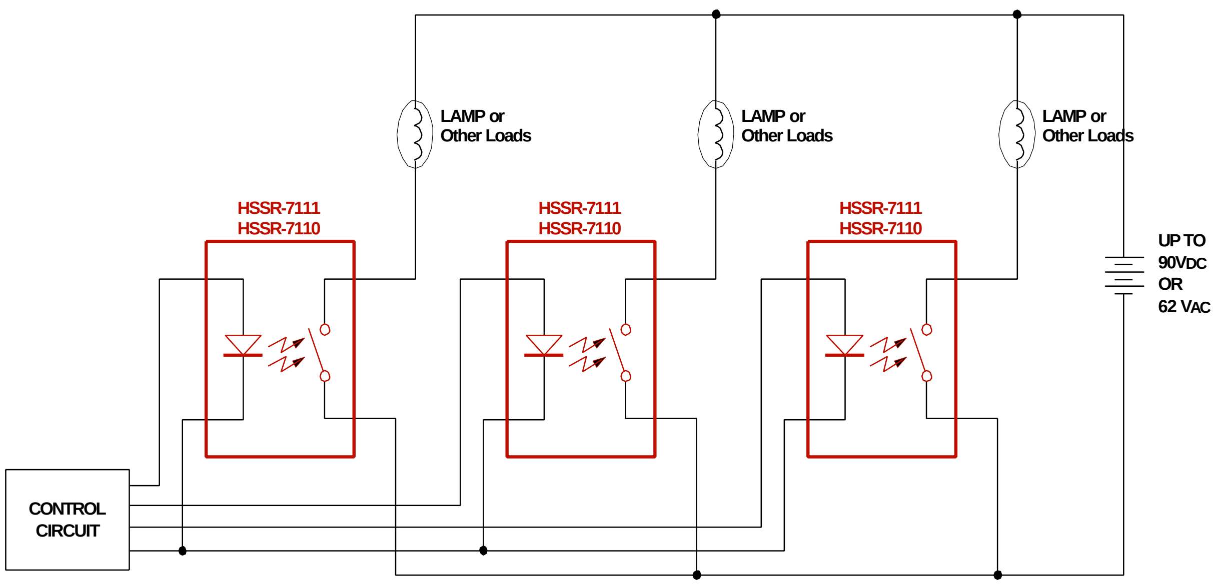


Figure 17. HSSR-7111 Controlling Lamps or Power Loads

Shown in Figure 17 is the use of the optocoupler in a lamp sequence control. This optocoupler is frequently used to control lamps in applications such as process equipment, navigational devices, illuminated signs and status indicators. In aircraft, submarine, and ship applications, the optocoupler may control lamps for cabin lighting, instrumentation lighting, and warning or status indicators. Compared to Electromagnetic relays (EMR) these optocouplers are particularly useful in rugged environments such as aeronautics, space and satellites, as they are immune to shock and vibration and are unaffected by electromagnetic interference.

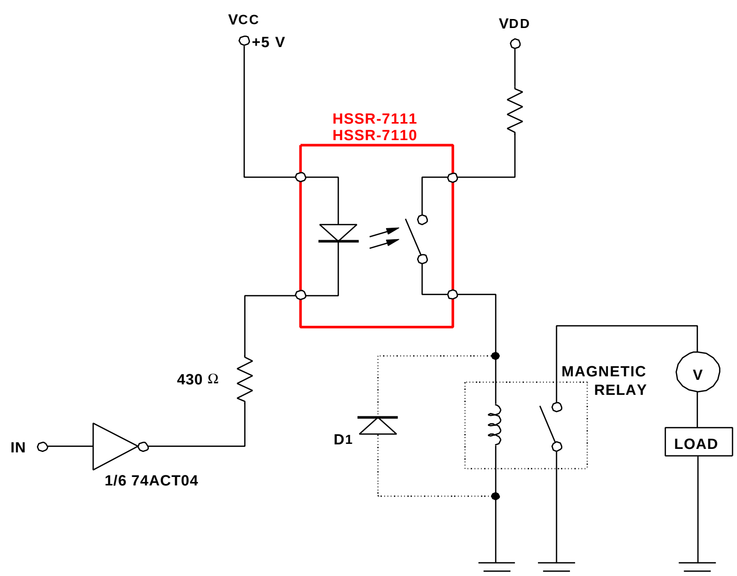


Figure 18. HSSR-7111 Driving an Electromagnetic Relay

Often a need arises to use an optically isolated device to drive an EMR. A need may arise where a much higher load current or power needs to be controlled, than can be handled by the HSSR-7111. In such cases, the optocoupler can be advantageously put to use to control the input current of the EMR. Figure 18 shows the optocoupler used to drive an input coil of an EMR, which is a highly inductive load. Since inductive loads are prone to generate very high voltage and current surges when switching off the load, it is highly recommended that a protective device be used across the output of the optocoupler when driving inductive loads. Surge protection components such as metal oxide varistors (MOV™) or TranZorbs™ should be used to protect the contacts of the optocoupler.

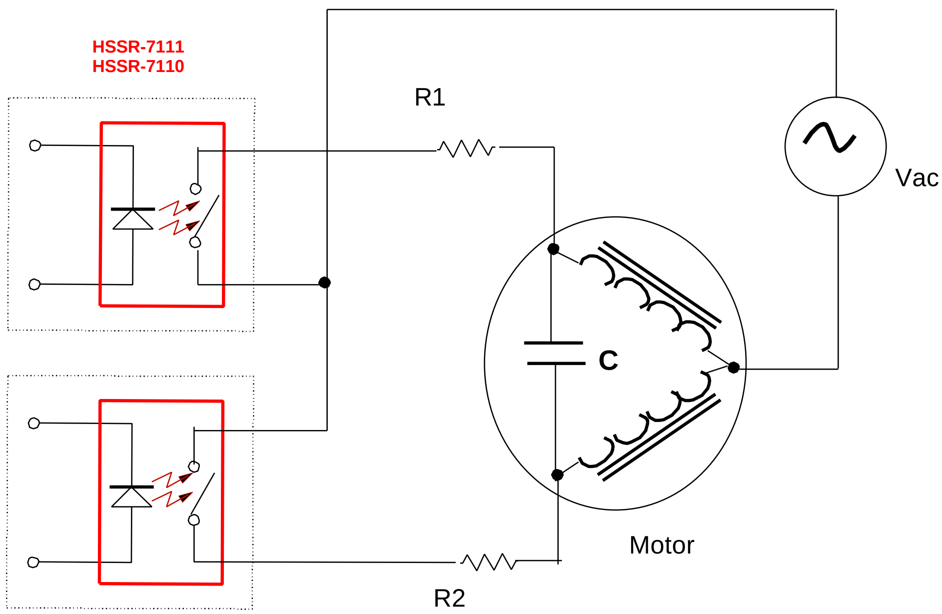


Figure 19. HSSR-7111 used for Motor Reversing Control

Motors are another example of large inductive loads. The optocoupler can be used to control shutdown or slowdown of small fractional motors A reversing control for a synchronous ac motor is shown in Figure 19. Motors that need to be frequently switched ON and OFF require the motor current to be switched ON and OFF at the cycling frequency. In such applications it is much preferable to use solid state relays, as these relays can withstand the inductive surges better than the EMR and do not produce any EMI. Similarly, these optocouplers may also be used to control small dc motors such as those used in computer disk drives, audio and video equipment, household electronics, or automotive electronics.

In test and measurement instrumentation electronics, a common requirement is to have relays perform gain and selection features for operational amplifier for analog applications. Figure 20 shows the optocoupler performing the gain selection for an OP-Amp application. This circuit configuration takes advantage of low on resistance, low offset voltage, and negligible nonlinearity of the closed contacts.

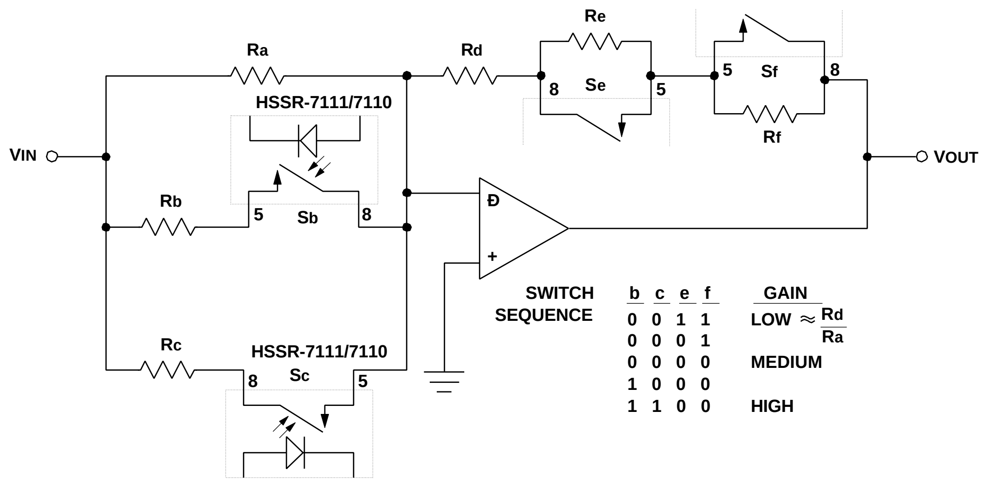


Figure 20. HSSR-7111 used in Operational Amplifier Gain Switching Circuits

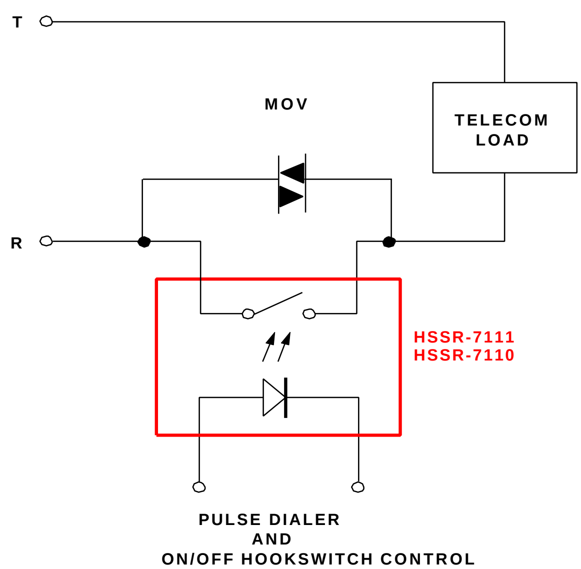


Figure 21. HSSR-7111 used in Telephone Switch Control

Solid state relays are commonly used in the telecommunications industry. Some examples of applications include on/off-hook switching, test and maintenance equipment, PBX (private branch exchange) and central office switching, and pulse dialing. The purpose of the on-off hook switch is to connect or disconnect the telephone equipment from the PBX. For an incoming or an outgoing telephone call, the output of the optocoupler is turned ON to energize the tip and ring conductors. In such telecommunication applications, a protection device such as MOV™ is necessary because of potential lightening induced surge voltages on the line. Other examples of applications for this optocoupler in Telecommunication include relays to switch test equipment on the lines for diagnostics or multiplexing incoming signals or this optocoupler may be used in the cross point matrixes of the switching stations.

Radiation Tolerant Hermetic Optocouplers From Avago Technologie

The Hermetic Optocouplers manufactured by Avago Technologies may not be characterized as "Rad-Hard", but have proven to be quite tolerant to most radiation effects. Avago Tech optocouplers utilize integrated photodiode detectors, whereas many optocouplers use phototransistors in their designs. The photodiode design permits shallower diffusion depths and a smaller transistor base area. Phototransistor optocouplers, on the other hand, maximize the base area for increased coupling. This scheme makes the device very susceptible to radiation effects. At the same radiation level, the device with the smaller exposed sensitive area will experience less radiation damage.

Proton-induced single event transients (SET) has a high level of occurrence on high-speed optocouplers such as the 6N134/HCPL-56xx and HCPL-54xx product families. This is not surprising as photodiodes make wonderful particle detectors. The high speed (bandwidth faster than 400 kbps) of some photodiodes allows some transients to induce a transient output, however, there *are* workarounds (e.g. one may be to increase the Vcc level, or use the optocoupler in inverting mode versus non-inverting mode, whichever appears to be less sensitive). For slower speed or bandwidth applications less highly integrated or simpler optocouplers, such as the 4N55 product family or 6N140A family are recommended. As this family shows a high rate of immunity to SET, it's an excellent example of the filtering capabilities of the slower speed optocouplers amplifier stage.

Total Dose up to 200Krads has been performed on the majority of the hermetic products, which have revealed a high degree of tolerance. In fact, with the exception of the "relay" devices (HSSR-711x), we have not experienced any device not meeting datasheet specifications after 200Krads. The MOSFETs utilized in the HSSR-711x family have a low threshold voltage that requires thin oxide for the gates. This design allows for total dose radiation levels up to 30Krads before significant leakage occurs.

Over the past several years, Avago Technologies has made a concerted effort to amass radiation data on our hermetic optocoupler portfolio. This data, consisting mostly of photon (gamma) and particle (protons and electrons), confirms our belief that the Avago Tech IC design provides high radiation immunity. Most of this data is available for disclosure to customers.

Conclusion

In this article we have shown that Avago Technologies provides a wide portfolio of high reliability Hermetic Optocouplers that include modern, state of the art, reliable, sophisticated, and application specific optocouplers. Optocouplers are primarily used for noise rejection and high voltage safety and isolation purposes. Application specific Hermetic optocouplers are available for diverse application needs. These applications include high speed digital data communication applications, feedback sensing element for switching power supplies, Intelligent Power Module (IPM) driver applications for motor control, analog optocouplers for current and voltage sensing applications, and power MOSFET optocouplers for power load switching and telecommunication switching applications. Through extensive radiation tests performed to date, these Hermetic Optocouplers have been found to be radiation tolerant to high levels and, with proper design considerations, may be used in applications that will encounter harsh environment.

The entire product offerings are contained within Defense Supply Center Columbus (DSCC) Standard Microcircuit Drawings (SMDs) and Avago Technologies is listed as a QML-38534 supplier for both high reliability Class H devices and the highest reliability class K devices. All of these devices, including the full line of commercial level product are considered COTS (Commercial Off the Shelf) per the definition endorsed by DSCC.

References

[1] Paul R Gray and Robert G. Meyer, "Analysis and Design of Analog Integrated Circuits," Second Edition 1984, John Wiley and Sons, Inc.

[2] Paul Horowitz and Winfield Hill, "The Art of Electronics," Second Edition 1989, Cambridge University Press

[3] Jamshed N. Khan, "Optocouplers For Variable Speed Motor Control Electronics in Consumer Home Appliances," Conference Proceeding, 2000 Appliance Manufacturer Conference and Expo (AMCE), pp. 35-60, 2000

[4] Drew Plant and Mike Walters, "Isolation Amplifiers: Isolation for Sense Resistor Applications," Principles of Current Sensors, Powersystems World, pp. 19-38, 1997

[5] Jamshed N. Khan, "Regulatory Guide to Isolation Circuits, " Hewlett-Packard Publication Number 5965-5853E, 1/1997

SUNSTAR 商斯达实业集团是集研发、生产、工程、销售、代理经销 、技术咨询、信息服务等为一体的高科技企业，是专业高科技电子产品生产厂家，是具有 10 多年历史的专业电子元器件供应商，是中国最早和最大的仓储式连锁规模经营大型综合电子零部件代理分销商之一，是一家专业代理和分銷世界各大品牌 IC 芯片和電子元器件的连锁经营綜合性国际公司，专业经营进口、国产名厂名牌电子元件，型号、种类齐全。在香港、北京、深圳、上海、西安、成都等全国主要电子市场设有直属分公司和产品展示展销窗口门市部专卖店及代理分销商，已在全国范围内建成强大统一的供货和代理分销网络。 我们专业代理经销、开发生产电子元器件、集成电路、传感器、微波光电元器件、工控机/DOC/DOM 电子盘、专用电路、单片机开发、MCU/DSP/ARM/FPGA 软件硬件、二极管、三极管、模块等，是您可靠的一站式现货配套供应商、方案提供商、部件功能模块开发配套商。商斯达实业公司拥有庞大的资料库，有数位毕业于著名高校——有中国电子工业摇篮之称的西安电子科技大学（西军电）并长期从事国防尖端科技研究的高级工程师为您精挑细选、量身订做各种高科技电子元器件，并解决各种技术问题。

微波光电部专业代理经销高频、微波、光纤、光电元器件、组件、部件、模块、整机；电磁兼容元器件、材料、设备；微波 CAD、EDA 软件、开发测试仿真工具；微波、光纤仪器仪表。欢迎国外高科技微波、光纤厂商将优秀产品介绍到中国、共同开拓市场。长期大量现货专业批发高频、微波、卫星、光纤、电视、CATV 器件： 晶振、VCO、连接器、PIN 开关、变容二极管、开关二极管、低噪晶体管、功率电阻及电容、放大器、功率管、MMIC、混频器、耦合器、功分器、振荡器、合成器、衰减器、滤波器、隔离器、环行器、移相器、调制解调器；光电子元器件和组件：红外发射管、红外接收管、光电开关、光敏管、发光二极管和发光二极管组件、半导体激光二极管和激光器组件、光电探测器和光接收组件、光发射接收模块、光纤激光器和光放大器、光调制器、光开关、DWDM 用光发射和接收器件、用户接入系统光光收发器件与模块、光纤连接器、光纤跳线/尾纤、光衰减器、光纤适 配器、光隔离器、光耦合器、光环行器、光复用器/转换器；无线收发芯片和模组、蓝牙芯片和模组。

更多产品请看本公司产品专用销售网站:

商斯达微波光电产品网:HTTP://www.rfoe.net/

商斯达中国传感器科技信息网：http://www.sensor-ic.com/

商斯达工控安防网：http://www.pc-ps.net/

商斯达电子元器件网：http://www.sunstare.com/

商斯达消费电子产品网://www.icasic.com/

商斯达实业科技产品网://www.sunstars.cn/ *射频微波光电元器件销售热线：*

地址：深圳市福田区福华路福庆街鸿图大厦 1602 室

电话：0755-83396822 83397033 83398585 82884100

传真：0755-83376182 （0）13823648918 MSN: SUNS8888@hotmail.com

邮编：518033 E-mail:szss20@163.com QQ: 195847376

深圳赛格展销部：深圳华强北路赛格电子市场 2583 号 电话：0755-83665529 25059422

技术支持: 0755-83394033 13501568376

欢迎索取免费详细资料、设计指南和光盘 ；产品凡多，未能尽录，欢迎来电查询。

北京分公司：北京海淀区知春路 132 号中发电子大厦 3097 号

TEL：010-81159046 82615020 13501189838 FAX：010-62543996

上海分公司：上海市北京东路 668 号上海赛格电子市场 D125 号

TEL：021-28311762 56703037 13701955389 FAX：021-56703037

西安分公司：西安高新开发区 20 所(中国电子科技集团导航技术研究所)

西安劳动南路 88 号电子商城二楼 D23 号

TEL：029-81022619 13072977981 FAX:029-88789382