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# About This Designer's Guide

Hewlett-Packard optocouplers can be used in an array of isolation applications ranging from power supply and motor control circuits to data communication and digital logic interface circuits.

To help you choose and design with Hewlett-Packard isolation components, this Designer's Guide contains 50 popular application circuits and recommended HP optocouplers.

This handbook begins with a selection guide followed by sections discussing critical optocoupler design parameters such as Insulation and Withstand Voltage, Regulatory Agency Safety Standards, Common-Mode Transient Rejection, Product Life and light emitting diode (LED) aging. The rest of the guide consists of application circuits.

Each application circuit is accompanied by:

1. A brief description.
2. Highlights of circuit performance.
3. Circuit benefits.
4. A list of alternative HP parts indicating comparably performing products available in varying package styles for maximum design flexibility.

## How to Use This Guide

Several indexes are included to help locate applications and products.

- The table of contents lists all the applications by their general description.
- Selection Guides in the form of tables contain basic product specifications which allow you to quickly select the products most suitable for your applications.

Most data sheets for products recommended here can be found in Hewlett Packard's Optoelectronic Designer's Catalog, or they may be ordered from your local HP representative.

## How to Order

To order any component in this guide or additional applications information, call your authorized HP distributor nearest you.

Although product information and illustrations in this guide were current at the time it was approved for printing, Hewlett-Packard, in a continuing effort to offer excellent products at a fair value, reserves the right to change specifications, designs, and models without notice.

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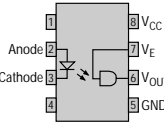
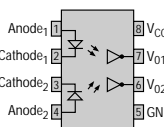
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# Optocoupler Selection Guide

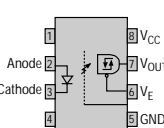
Hewlett-Packard offers a broad range of isolation products which provide performance features and benefits that are unmatched in the industry. Some of the leading product performance technologies that Hewlett-Packard offers include:

- Dielectric Withstand Voltage Rating as high as 5000 Vac/1 min (per UL)
- Worldwide Safety Approvals, including the highest Maximum Working Insulation Voltage ( $V_{IORM}$ ) at 1000 V (per VDE)
- Common-Mode Transient Noise Immunity as high as 15 kV/ $\mu$ s (Minimum)
- A wide variety of surface mount and multi-channel packages, including the highest density optocouplers in the world.
- Lowest power dissipation optocouplers available, with input currents as low as 40  $\mu$ A
- Highest speed optocouplers, with data rates as high as 25 MBd and propagation delays as low as 40 ns
- Wide operating temperature ranges for industrial and military environments
- A full line of hermetically-sealed optocouplers for high reliability applications. Available as commercial grade or Certified and Qualified to MIL-PRF-38534 Class H or K. DSCC Standard Microcircuit Drawings (SMDs) are available on all hermetic products.

## 10 MBd Logic Gate Optocoupler

Device	Part No.	Package				IF	Prop Delay	CMR-V/ $\mu$ s @ (Vcm)						VDE 0884		Insulation		Note
		300 mil DIP	S08	400 mil DIP	S05			mA	tPHL/tPLH ns (max)	1000 (50 V)	2000 (200 V)	5000 (50 V)	10000 (200 V)	10000 (1 kV)	15000 (1 kV)	Peak Voltage 630 V   1414 V	UL = 1 min. 2500 V   5000 V	
	6N137	•				5	100									•	B	
	HCPL-0600		•			5	100									•		
	HCNW137			•		5	100								•		•	
	HCPL-M600				•	5	100											
	HCPL-2601	•				5	100			•						•	B	
	HCPL-0601		•			5	100			•						•		
	HCNW2601			•		5	100			•					•		•	
	HCPL-M601				•	5	100			•								
	HCPL-2611	•				5	100						•		•	•	B	2
	HCPL-0611		•			5	100						•			•		
	HCPL-M611				•	5	100						•				•	
	HCNW2611			•		5	100						•		•		•	
	HCPL-261A	•				2	100		•	•					•	•	B	2
	HCPL-061A		•			2	100		•	•						•		
	HCPL-261N	•				2	100						•	•	•	•	B	2
	HCPL-061N		•			2	100						•	•		•		
HCPL-2400	•				4	60		•						•	•		2	
	HCPL-2630	•				5	100									•	B	
	HCPL-0630		•			5	100									•		
	HCPL-2631	•				5	100			•						•	B	
	HCPL-2430	•				•	60		•							•		
	HCPL-0631		•			5	100			•						•		
	HCPL-4661	•				5	100					•				•	B	
	HCPL-0661		•			5	100					•				•		
	HCPL-263A	•				2	100		•	•						•	B	
	HCPL-063A		•			2	100		•	•						•		
	HCPL-263N	•				2	100					•	•			•	B	
HCPL-063N					2	100					•	•			•			

## 5 MBd Logic Gate Optocoupler

Device	Part No.	Package				IF	CMR-V/ $\mu$ s @ (Vcm)				VDE 0884		Insulation		Note		
		300 mil DIP	S08	400 mil DIP	S05		mA	100 (50 V)	1000 (50 V)	2500 (1400 V)	10000 (1 kV)	Peak Voltage 630 V   1414 V	UL = 1 min. 2500 V   5000 V				
	HCPL-2200	•				1.6		•				•		•			2
	HCPL-2219	•				1.6			•			•		•			2
	HCPL-2201	•				1.6			•			•		•			2, 4
	HCPL-2202	•				1.6			•			•		•			2, 4, 5
	HCPL-0201		•			1.6			•					•			4
	HCNW2201			•		1.6			•				•		•		4
	HCPL-2211	•				1.6					•	•		•			2, 4
	HCPL-2212	•				1.6					•	•		•			2, 4, 5
	HCPL-0211		•			1.6					•	•		•			4
	HCNW2211			•		1.6					•	•		•			4
	HCPL-2300	•				0.5		•				•	•		•		2
Dual Version	HCPL-2231	•				1.8			•					•			
	HCPL-2232	•				1.8					•			•			6

Recommended for New Designs

### Notes:

- PIN 7 not connected
  - 630 V peak VDE 0884 with option 060
  - No built-in pull up resistor
  - PIN 6 not connected
  - PINS 6 and 7 reversed
  - CMR = 5000
  - 890 V peak VDE 0884 with option 060
  - HCPL-7800 A with 1% Gain Tolerance
  - available soon
- Options:**
- 3750 Vrms/1 min
  - Option 020

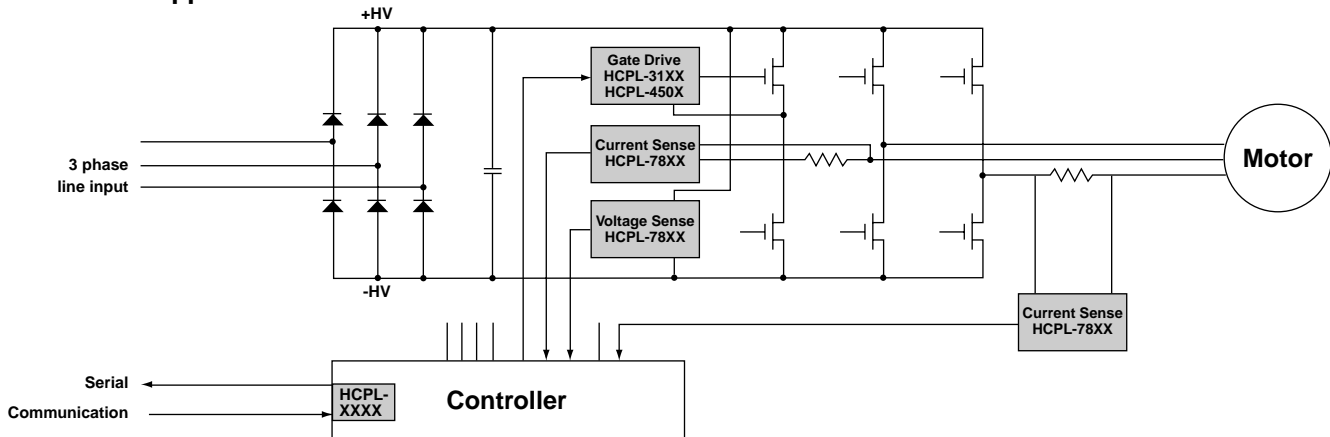
## 1 Mbd Transistor Output Optocoupler

Device	Part No.	Package				IF		Prop Delay		CTR		CMR-V/ $\mu$ s @ (Vcm)			VDE 0884			Insulation		Note
		300 mil DIP	S08	400 mil DIP	S05	mA	tPHL $\mu$ s (max)	tPLH $\mu$ s (max)	Min %	Max %	1000 (10 V)	10000 (1.5 kV)	15000 (1.5 kV)	Peak Voltage			UL = 1 min.			
													630 V	890 V	1414 V	2500 V	5000 V			
	6N135	•				16	2.0	2.0	7	50	•						•	B		
	HCPL-0500		•			16	2.0	2.0	7	50	•						•			
	HCNW135			•		16	2.0	2.0	7	150	•				•		•			
	6N136	•				16	1.0	1.0	19	50	•						•	B		
	HCPL-0501		•			16	1.0	1.0	19	50	•						•			
	HCNW136			•		16	1.0	1.0	19	150	•				•		•			
	HCPL-4502	•				16	1.0	1.0	19	50	•						•	B	1	
	HCPL-M452				•	16	1.0	1.0	19	50		•								3
	HCPL-0452		•			16	1.0	1.0	19	50	•							•		1
	HCNW4502			•		16	1.0	1.0	19	150	•				•		•	•		1
	HCPL-4503	•				16	1.0	1.0	19	50			•	•			•	B	1, 2	
	HCPL-0453		•			16	1.0	1.0	19	50			•				•			1
	HCNW4503			•		16	1.0	1.0	19	150			•				•	•		1
	HCPL-M453				•	16	1.0	1.0	19	50			•					•		3
	HCPL-M454				•	12	1.0	1.4	26	65		•								3
	HCPL-M456				•	10	0.4	0.55	44	>90			•							
	HCPL-4504	•				12	1.0	1.14	26	65		•		•				•	B	1, 2
	HCPL-0454		•			12	1.0	1.14	26	65		•						•		1
	HCPL-J454	•				12	0.5	0.7	21	65			•		•			•		
	HCNW4504			•		12	0.5	0.7	25	65		•			•		•	•		1
HCPL-4506	•				10	0.4	0.55	44	>90			•	•			•	B	3		
HCPL-0466		•			10	0.4	0.55	44	>90			•					•			
HCPL-J456	•				10	0.4	0.55	44	>90			•		•			• A			
HCNW4506			•		10	0.4	0.5	44	>90			•		•		•	•			
	HCPL-2530	•				16	2.0	2.0	7	50	•						•	B		
	HCPL-0530		•			16	2.0	2.0	7	50	•							•		
	HCPL-2531	•				16	1.0	1.0	19	50	•							•	B	
	HCPL-0531		•			16	1.0	1.0	19	50	•							•		
	HCPL-4534	•				16	1.0	1.0	19	50			•					•	B	
HCPL-0534		•			16	1.0	1.0	19	50			•					•			

## 100 Kbd Darlington Transistor Output Optocoupler

Device	Part No.	Package				IF			CTR	VDE 0884		Insulation		Note					
		300 mil DIP	S08	400 mil DIP	S05	40 $\mu$ A	0.5 mA	1.6 mA		Min. %	Peak Voltage		UL = 1 min.						
										630 V	1414 V	2500 V	5000 V						
	6N138	•							•	300				•					
	HCPL-0700		•							•	300				•				
	HCNW138			•						•	300			•		•			
	HCPL-M700				•					•	300								
	6N139	•								•	400				•	B			
	HCPL-0701		•							•	400				•				
	HCNW139			•						•	400			•		•			
	HCPL-M701				•					•	400								
	HCPL-4701	•								•	800				•	B			2
	HCPL-070A		•							•	800				•				
	HCPL-2730	•							•	300				•	B			1	
	HCPL-0730		•						•	300					•				1
	HCPL-2731	•							•	400					•				1
	HCPL-0731		•						•	400					•				1
	HCPL-4731	•				•			•	800					•				1
HCPL-073A		•			•			•	800					•				1	

## Motor Drive Application



## Integrated Gate Drive Optocoupler

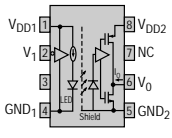
Device	Part No.	Package			IF (on)		Iout			Prop Delay			PWD		Vcc	VDE 0884			Insulation		CMR-V/μs @ (Vcm)			Note	
		300 mil DIP	400 mil DIP	SO 16	mA	A	min	tPHL μs (max)	0.5	1	2	5	0.3 μs max	0.8 μs max	V max	Peak Voltage			UL = 1 min.		8000 (1500)	10000 (1500)	15000 (1500)		
	HCPL-3000	•			8	0.6									18										
	HCPL-3100	•			12	0.1									24										
	HCPL-3101	•			8	0.1									24										
	HCPL-T250	•			7	1.5									30										
	HCPL-3120	•			7	2									30										2
	HCPL-J312	•			7	2									30										
	HCNW3120		•		7	2									30										
	HCPL-3150	•			7	0.5									30										
	HCPL-314J			•	10	0.4								35											9
	Dual 0.4 A Gate Drive Optocoupler with two separated channels																								
	HCPL-315J			•	16	0.5								30											9
	Dual 0.5 A Gate Drive Optocoupler with two separated channels																								
	HCPL-316J			•	1	μA	2							30											
	2.0 A Gate Drive Optocoupler with integrated over-current Protection and Fault Feedback																								
<ul style="list-style-type: none"> <li>• CMOS compatible</li> <li>• Under Voltage Lock-Out Protection (UVLO) with Hysteresis</li> <li>• Regulatory Approvals: UL, CSA, VDE = 890 Vpeak</li> </ul>																									

## Miniature Isolation Amplifiers

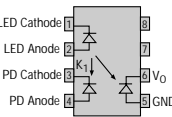
Device	Part No.	Package			Gain Toler.		Non-Linearity				Prop Delay			VDE 0884			Insulation		CMR-V/μs @ (Vcm)		Note			
		300 mil DIP	400 mil DIP	SO 16	3%	5%	% (max)				μs max.			Peak Voltage			UL = 1 min.		10000 (1000)	20000 (1000)				
	HCPL-7800	•																				8		
	HCPL-7840	•																				7		
	HCPL-7860	Isolated 12 bit A/D Converter with Isolated Modulator (HCPL-7860) and																						
	HCPL-7870	Interface IC (HCPL-7870/0870)																						
	HCPL-0870																							
HCPL-788J																								
<ul style="list-style-type: none"> <li>• Smart Current Sensor with integrated fast short circuit detection (3 μs)</li> <li>• Analog Output direct compatible with A/D converters</li> <li>• 1 μV/°C offset change vs temperature</li> <li>• 16 kHz bandwidth</li> <li>• 2500 Vac UL approval, VDE = 890 Vpeak</li> </ul>																								

# Optocouplers with Integrated Functions

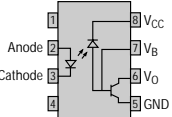
## High Speed CMOS Logic Gate

Device	Part No.	Package		Data Rate	PWD		Prop Delay
		300 mil DIP	S08		8 ns (max)	6 ns (max)	
	HCPL-7710	•		12.5	•		40
	HCPL-7720	•		25	•		40
	HCPL-7721	•		25		•	40
	HCPL-0710		•	12.5	•		40
	HCPL-0720		•	25	•		40
	HCPL-0721		•	25		•	40
<ul style="list-style-type: none"> <li>• 10 kV/μs CMR @ Vcm = 1000 V</li> <li>• Viorm = 630 V VDE, 3750 Vac UL Approval</li> </ul>							

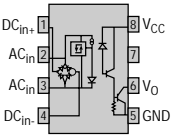
## High Linearity Analog

Device	Part No.	Pkg.	Transfer Gain	DC Non-Linearity	CTR	
					400 mil DIP	max %
	HCNR200	•	±15	0.25	0.25	0.75
	HCNR201	•	±5	0.05	0.36	0.72
<ul style="list-style-type: none"> <li>• -65 ppm/°C gain temperature coefficient</li> <li>• 1.5 MHz bandwidth</li> <li>• 1 kV VDE (option 050), 5000 Vac UL Approval</li> </ul>						

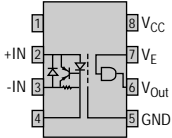
## Wideband Analog/Video

Device	Part No.	Package		Bandwidth	Non-Linearity	CTR	IMRR	VDE 0884
		300 mil DIP	400 mil DIP					
	HCPL-4562	•		17	0.25	45	122	
	HCNW-4562		•	9	0.15	52	119	•
<ul style="list-style-type: none"> <li>• UL Approval — 5000 V rms for 1 min for HCPL-4562 option 020</li> <li>• 0.3%/°C gain temperature coefficient</li> </ul>								

## AC/DC to Logic Interface

Device	Part No.	Pkg.	Input Threshold Current		Hysteresis	Prop Delay
			300 mil DIP	mA (min)		
	HCPL-3700	•	1.96	3.11	1.2	40
	HCPL-3760	•	0.87	1.56	0.6	40
<ul style="list-style-type: none"> <li>• CMOS compatible output</li> <li>• 600 V/μs CMR @ Vcm = 150 V</li> <li>• 2500 Vac UL Approval</li> </ul>						

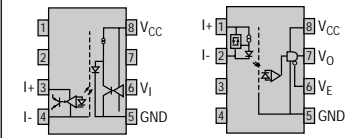
## Line Receiver

Device	Part No.	Pkg.	Output Collector Current	Prop Delay	CMR-V/μs @ (Vcm)	
					300 mil DIP	mA (max)
	HCPL-2602	•	50	100	•	
	HCPL-2612	•	50	100		•
<ul style="list-style-type: none"> <li>• 40 ns max propagation delay skew (part to part)</li> <li>• Line termination circuitry included</li> <li>• 2500 Vac UL approval</li> </ul>						

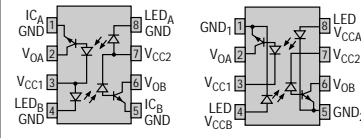


## Optocouplers with Integrated Functions, continued

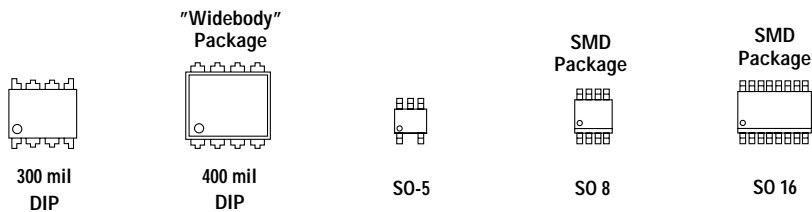
### 20 mA Current Loop Transmitter/Receiver

Device	Part No.	Pkg.	Prop Delay	CMR-V/ $\mu$ s @ (Vcm)	
				1000 (150)	1000 (50)
	HCPL-4100	•	1.6	•	
	HCPL-4200	•	1.6		•
<ul style="list-style-type: none"> <li>• CMOS compatible data input for HCPL-4100</li> <li>• CMOS compatible data output for HCPL-4200</li> <li>• 20 kB data rate at 400 meters</li> <li>• 2500 Vac UL approval</li> </ul>					

### Bi-Directional 1 MBd Optocoupler

Device	Part No.	Pkg.	If	Prop Delay		CTR		Common	
				tPHL $\mu$ s (max)	tPLH $\mu$ s (max)	min%	max%	Vcc	GND
	HCPL-0560	•	16	1	1	19	55	•	
	HCPL-0561	•	16	1	1	19	55		•
<ul style="list-style-type: none"> <li>• TTL compatible</li> <li>• Open collector output</li> <li>• RS232C interface compatible</li> </ul>									

### Packages



### Options

- 5000 Vac UL withstand (020)
- 630 V peak (060)
- gullwing leads (300)
- tape and reel (500)

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## Design Considerations

### Insulation and Regulation of Optically Coupled Isolation Devices

The primary purpose of optocoupler devices is to provide both electrical insulation and signal isolation. The popularity of Hewlett-Packard's product offering can be accredited to cost-effective innovations in these areas. Yet there exists a surprising level of misunderstanding regarding these two terms from both vendor and user alike. The discrepancies that exist within the worldwide regulatory community add to the frustration level for many designers. This discussion attempts to help the designer capitalize on HP's knowledge.

#### Insulation Defined

The electrical insulating capability of an optocoupler, sometimes referred to as withstand voltage, is determined by its ability to protect surrounding circuitry, as well as itself, against physical damage resulting from different voltage potentials. This potentially damaging phenomena can be system induced (e.g., motor rail voltage) or externally coupled (e.g., lightning pulse). The insulating material between input and output as well as the packaging technology are the primary determinants of withstand voltage capability. In contrast, signal isolation, although sharing some common causes, defines the

ability of the optocoupler to prevent the distortion of data through the suppression and filtration of common-mode transients. A further discussion of signal isolation can be found in the section entitled "Common-Mode Transient Rejection."

The effects of repeated long-term high-voltage stress between input and output of an optocoupler has continued to be an area of uncertainty. Much of the technical emphasis has been on the ability of optocouplers to withstand one-time short-term high-voltage transients (e.g., U.L. 1 minute dielectric voltage withstand rating). Hewlett-Packard has conducted extensive operating life tests to determine the effects of continuous high-voltage stress, both transient as well as steady-state, on the degradation of insulating performance. On completion, the test data was analyzed to determine safe operating areas for steady-state input-output high-voltage stress. The boundary conditions, as shown in Figures 1, 2, 3, have been defined by Hewlett-Packard as Endurance Voltage. The lower region refers to the safe operating area for the application of continuous steady-state ac and dc input-output voltage stress, or

working voltage, and the middle region to transient voltage stress. Operation above these regions has shown to cause wear-out either in functionality or insulating capability and is not recommended. Endurance Voltage is based on the inherent properties of Hewlett-Packard optocouplers that utilize unique packaging technologies and does not apply to products manufactured by other vendors. In addition, as these tests do not take into consideration particular equipment use conditions, Hewlett-Packard recommends the designer consult the appropriate regulatory agency guidelines to determine applicable working voltage. For an in-depth discussion on Endurance Voltage, consult Hewlett-Packard Application Note AN1074.

#### Regulatory Environment

Because electrical insulation is a function of safety, optocoupler performance, both at component and system levels, is often subject to regulatory requirements and approvals that vary according to country as well as industry. Most agencies are a mixture of governmental and private organizations with industry representation. Some common regulatory agencies are listed in Table 9.

Category 1 Optocouplers

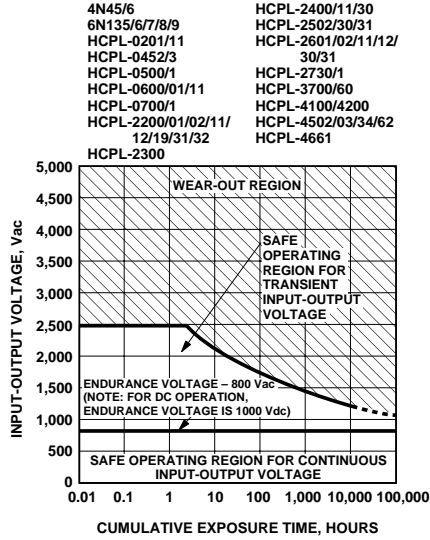


Figure 1. Recommended Safe Operating Area for Input-Output Voltage-Endurance Voltage for Category 1 Optocouplers.

Category 2 Optocouplers:

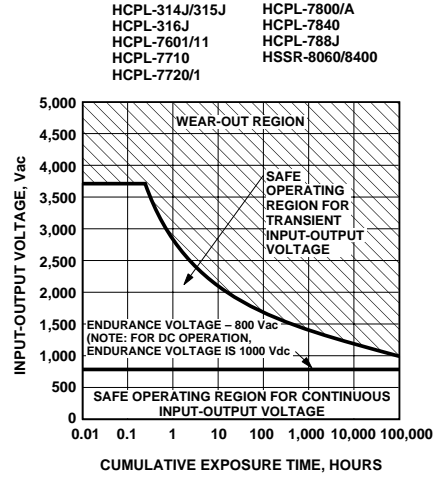


Figure 2. Recommended Safe Operating Area for Input-Output Voltage-Endurance Voltage for Category 2 Optocouplers.

Category 3 Optocouplers:

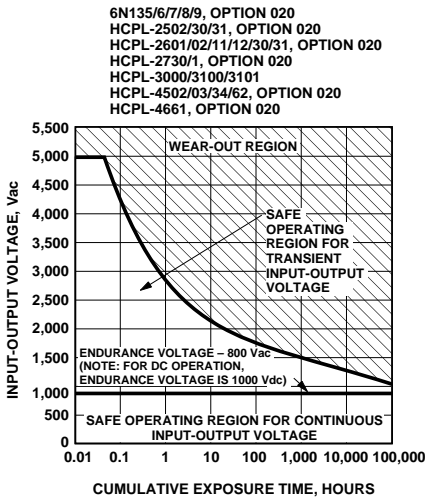
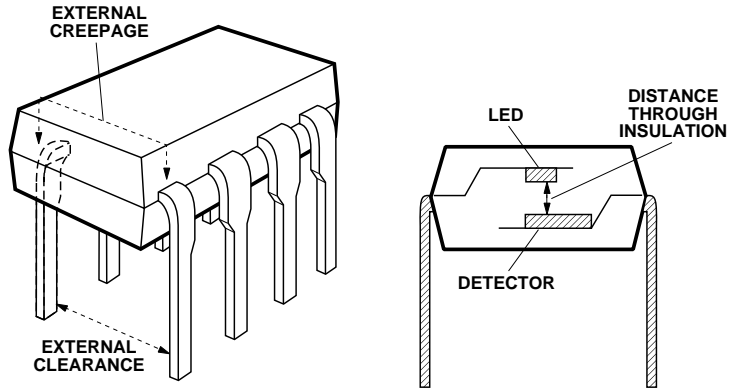


Figure 3. Recommended Safe Operating Area for Input-Output Voltage-Endurance Voltage for Category 3 Optocouplers.



OPTOCOUPLER'S INSULATION PARAMETERS

Figure 4. Optocoupler's Insulation Parameters.

**WARNING:** In all cases where regulatory compliance is required, working voltage as defined by the regulatory agency cannot be exceeded.

**Table 9**

<b>COMMON REGULATORY AGENCIES</b>		
<b>Name</b>	<b>Country</b>	<b>Abbreviation</b>
Verband Deutscher Electrotechniker	Germany	VDE
Underwriters Laboratories	United States	UL
Canadian Standards Association	Canada	CSA
British Standards Institute	United Kingdom	BSI
Norge Elektriske Materielkontrol	Norway	NEMKO
Danmarks Elektriske Materielkontrol	Denmark	DEMKO
Svenska Elektriske Materielkontrollanstalten AB	Sweden	SEMKO
Sahkotarkastuskeskus Elinspektionscentralen	Finland	SETI

Currently, little conformity exists between the various agencies regarding mechanical configurations and electrical test requirements. Within the European Union, however, standardization of equipment as well as component level specifications is in progress. In the interim, testing and approval according to equipment type and environmental factors must be obtained according to the control documents of each country. The International Electrotechnical Commission (IEC), with worldwide representation, provides a forum for generating technical standards. The European Committee for Electrotechnical Standardization (CENELEC), has European Commission authority to adopt IEC standards as European Norms (EN), with the force of law.

### **Common Terms**

#### **External Clearance**

The shortest distance through air, between conductive input and output leads, measured in mm. Refer to Figure 4.

#### **Comparative Tracking Index (CTI)**

Outer molding material characterization in the presence of aqueous contaminants. The higher the CTI value, the more resistant the material is to electrical arc tracking. CTI is often used with creepage by safety agencies to determine working voltage.

#### **External Creepage**

The shortest distance along the outside surface, between input and output leads, measured in mm. Refer to Figure 4.

#### **Dielectric Insulation Voltage Withstand Rating**

The ability to withstand without breakdown a 60 second application of a defined dielectric insulation voltage between input and output leads.

#### **Distance Through Insulation**

Distance between the photo-emitter and photodetector inside optocoupler cavity (also called internal clearance). Refer to Figure 4.

#### **Installation Class**

- I Equipment in closed systems (e.g., telecom)

protected against over-voltage with devices such as diverters, filters, capacitors, etc.

- II Energy consuming equipment (e.g., appliances) supplied through a fixed installation.
- III Primarily equipment in fixed installations (e.g., fixed industrial equipment).
- IV Primary supply level for industrial factories.

#### **Insulation**

Operational - required for correct equipment operation but not as a protection against electric shock.

Basic - protects against electric shock.

Supplementary - independently applied to basic insulation to protect against shock in the event of its failure.

Double - composed of both basic and supplementary.

Reinforced - A single insulation system composed of several layers (e.g., single and supplementary).

#### **Internal Clearance**

See Distance Through Insulation.

**Internal Creepage**

The shortest border distance between two separate insulating materials measured between emitter and detector.

**Material Group** (see Comparative Tracking Index)

- I 600 < CTI
- II 400 < CTI < 600
- IIIa 175 < CTI < 400
- IIIb 100 < CTI < 175

**Partial Discharge**

Electric discharge that partially bridges the insulation between two electrodes. Hewlett-Packard supports partial discharge measurements per VDE0884, a technique developed to evaluate the integrity of insulating materials. VDE's philosophy is that partial discharge testing

offers advantages over Dielectric Withstand Voltage testing, which might adversely affect the insulating material, and over through insulation distance requirements which not only increase manufacturing costs but also do not necessarily result in acceptable insulating capability.

**Pollution Degree**

- 1 - Nonconductive pollution only.
- 2 - Only occasional, temporary conductivity due to condensation.
- 3 - Frequent conductive pollution due to condensation.
- 4 - Persistent conductive pollution due to dust, rain or snow.

**Rated Mains Voltage**

Primary power voltage declared by manufacturer. Used to categorize optocoupler maximum allowable working voltage.

## Common-Mode Transient Rejection

Circuit designers often encounter the adverse effects of common-mode noise in a design. Once a common-mode problem is identified, there are several ways that it can be resolved. However, common-mode interference manifests itself in many ways; therefore, it may be hard to determine whether it is the cause of a circuit's misbehavior. If a system is connected and running but only produces erroneous data, common-mode noise may be the reason. This section describes sources of common-mode problems, presents possible solutions, and highlights the technology that Hewlett-Packard Components Group uses to produce opto-isolators with superior Common-Mode Performance.

Common-mode rejection (**CMR**) is a measure of the ability of a device to tolerate common-mode

noise. Hewlett-Packard specifies common-mode rejection as **common-mode transient rejection (CMTR)**. CMTR describes the maximum tolerable rate-of-rise (or fall) of a common-mode voltage (given in volts per microsecond). The specification for CMTR also includes the amplitude of the common-mode voltage ( $V_{CM}$ ) that can be tolerated. Common-mode interference that exceeds the maximum specification might result in abnormal voltage transitions or excessive noise on the output signal. (CMTR is slightly different than common-mode rejection ratio **CMRR**, often used for analog devices and commonly specified in dB as the ratio of the differential-mode gain to the common-mode gain.)

HP optocouplers rely on two key technical strengths to achieve high CMTR. The first is use of a

proprietary, low-cost Faraday shield which decouples the optocoupler input side from the output side. The second method is by unique package design which minimizes input-to-output capacitance. The importance of these two strengths is explained as follows.

Figure 5 illustrates a Common-mode transient pulse ( $V_{CM}$ ).

Figure 6a and 6b show interference circuit models for two types of possible common-mode failure mechanisms for a single-transistor optocoupler. The dashed lines are shown to indicate external components added to the optocoupler.  $V_{CM}$  represents a voltage spike across the optocoupler isolation path between the output-side ground ( $V_{G2}$ ) and input-side ground ( $V_{G1}$ ).  $V_{DM}$  represents a signal voltage applied across the input side.

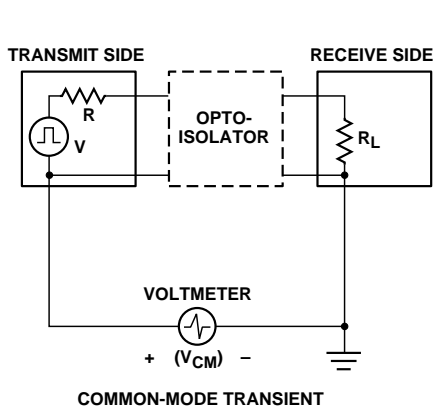
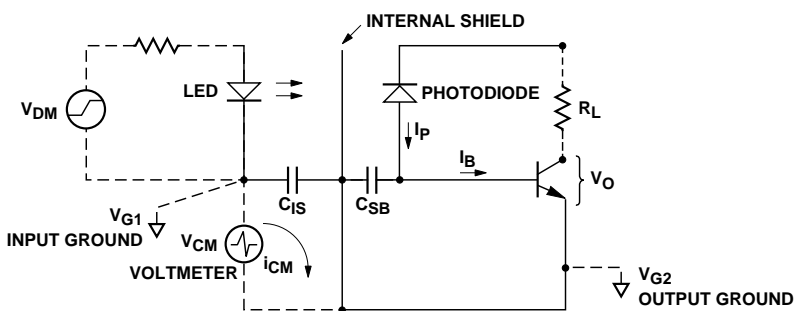


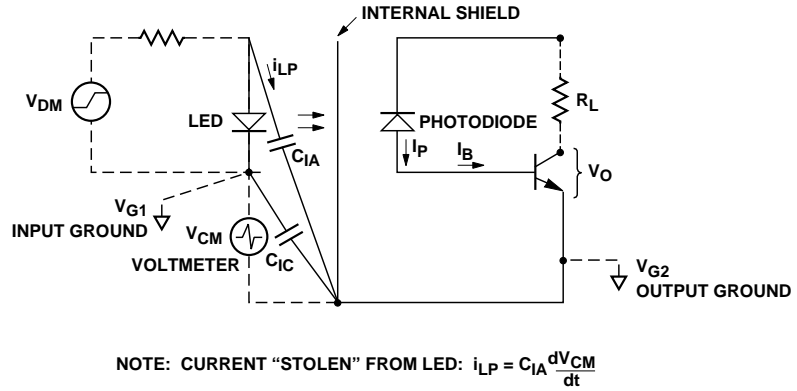
Figure 5. Illustration of  $V_{CM}$  Common-Mode Pulse.



NOTE:  $i_{CM}$  GETS DIVERTED TO GROUND,  $V_{G2}$ , WHEN INPUT IS OFF.  
 $i_{CM}$  IS SUPPLIED FROM GROUND,  $V_{G2}$ , WHEN OUTPUT IS ON.

Figure 6a. Interference Circuit Model.

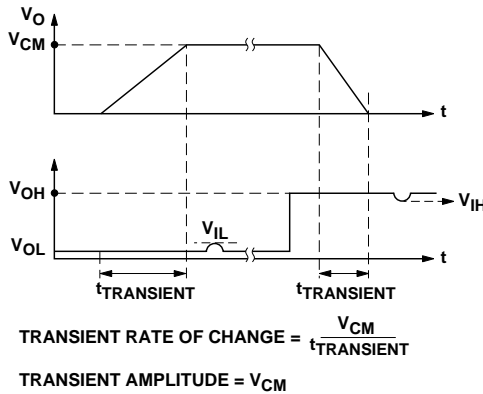
Referring to Figure 6a the parasitic distributed capacitance  $C_{IS}$ , which might tend to couple transient current into the transistor base node (for example when the transistor is in the "off" state) terminates on an internal Faraday shield. Therefore the transient current,  $I_{CM}$ , gets diverted to output ground ( $V_{G2}$ ). Referring to Figure 6b, the parasitic distributed capacitances,  $C_{IA}$  and  $C_{IC}$  are shown across the LED anode-to-ground ( $V_{G2}$ ) and LED cathode-to-ground ( $V_{G1}$ ) respectively. Because the LED anode is at a relatively higher impedance than the cathode (i.e.,  $R_{LED}$  to ground) current at this point will tend to be modulated slightly during CM transients. For instance, if the LED is on, then during a positive transient (i.e.,  $dV_{CM}/dt > 0$ ) current will be diverted away from the LED. For fast enough transients, this may turn the LED off. (If  $R_{LED}$  is connected to the LED cathode side then  $C_{IC}$  provides a parasitic path to divert current towards or away from the LED.) This type of failure is avoided by ensuring that  $C_{IA}$  and  $C_{IC}$  are small.



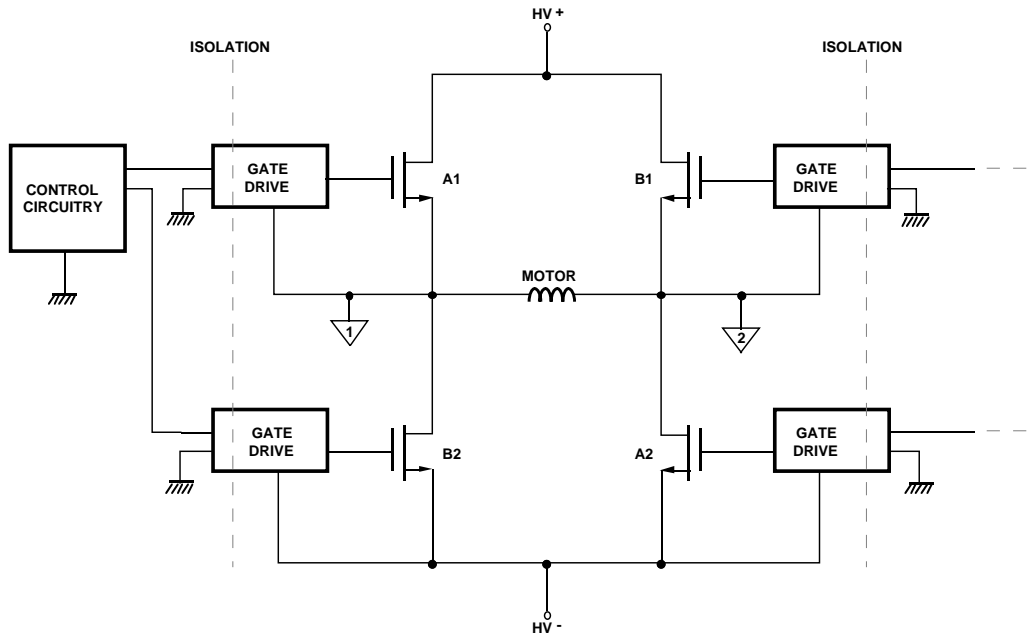
**Figure 6b. Interference Circuit Model.**

Figure 7 shows the possible effect on the output voltage level of an optocoupler due to a common-mode pulse. The output

is shown (successively) in the high and low states. (This might be observed if  $R_{led}$  were connected as in Figures 6a, 6b.)



**Figure 7. Common Mode Interference Effect.**



**Figure 8. Full-Bridge Power Switch Configuration.**

As long as the amplitude  $V_{CM}$  and value of  $dV_{CM}/dt$  are less than the ratings for the optocoupler being used,  $V_{OH}$  will remain above 2 V (maximum TTL  $V_{IH}$ ) and  $V_{OL}$  will remain below 0.8 V (minimum TTL  $V_{IL}$ ). Note that the slight perturbations in output voltage occur sometime after the input pulse which causes them, due to the non-zero response time of the output transistor to the “perturbation signal.”

Common-mode signals can originate from several different sources. A full bridge power inverter, shown in Figure 8, is a good example of an application that can exhibit large amounts of common-mode noise. Full-bridge inverters are commonly found in motor-speed control and switching power supply applications. The power inverter is generally used to produce an ac output from a dc input. In a full-bridge inverter application like that shown in Figure 8, the source of one set of

transistors (A1, B1) is attached to the drain of a second set of transistors (A2, B2). When transistor set A turns on, set B turns off. Current flows from the positive supply, through transistor A1, through the load, and through transistor A2. When set B turns on, set A turns off, and the polarity of the current through the inductive load is reversed.

How does this operation create a common-mode problem? The input of each gate drive circuitry is referenced to the ground of the digital control circuitry; the output common, on the other hand, is floating and referenced to the source of its associated power transistor. The floating commons of the upper gate drive circuits rapidly switch between the positive and negative power supplies. This rapid switching creates a large voltage swing across the input to output of the gate drive circuitry. As an

example, a half bridge circuit that switches between +250 V and -250 V in 100 ns creates a common-mode transient signal of 5000 V/ $\mu$ s with an amplitude of 500 V (see Figure 9). The device that carries the control information to each MOSFET must be able to withstand this level of common-mode interference. Although this example may seem extreme, it is a fact that engineers continue to use faster-switching transistors to increase motor efficiency. Power MOSFETs, for example, are commonly used in power inverter applications because they are capable of high frequency, high power switching. The fast switching speeds of the transistors, however, can generate common-mode signals with very high rates of change ( $dV_{CM}/dt$ ).

The common-mode signal rate of rise can also be affected by the reverse recovery characteristics of diodes D1 and D2 in the power



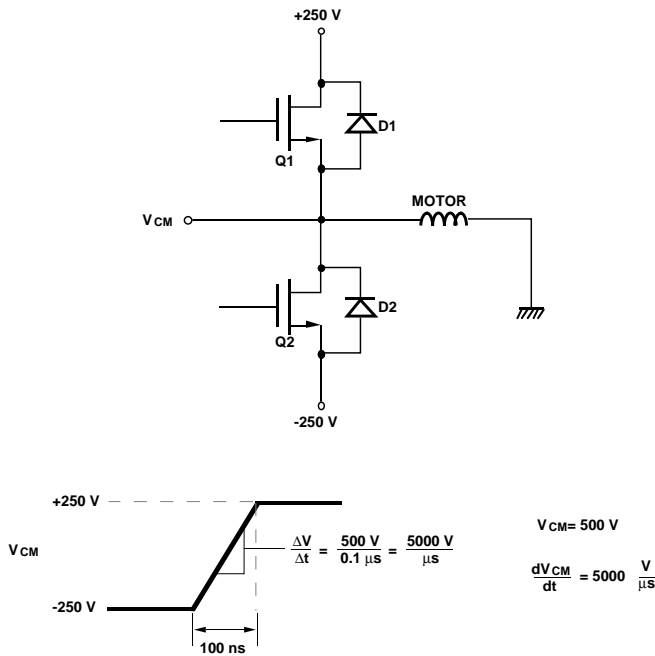


Figure 9. Half-Bridge Example.

inverter shown in Figure 9; these diodes are often referred to as “freewheeling” diodes. If the inverter is driving an inductive load, such as a motor winding, these diodes may become forward biased during the normal operation of the inverter. For example, assume that Q1 of Figure 9 is turned on, Q2 is off, and current is flowing through Q1 and into the inductive load. When Q1 turns off, voltage  $V_{CM}$  swings in the negative direction until diode D2 becomes forward biased and conducts the load current.

It is when Q1 turns back on that very high rates of rise can be generated. In extreme cases, when Q1 turns on again, the rate of rise of voltage  $V_{CM}$  is determined by how quickly diode D2 recovers from forward conduc-

tion. The voltage and current waveforms shown in Figure 10 illustrate what happens when Q1 turns back on. As Q1 starts to turn on, the current through D2 begins to decrease. The current through D2 continues to decrease and actually goes negative for a short time due to the storage of minority carrier charge in its junction. It is when this charge has been depleted that D2 begins to turn off and  $V_{CM}$  begins to increase. If D2 turns off very quickly,  $V_{CM}$  can also rise very quickly, generating a large common-mode transient signal.

For the particular case of driving the gate of an IGBT or power MOSFET in a power inverter, the HCPL-3120 IGBT/MOSFET gate drive optical isolator is an effective solution for common-

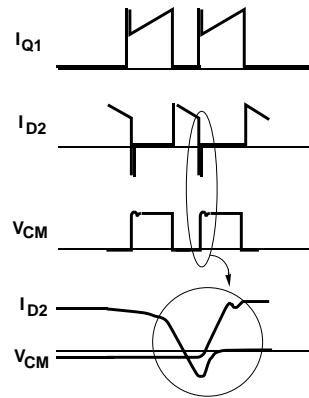


Figure 10. Half-Bridge Inverter Waveforms.

mode problems, providing protection against common-mode transients with slew rates as fast as  $15 \text{ kV}/\mu\text{s}$  at  $V_{CM}$  as high as  $1500 \text{ V}$ .

High electrical noise levels can also contribute to common-mode problems. A significant amount of electrical noise is found in industrial environments as a result of the starting and operating of electric motors. When a large motor first turns on, it normally requires a large in-rush current to reach operating speed. This large current spike can generate a significant amount of electrical noise in its own and nearby systems. Even the electric motors in a typical household environment vary in size from fractional to low integral horsepower units and are often noisy ac-operated or brushed dc-motors. Other sources of electrical noise include microwave ovens, welding equipment, and automobile ignitions.

Common-mode noise can enter a system through conductive, inductive, or capacitive coupling. An example of a “conducted”

noise voltage is the difference in ground potential that may exist between two connected systems in a plant. The two systems may experience a small voltage difference between their ground references. This voltage difference might cause a ground-loop current to flow. If the impedance of the path through which the ground-loop current flows is large enough, a significant amount of interference will result. Capacitive or inductive coupling may occur when signal wires run close to ac power cables. Electromagnetically induced interference (EMI) can also be coupled from adjacent signal lines or nearby equipment, especially in factory environments. Other sources of common-mode noise that can be coupled into a system include lightning strikes and electrostatic discharge (ESD).

Optical isolation is a useful technique for reducing common-mode interference. Optocouplers, like transformers and capacitively-coupled devices, provide isolation between the input and output of a system. Transformers, by virtue of their high primary-to-secondary capacitance, tend to have lower CMTR capability. Capacitively-coupled devices tend to have poor CMTR capability (since in these devices fast, transient common-mode pulses pass across the coupling capacitor and are not filtered out.) Optocouplers, having low input-

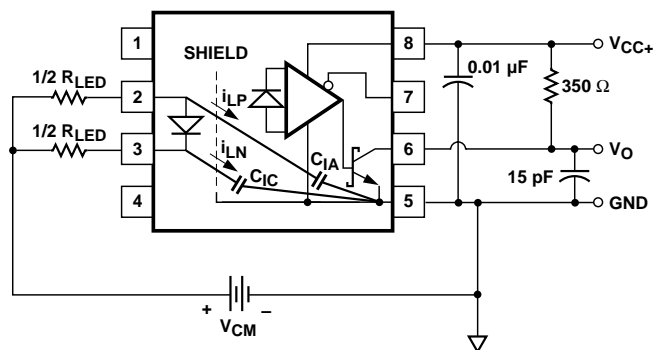


Figure 11. AC Equivalent Circuit for HCPL-261X.

to-output capacitance, typically provide better common-mode rejection than transformers or capacitively-coupled devices. The CMR specification of an optocoupler ranges up to  $V_{CM} = 1500$  V amplitude and up to 15,000 V/ $\mu$ s rate of change of  $V_{CM}$ , for high-CMR products.

Another advantage of optocouplers lies in the area of EMI generation and susceptibility. Transformers typically radiate electromagnetic interference (EMI) and are susceptible to magnetic fields. Capacitively-coupled devices generate ground-loop current, thus generating EMI. Optocouplers use light for data transmission; additionally, they effectively eliminate ground-loop current. Therefore, they do not radiate nor are they affected by stray magnetic fields. This ability is well-recognized in the

European Community where systems designers need to achieve system-level standards (now adopted as EN50081/EN50082 which set limits on the amount of acceptable EMI a system radiates or to which it is immune.)

A technique which may be used to further enhance CMTR is an "LED split-resistor" technique as shown in Figure 11; (note that the  $V_{DM}$  which would appear between the top and bottom  $R_{LED}$ s has not been shown in this "ac equivalent circuit"). By using two LED-resistors (instead of one) the current change at the anode of the LED is nearly canceled by the current change at the cathode, thus tending to keep the LED current constant. This makes the optical isolator more immune to CM transients where  $C_{LA}$  and  $C_{LC}$  limit CMTR.

## LED Degradation over Time

One concern for optocoupler lifetime is that LED light-output (LOP) decreases over time. Generally, light-output degradation gets worse with increasing operating temperature and operating LED current. A worst-case scenario is that over time, as the LED becomes dimmer, the LOP will fall below the minimum value needed for a part to switch properly. Hewlett-Packard, an industry leader in LED technology, tests LOP degradation under accelerated conditions in order to provide designers with information on the expected operating lifetime of optocouplers. Optocouplers which have an input driver IC are designed such that the driver IC sets the proper input  $I_F$ , guardbanding for expected LED LOP degradation over the life of the optocoupler. (Examples are the HCPL-3700, HCPL-7101, and HCPL-7820.) On the other hand, optocouplers requiring an input current-setting resistor (i.e., without an input driver IC) require that the circuit designer guardband the minimum

recommended operating  $I_F$  by an amount sufficient to account for expected LOP degradation.

Hewlett-Packard has undertaken testing of LED degradation for periods of continuous operation up to at least 10 khours for various LEDs used in Hewlett-Packard optocouplers. Figures 12a and 12b show the normalized light output over a 10,000 hour period for Gallium Arsenide Phosphide (GaAsP) and Aluminum Gallium Arsenide (AlGaAs) LEDs respectively.

Figure 13 shows LOP as a function of  $I_F$  for a GaAsP LED under operating conditions of  $I_F = 20$  mA at an ambient temperature of  $T_A = 125^\circ\text{C}$ . Curves are shown for  $t = 0$  hours and  $t = 10$  khours of continuous operation.

Optocouplers which use the GaAsP and AlGaAs LEDs are listed in Figures 12a and 12b.

Figure 14 illustrates how, based on knowledge of initial and post-stress LOP vs.  $I_F$ , (for a GaAsP LED) a minimum guardbanded  $I_F$  can be determined to provide for LOP degradation over the life of the LED. For this case, the minimum recommended  $I_F$  at  $t = 0$  hours ( $I_{F(\min)}$ ) of 5 mA is guardbanded for 10 khours of operation to a value of 6.1 mA.

Note that in Figure 14 if the LOP vs.  $I_F$  curves were linear over the range between  $I_{F(\min)}$  and  $I_{GB(\min)}$  (minimum  $I_F$  guardbanded for  $t = 10$  khours) then the amount of guardbanding (percent change) would be equal to the amount of LOP degradation (percent change). Since in our case the curve is "concave up" the amount of guardbanding is slightly less than the percent change in LOP between  $t = 0$  and  $t = 10$  khours. Figure 15 (which is a plot of the slope of the ( $t = 0$ ) curve in Figure 14), shows that the slope is increasing up to about  $I_F = 20$  mA, at which

point it flattens out and begins decreasing.

By empirically modeling the typical GaAsP LOP vs.  $I_F$  curve and applying knowledge of worst-case ( $-3\sigma$ ) degradation over time, guardbanded  $I_{GB(min)}$  for a typical LED can be reduced to the following equation:

$$I_{GB(min)} = \frac{I_{F(min)}}{\delta^{\frac{1}{a}}}$$

$$\approx I_{F(min)} \times 1.214$$

where,

- $I_{F(min)}$  = minimum recommended  $I_F$  at  $t = 0$  hours.
- $I_{GB(min)}$  = minimum guardbanded  $I_F$  after  $t = 10$  khours.
- $a = 1.3$  (empirical curve - fit)
- $\delta$  = Post-stress LOP Factor ( $\approx 0.784$  for 10 khours,  $T_A = 125^\circ\text{C}$ ,  $I_F = 20 \text{ mA}$ )

This equation applies well when  $I_F$  is approximately constant.

*Example: To calculate the appropriate  $I_{GB(min)}$  for an HCPL-3120 note that  $I_{F(min)} = 7 \text{ mA}$ . Applying the above relationship for 10 khour guardbanding,  $I_{GB(min)} = 8.50 \text{ mA}$ .*

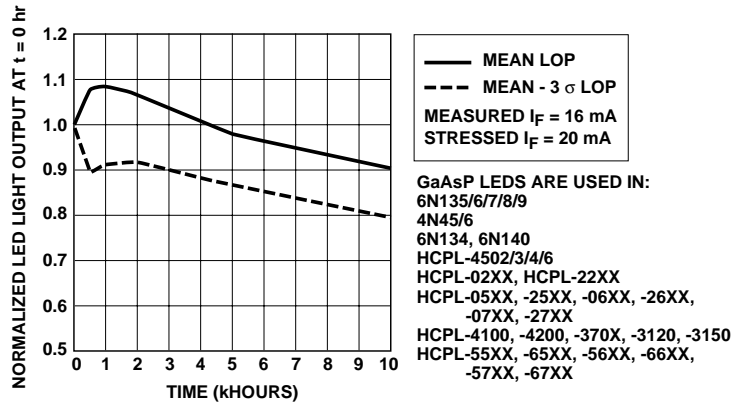


Figure 12a. Normalized LED Light Output (LOP) vs. Time for GaAsP LED (Stress  $I_F = 20 \text{ mA}$ ,  $T_A = 125^\circ\text{C}$ ).

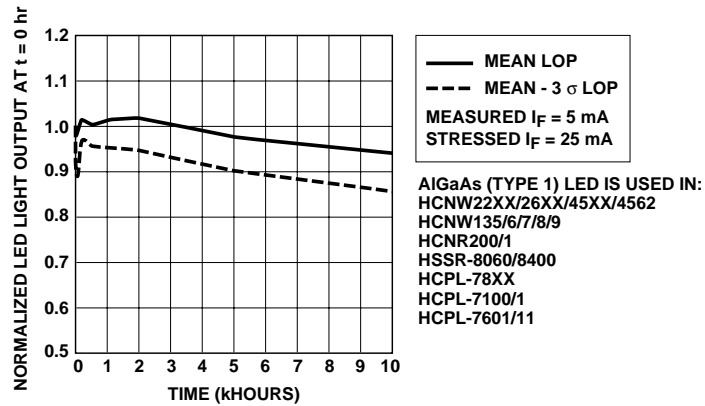


Figure 12b. Normalized LED Light Output (LOP) vs. Time for AlGaAs LED (Stress  $I_F = 25 \text{ mA}$ ,  $T_A = 125^\circ\text{C}$ ).

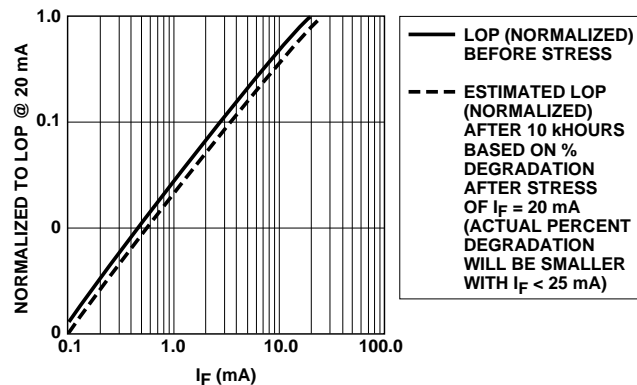


Figure 13. Typical GaAsP LED Light-Output (LOP) vs.  $I_F$  After 0 khours and 10 khours of Continuous Operation at  $125^\circ\text{C}$ ,  $I_F = 20 \text{ mA}$ .

# LED DEGRADATION

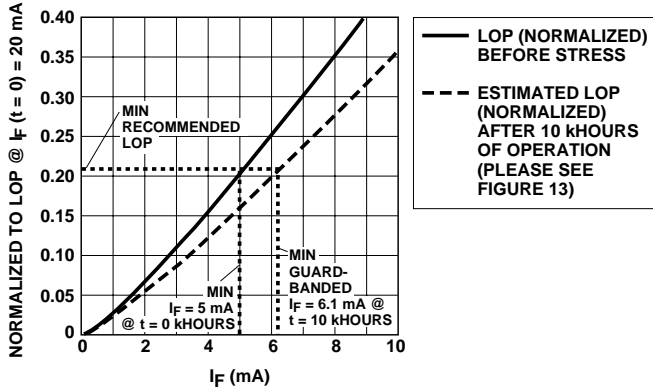


Figure 14. GaAsP LED Light Output (LOP) vs.  $I_F$  on a Linear Scale (Stressed at  $T_A = 125^\circ\text{C}$ ,  $T_F = 20$  mA).

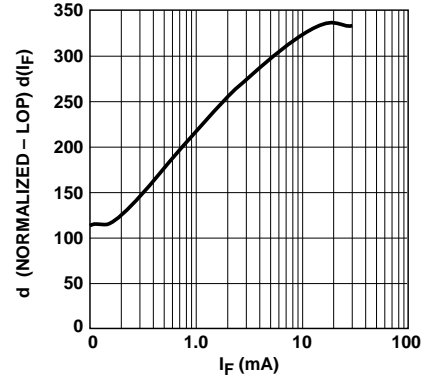


Figure 15. Slope of Typical GaAsP LOP vs.  $I_F$ .

Factors which will increase expected LED guardbanded-operation times are:

- 1. Operation at lower  $I_F$ :** LOP decreases less with reduced operating  $I_F$ . Therefore, operation at  $I_{GB} < I_F < 20$  mA will result in guardbanded operating lifetimes longer than 10 khours. This is due to the fact that lower operating  $I_F$  reduces junction temperature ( $T_J$ ) which subsequently reduces the amount of degradation over time. Generally, the lower

the operating  $I_F$ , the lower the percent degradation will be as a function of time.

- 2. Operation at Duty Factor (DF) less than 100%** will increase guardbanded operating lifetimes. For any particular duty factor, the new guardbanded lifetime becomes:

$$\frac{\text{lifetime}_{\text{continuous}}}{\frac{DF (\%)}{100}}$$

- 3. Operation at ambient temperature  $T_A < 125^\circ\text{C}$**  will also decrease the amount of LOP degradation (again, due to decreased  $T_J$ ) increasing operation lifetime.

Hewlett-Packard also has LED degradation data available for other LED types. AlGaAs LEDs tend to be more linear than GaAsP LEDs and display less degradation over time than GaAsP. Therefore the calculations used here can be applied with confidence to optocouplers using AlGaAs LEDs. For further specific questions, please contact your local HP sales representative.

## Guidelines for Printed Circuit Board Assembly and Layout

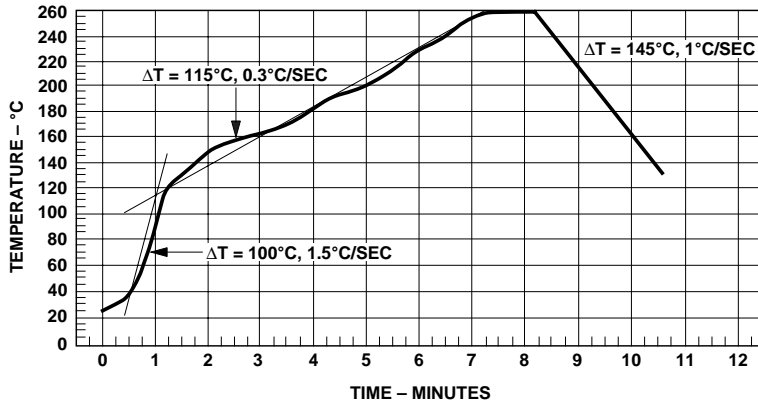


Figure 16. Maximum Solder Reflow Thermal Profile.

HP optocouplers are suitable for automatic printed circuit board (PCB) assembly operations including surface mount assembly. The following guidelines are recommended for proper operation and long term reliability of HP optocouplers.

**Solder Reflow Process:** Only one soldering operation is recommended within the thermal profile shown in Figure 16. With infrared lamp heating, use precautions to avoid localized temperature rise in the resin. Also, the resin should not be immersed in the

solder. To prevent chloride corrosion of the lead frame, halide fluxes should not be used.

**Wave Soldering:** The maximum solder temperature allowed is 260°C for 10 seconds, with the solder 1.6 mm below the seating plane.

**Solvent Cleaning:** The solvent temperature and immersion time should not exceed 45°C and three minutes respectively. For ultrasonic cleaning, environmentally safe solvents such as ethyl and methyl alcohol are recommended.

**ESD Precautions:** Standard electrostatic discharge precautions should be taken in handling and assembly of the optocouplers to prevent damage or degradation of the device.

### Printed Circuit Board Layout:

An optocoupler performs reliably only in a correctly designed circuit. In most digital optocouplers the amplifier at the output is required to operate with the very low photocurrent from the photodetector. Consequently these amplifiers can be sensitive to electrical disturbances. It is therefore necessary to have proper shielding and bypassing of the  $V_{CC}$  and Ground traces. Bypassing closely to each of the optocouplers  $V_{CC}$ -to-Ground pins with low-inductance ceramic capacitor is recommended as shown in Figure 17.

Figure 17 shows an optional PCB layout for a high speed digital optocoupler for improving electrical noise immunity. The optional  $V_{CC}$  and Ground traces between the pin rows of the optocoupler help shield the output circuitry from electrical disturbances on the input pins, thus improving common-mode rejection.

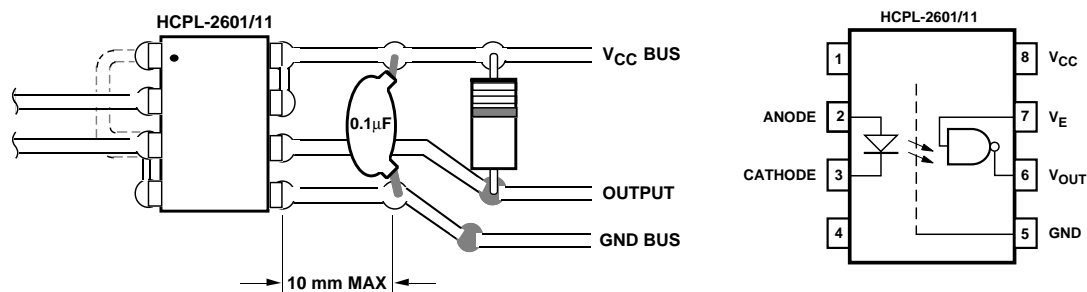


Figure 17. Optional Printed Circuit Board Layout for Improved Electrical Noise Immunity.



# Digital Optoisolators: An Overview

## Introduction

Hewlett-Packard offers a wide array of Optoisolators for noise rejection, ground loop current elimination, and high voltage isolation for digital data transmission and communication applications. The product offering includes low speed (100 kbit/s to 1 M bit/s) split Darlington or single transistor type optoisolators to high speed 25 M bit/s cascaded amplifier stage optoisolators with Schottky transistor or CMOS output stage.

## Description

Figure 1 shows a Photodiode/Transistor Optoisolator where a PIN photodiode detector is coupled to a single transistor amplifier output stage (e.g. HCPL-4504). Compared to a typical phototransistor optoisolator, a PIN photodetector diode reduces the base-collector "Miller" capacitance and allows operability at a much higher speed.

Figure 2 shows a Split Darlington Output Stage, where an emitter-follower stage is added between a PIN photodiode and the output amplifier. This allows the optoisolator to be driven at a much lower input drive current, as low as 40  $\mu$ A for the HCPL-4701/HCPL-4731 family or 0.5 mA for the 6N139 family. This allows much higher current transfer ratio (CTR) or current gain at the output, and TTL/CMOS gates can be easily driven.

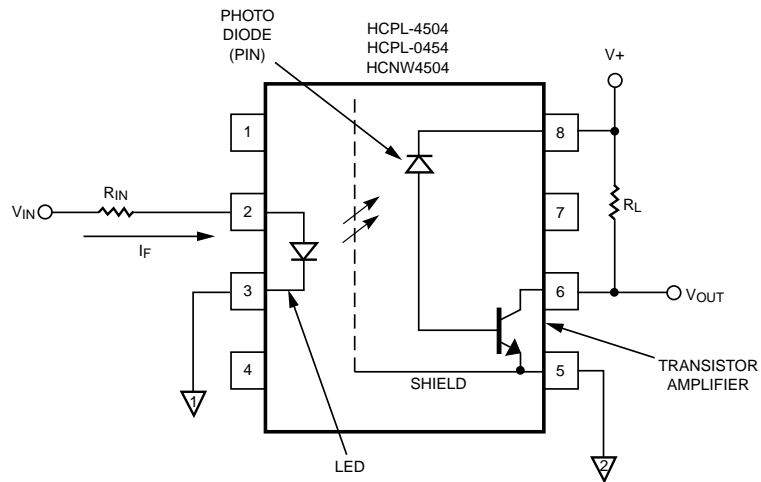


Figure 1. Photodiode/Transistor Optoisolator

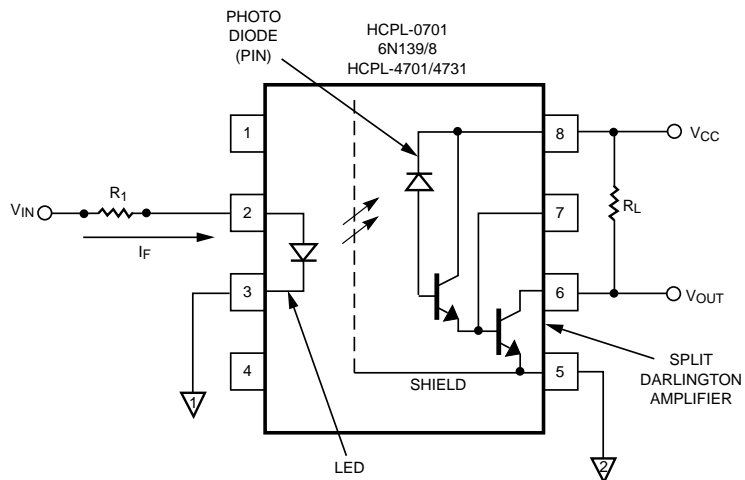
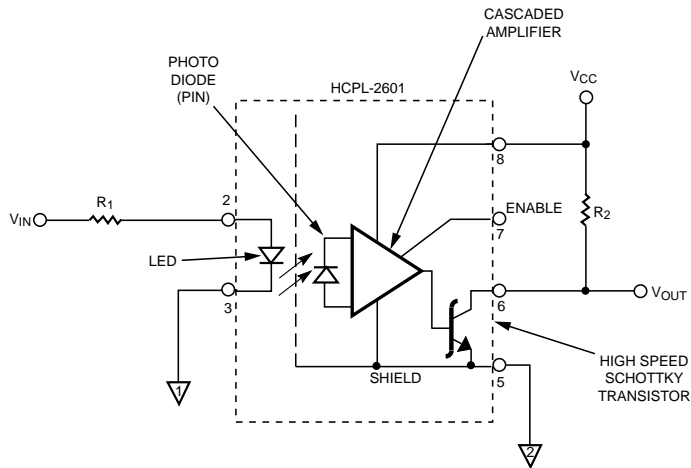


Figure 2. Split Darlington Transistor Optoisolator

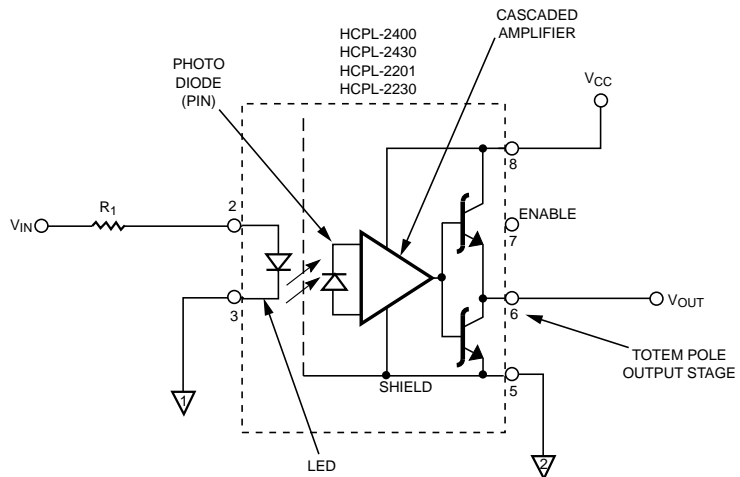


Figure 3 shows a photodiode cascaded amplifier, coupled to a Schottky transistor, open collector output stage. In order for an open collector output stage to function, a pull-up resistor is required at the output of the Optoisolator.



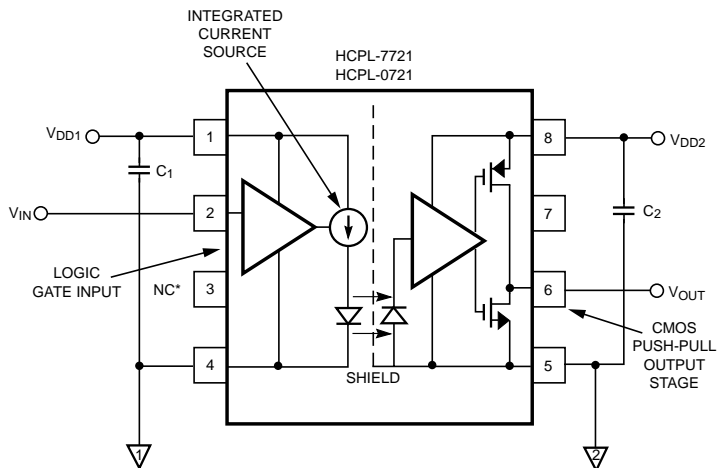
**Figure 3. Cascaded Amplifier Optoisolator**

Figure 4 shows a photodiode and cascaded amplifier, coupled to a totem pole output stage. This type of output stage eliminates the necessity of using a pull-up resistor at the output. The outputs can sink or source current allowing higher output power drive capability.



**Figure 4. Totem Pole Output Optoisolator**

Figure 5 shows a push-pull CMOS output stage. These types of optoisolators are designed to achieve highest speed performance (up to 25 M bit/s for HCPL-7721/7720). The amplifier stage presents very low input impedance to the photodiode, and does not become saturated, while allowing the signal to be amplified several folds through the amplifier stages, allowing operation at relatively low LED drive currents (2 to 5 mA).

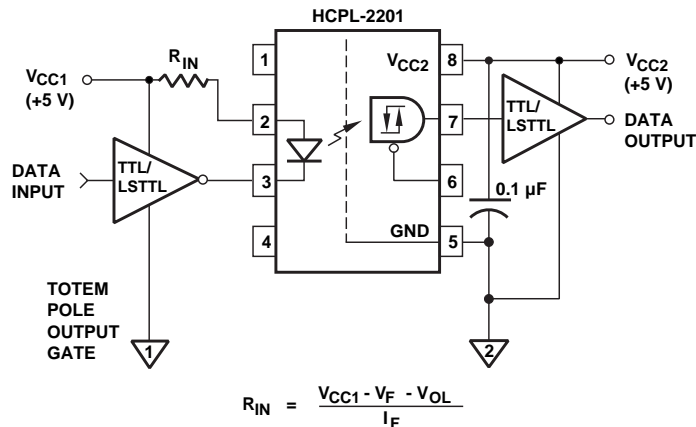


\*PIN 3 IS THE ANODE OF THE INTERNAL LED AND MUST BE LEFT UNCONNECTED FOR GUARANTEED DATA SHEET PERFORMANCE.  
C<sub>1</sub>, C<sub>2</sub> = 0.01 TO 0.1 μF

**Figure 5. High Speed CMOS Optoisolators**

# Digital Logic Interface/Level Shifting Applications

## TTL Interface with Series LED Drive



RECOMMENDED  $R_{IN} = 1.1 \text{ k}\Omega$

### Description

The circuit shown is an interface between two TTL gates using an active output (totem pole) optocoupler, the HCPL-2201. A series switching circuit drives the optocoupler LED. The designer chooses  $R_{IN}$  to agree with the equation shown in the schematic. The active output of the HCPL-2201 can be directly connected to a TTL gate, and no pull-up resistor is required. The HCPL-2201 can sink enough current to handle up to 16 LSTTL or 4 TTL loads.

### Performance of Circuit

- Maximum optocoupler propagation delay: 300 ns (refer to alternative HP parts for lower propagation delay times)
- Typical signaling rate: dc to 5 MBd (refer to alternative HP parts for higher speeds)
- Typical optocoupler LED drive current: 2 mA

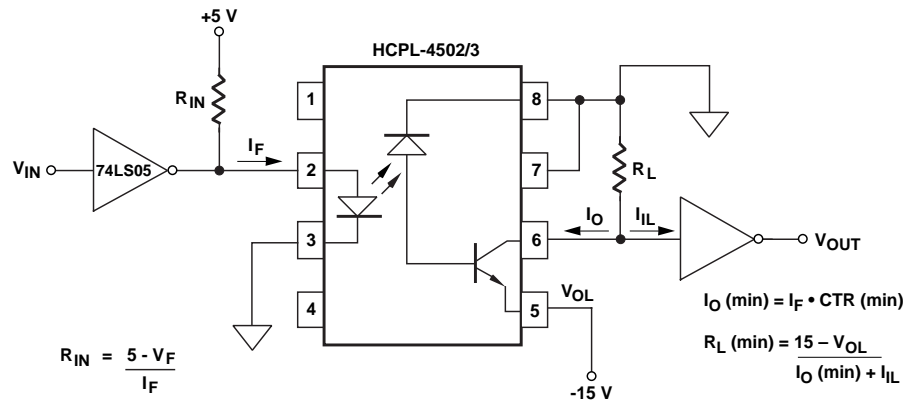
### Benefits

- No pull-up resistor required on the optocoupler output interface
- Low power dissipation on the optocoupler input circuit
- Up to 20 V supply voltage for the HCPL-2201

### Alternative HP Parts

- 1) HCPL-07XX, HCPL-2730/1, HCPL-4701, 6N138/9, CNW138/9 Low Input Current Optocouplers
- 2) HCPL-0201/11 Small-Outline Logic-Gate Optocoupler
- 3) HCPL-52XX Hermetic Logic-Gate Optocoupler
- 4) CNN2201/11 Widebody Logic-Gate Optocoupler
- 5) HCPL-2230/1 Dual-Channel Logic-Gate Optocoupler
- 6) HCPL-05XX, HCPL-2530/1, HCNW135/6, 6N135/6 High Speed Optocoupler

## Level Shifting/TTL Interface with Shunt LED Drive



NOTE: FOR BEST CMR PERFORMANCE, CONNECT PIN 7 TO PIN 8.

### Description

The above circuit shows how a 0 to 5 V logic signal can be level shifted to a -15 to 0 V signal. The circuit can safely be used for level shifting up to  $\pm 800$  V. The circuit uses an open collector output logic gate, the 74LS405, to drive the LED of the HCPL-4502/3 optocoupler. The HCPL-4502/3 also has an open-collector output. The designer chooses  $R_{IN}$  to agree with the equation shown in the schematic. This equation sets the value of the optocoupler LED forward current. The output of the HCPL-4502/3 requires a pull-up resistor,  $R_L$ . The current-transfer ratio (CTR) of the optocoupler determines the maximum amount of current the optocoupler output can sink while maintaining the output voltage (between pins 5 and 6) of 0.5 V or less.

### Performance of Circuit

- Maximum optocoupler propagation delay: 2  $\mu\text{s}$  (refer to alternative HP parts for lower propagation delays)
- Typical signaling rate: dc to 1 MBd (refer to alternative HP parts for higher speeds)
- Typical optocoupler LED drive current: 10 to 16 mA
- Maximum output supply voltage (pins 8-5): 30 V
- Minimum CMR: 15 kV/ $\mu\text{s}$  slew rate, 1500 V peak

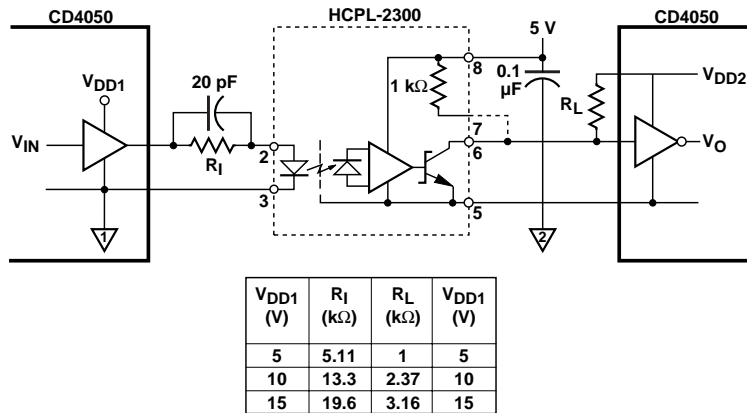
### Benefits

- Reduces transient immunity problems
- Convenient way of replacing pulse transformer for high-voltage level shifting

### Alternative HP Parts

- 1) HCPL-07XX, HCPL-2730/1, HCPL-4701, 6N138/9, HCNW138/9 Low Input Current Optocouplers
- 2) HCPL-55XX Hermetic High Speed Optocoupler
- 3) HCPL-0710 SO-8 High Speed CMOS Optocoupler

# Low Power 8 MBd CMOS Interface



## Description

A CMOS-to-CMOS interface is possible with HP optocouplers. The above circuit shows an interface circuit for 8 MBd applications. Over the temperature range a CMOS CD4050 Hex Buffer can source about 0.7 mA (minimum), which is sufficient to drive the HCPL-2300 optocoupler. The 20 pF capacitor allows peaking currents to assist the LED turn on and off quickly.

## Performance of Circuit

- Optocoupler LED current: 0.5 mA minimum
- Typical signaling rate: dc to 8 MBd

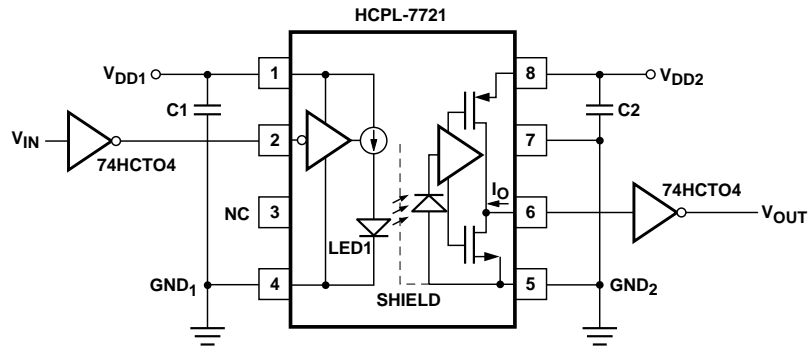
## Benefits

- Low power consumption
- Simple interface

## Alternative HP Parts

- 1) HCPL-7721/7720/7710 High Speed CMOS Optocoupler
- 2) HCPL-0721//0720/0710 Small Outline High Speed CMOS Optocoupler

## 25 MBd CMOS Interface



C1, C2 = 0.01  $\mu$ F TO 0.1  $\mu$ F

### Description

Up to 25 MBd CMOS-to-CMOS interface is possible with the HCPL-7721 optocouplers. The above circuit requires only a bypass capacitor on each of the HCPL-7721 input-side and output-side power supply pins.

### Performance of Circuit

- Typical logic low input power supply current for HCPL-7721: 1.5 mA
- Typical logic low input power supply current for HCPL-7721: 7 mA
- Typical HCPL-7721 signalling rate: dc to 25 MBd
- Typical HCPL-7721 pulse-width distortion: 3 ns
- Typical HCPL-7721 propagation delay: 20 ns

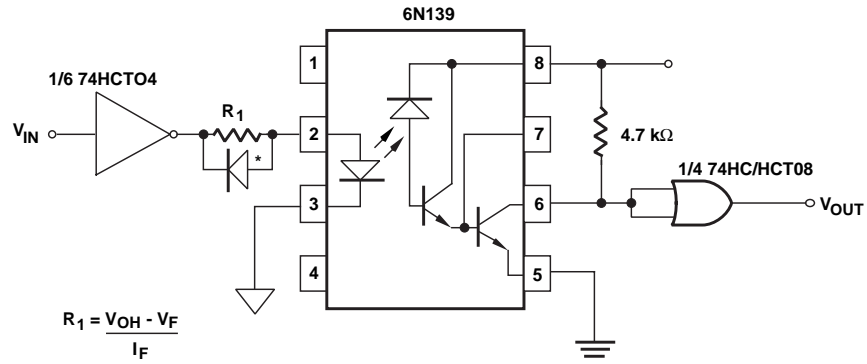
### Benefits

- Lower power consumption
- Very simple interface

### Alternative HP Parts

- 1) HCPL-0721: SO8 package
- 2) HCPL-7720/0720: 25 MBd, 8 ns PWD CMOS interface optocoupler
- 3) HCPL-7710/0710: 25 MBd, 8 ns PWD CMOS interface optocoupler

# Low Power 100 kBd CMOS Interface



\* USE ANY SIGNAL DIODE FOR CMR PROTECTION

## Description

A CMOS-to-CMOS interface is possible with HP optocouplers. The above circuit shows a cost-effective interface for 100 kBd applications. The 74HCT04 CMOS Hex Inverter that drives the optocoupler LED can source and sink up to 4 mA current. The 6N139 optocoupler requires only 0.5 mA LED current for operation. The signal diode across resistor  $R_1$  protects against common-mode transient voltages and is optional. The output circuit uses a 74HCT08 so that the signal from  $V_{IN}$  to  $V_{OUT}$  is not inverted.

## Performance of Circuit

- Minimum optocoupler LED turn-on current: 0.5 mA (The HCPL-4701 optocoupler requires only 40  $\mu$ A)
- Typical signaling rate: dc to 100 kBd
- Minimum optocoupler current transfer ratio: 400%

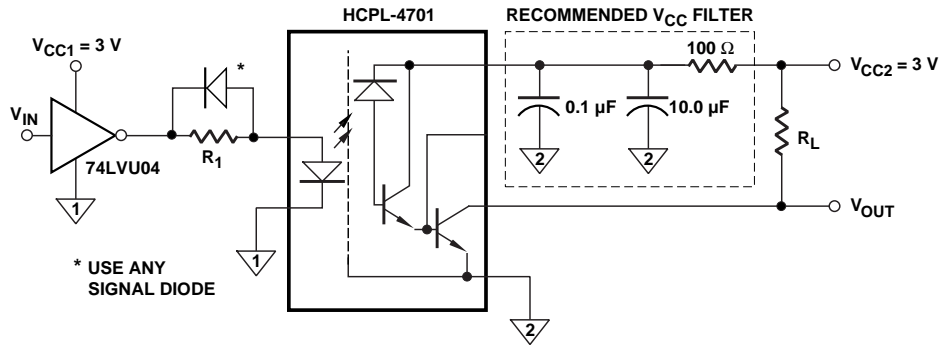
## Benefits

- Low power consumption
- Simple interface

## Alternative HP Parts

- 1) HCPL-4701 Very Low Power High Gain Optocoupler
- 2) HCPL-2730/1 Dual Channel High Gain Optocoupler
- 3) HCPL-0731 Small Outline High Gain Optocoupler
- 4) HCPL-57XX, HCPL-67XX, 6N140 Hermetic High Gain Optocoupler

# Isolated 3 V Logic Interface/Battery Operated Applications



TYPICAL POWER DISSIPATION FOR 3 V APPLICATION  
( $V_{CC1}, V_{CC2} = 3.0\text{ V}, R_L = 11\text{ k}\Omega, R_1 = 43.8\text{ k}\Omega$ )

$V_{CC1}$  SIDE:

OPTOCOUPLER LED	50 $\mu\text{W}$
INPUT RESISTOR $R_1$	70 $\mu\text{W}$
TOTAL $V_{CC1}$ SIDE	120 $\mu\text{W}$

$V_{CC2}$  SIDE:

OPTOCOUPLER ( $V_O, V_{CC2}$ )	85 $\mu\text{W}$
PULL-UP RESISTOR $R_L$	790 $\mu\text{W}$
TOTAL $V_{CC2}$ SIDE	875 $\mu\text{W}$

## Description

The HCPL-4701 low-power optocoupler is used for 3 V-to-3 V Logic interface across an isolation barrier. Only 40  $\mu\text{A}$  of LED current ( $I_F$ ) is required to turn-on the optocoupler. Typical power for dissipation for just the optocoupler is 135  $\mu\text{W}$  at  $I_F = 40\text{ }\mu\text{A}$ , and 965  $\mu\text{W}$  at  $I_F = 500\text{ }\mu\text{A}$ .

## Performance of Optocoupler

- Typical optocoupler current transfer ratio: 3500% at  $I_F = 40\text{ }\mu\text{A}$
- Input current for optocoupler turn-on: 40  $\mu\text{A}$

## Benefits

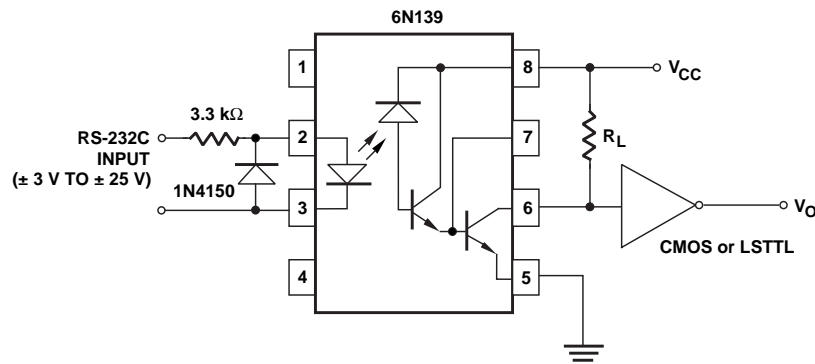
- Low power dissipation

## Alternative HP Parts

- 1) HCPL-4731 Dual Low Power Optocoupler
- 2) HCPL-070A SO-8 Low Power Optocoupler
- 3) HCPL-073A SO-8 Dual Channel Low Power Optocoupler

# Data Communications Applications

## Isolated RS-232C/E Interface



### Description

The above schematic shows a very simple RS-232C data communication isolation interface using a 6N139 optocoupler. This circuit operates with an LED forward current of 0.5 mA when the input is at 3 V. The 1N4150 diode protects the LED during negative signal voltages. Since a low diode current is used to operate the 6N139, the twisted pair line can be up to 120 m. However, the data rate may have to be lowered to account for slower charging and discharging of the total line capacitance.

### Performance of Circuit

- RS-232C link twisted pair cable length: up to 120 m for low data rates
- Typical optocoupler propagation delay: 20  $\mu$ s

### Benefits

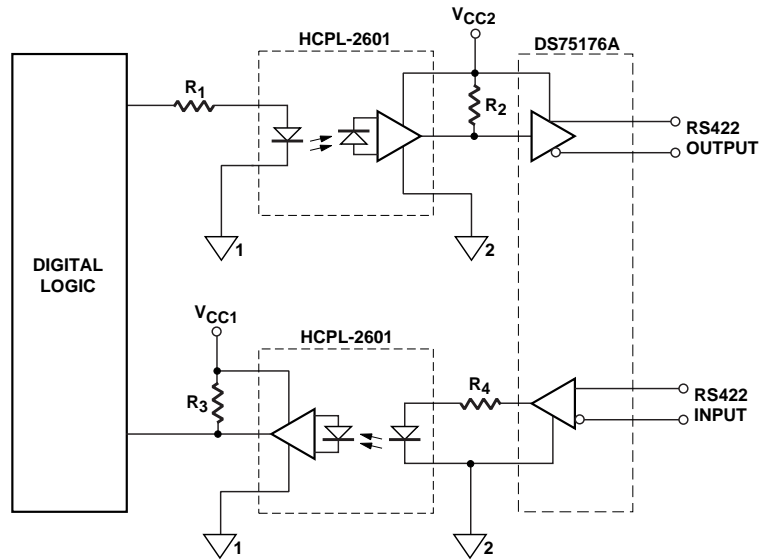
- Simple, low cost isolated interface
- Meets worldwide regulatory standards for isolation

### Alternative HP Parts

- 1) HCPL4701, 6N138/9, 4N45/6, HCPL-2730/1 High-Gain, Low Input Current Optocoupler
- 2) HCPL-0700/1, HCPL-0730/1, HCPL-M700/1 Small Outline High-Gain, Low Input Current Optocoupler
- 3) HCPL-0560 Bidirectional Optocoupler



# Isolated RS-422 Interface



### Description

The above isolated RS-422 circuit uses two high-speed optocouplers that can switch up to 10 MBd signals. An isolated power supply ( $V_{CC2}$ ) is required to power the DS75176A driver/receiver integrated circuit.

### Performance of Circuit

- Typical signaling rate: up to 10 MBd
- Optocoupler LED drive current: 5 mA
- Typical Optocoupler Transient Rejection: 10,000 V/ $\mu$ s slew rate, 50 V peak (higher transient rejection with HCPL-2611)

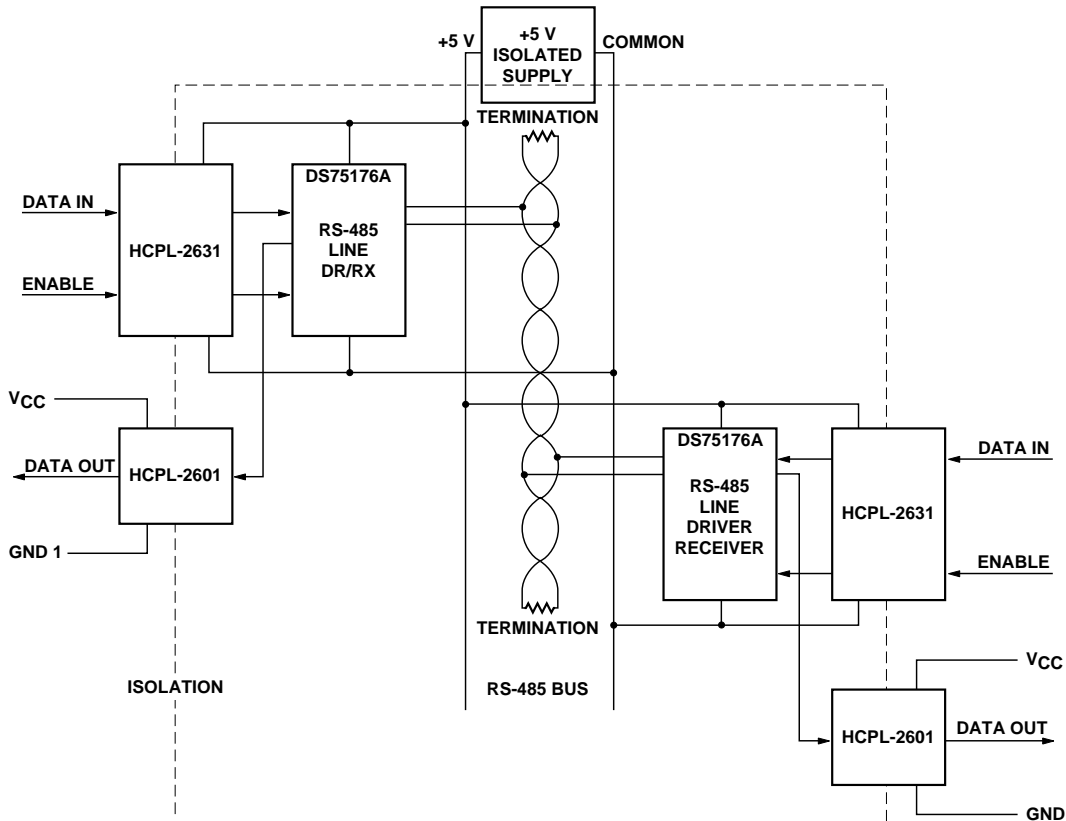
### Benefits

- Compact design with small outline optocouplers
- Prevents common-mode transients from interfering with the signal

### Alternative HP Parts

- 1) HCPL-0611 High-CMR, Small Outline High Speed Optocoupler
- 2) HCPL-2611 High Speed, High CMR Optocoupler
- 3) HCNW2601/11 Widebody High Speed Optocoupler
- 4) HCPL-56XX Hermetic High Speed Optocoupler

# Isolated RS-485 Bus Interface



## Description

The above isolated RS-485 interface circuit uses the HCPL-26XX High Speed CMOS optocoupler, which can transmit digital signals faster than 10 MBd. An isolated 5 V power supply is required to power the RS-485 bus side of the circuit.

## Performance of Circuit

- Typical optocoupler signaling rate: greater than 10 MBd
- Typical optocoupler propagation delay: 28 ns
- Typical optocoupler pulse-width distortion: 2 ns

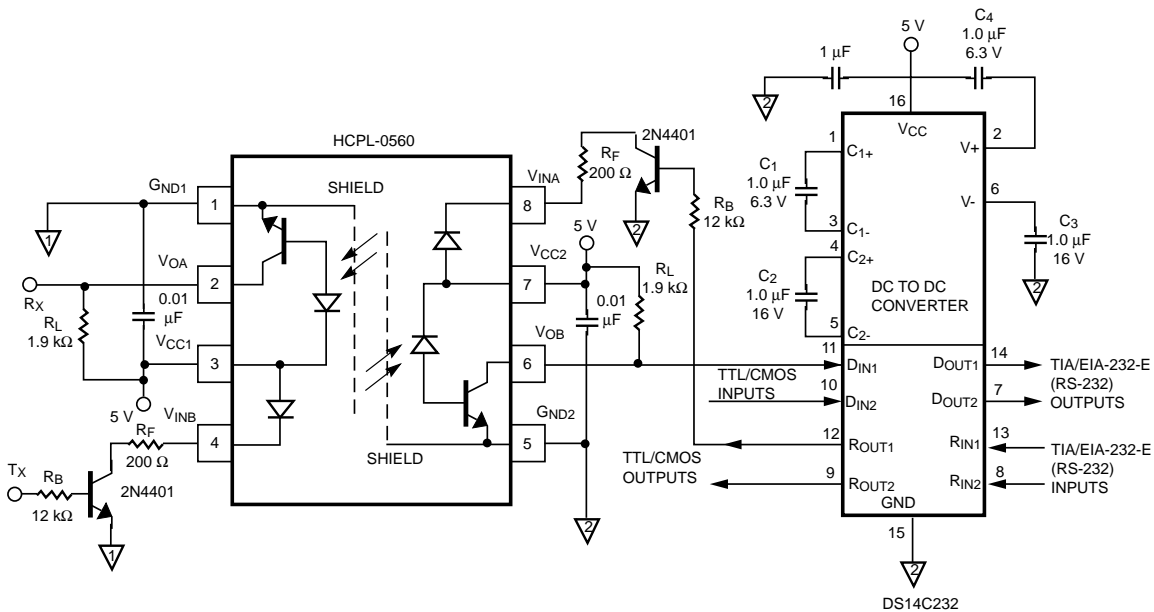
## Benefits

- Low signal distortion
- Good transient immunity

## Alternative HP Parts

- 1) HCPL-2400/30 High Speed Optocoupler
- 2) HCPL-7721/7720/7710 High Speed CMOS Optocoupler
- 3) HCPL-54XX Hermetic High Speed Optocoupler
- 4) HCPL-0721/0720/0710 SO-8 High Speed CMOS Optocoupler

# Isolated Full Duplex RS232E Interface



## Description

The HCPL-0560 is a bi-directional optoisolator that can be used for isolated full duplex communications with an RS-232-E (TIA/EIA-232-E) standard. The HCPL-0560 is referred here as a common  $V_{CC}$  internal configuration, because the  $V_{CC}$  at either side of the isolation barrier is common to transmit and receive circuitry. The figure above shows an RS-232-E isolated interface using the HCPL-0560. The LED is shown driven with an NPN transistor (2N4401). The input series current limiting sets the LED current.

## Performance of Circuit

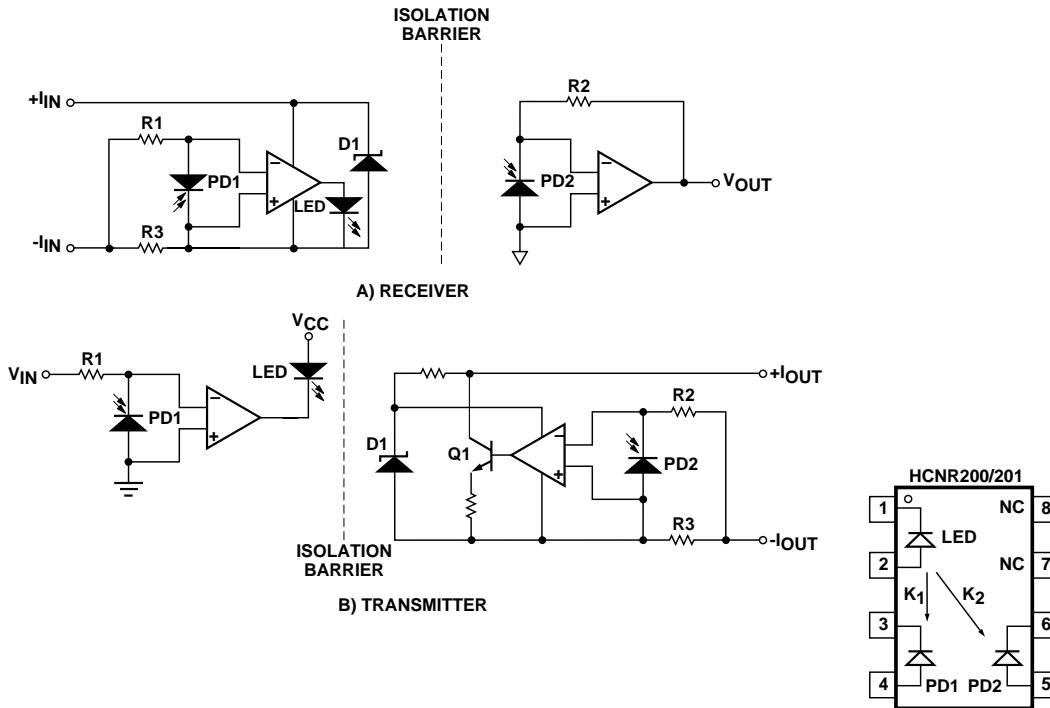
- Common  $V_{CC}$  (HCPL-0560) configurations
- Full duplex communication interface
- SOIC-8 package
- Open collector TTL compatible output
- Maximum propagation delay of optoisolator: 1µsec
- Data Rate: 1 Mbit/s maximum for optoisolator

## Benefits

- Allows simultaneous bi-directional communication in one package
- Speed optimized for RS-232-E
- Small outline surface mount package offers space/footprint saving
- Performance guaranteed over temperature (0 to 70°C)



# Isolated 4-20 mA Analog Current Loop Transmitter/Receiver



## Description

The HCNR200/1 Analog Optocoupler isolates both the transmitter and receiver circuit from the 4 - 20 mA Analog Current Loop. One important feature of this circuit is that the loop side of the circuit is powered by the loop current. No isolated power supply is required.

## Performance of Circuit

- Converts an analog voltage input to an analog current and vice versa
- HCNR200/1 nonlinearity: 0.1%
- HCNR201 gain tolerance:  $\pm 5\%$

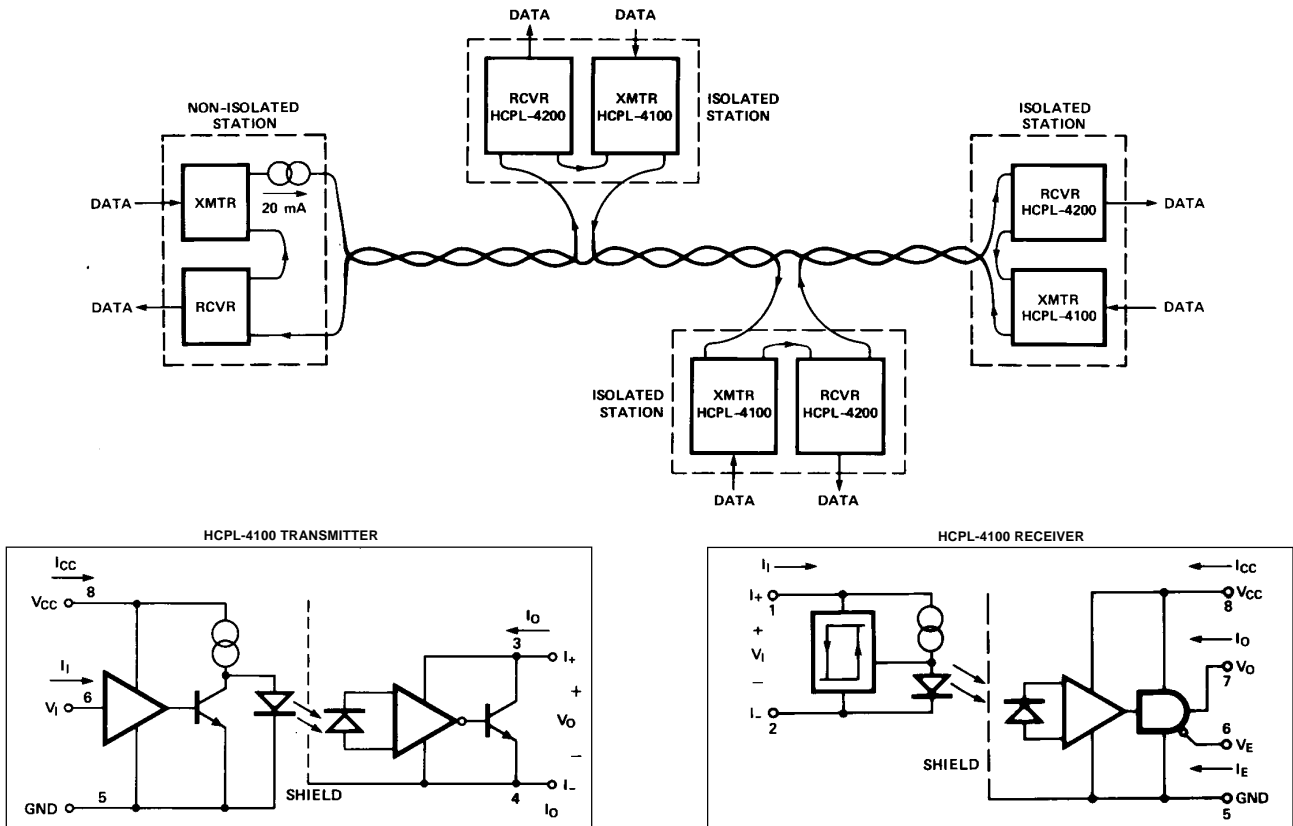
## Benefits

- Low-cost simple circuit
- No isolated power supply needed on the 4 - 20 mA side of the circuit

## Alternative HP Parts

- 1) HCPL-4100 20 mA Current Loop Transmitter
- 2) HCPL-4200 20 mA Current Loop Receiver

# Isolated 20 mA Current Loop Interface



## Description

The above half-duplex, point-to-point, multi-drop, 20 mA current loop configuration can alternately transmit bi-directional data over two wires. Only one current source is required. Each isolated station with an HCPL-4100 transmitter and HCPL-4200 receiver optocouplers provides excellent common-mode rejection.

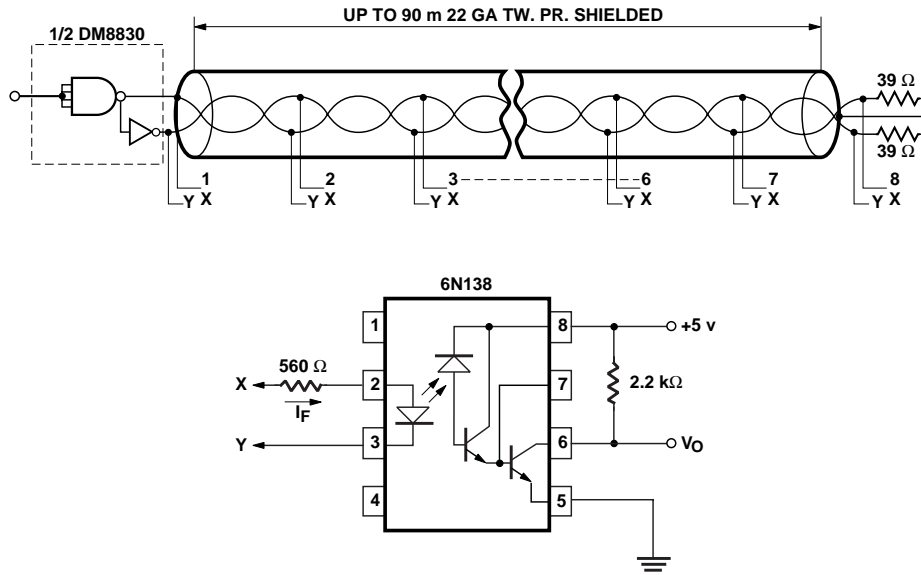
## Performance of Circuit

- 1 mA noise margin in the "space" state
- 8 mA noise margin in the "mark" state
- Typical signal rate and distance: 40 m at 100 kBd; over 200 m at 10 kBd

## Benefits

- Maintains data integrity
- Simple data transmission system for industrial applications

# Multidrop Line Receiver



## Description

The above differentially driven circuit can use up to eight 6N138 optocouplers at various receivers along the 90 m line. All stations are isolated. The first station would draw approximately 2.7 mA current, and the last station 1.8 mA of LED drive current. The output grounds of the optocoupler may be electrically separate.

## Performance of Circuit

- Typical signaling rate: 18 kBd (faster signaling rates can be obtained with HCNW139 and 6N139)
- Typical optocoupler propagation delay time:  $t_{PHL} = 2 \mu s$ ;  $t_{PLH} = 20 \mu s$
- Up to 90 m distance

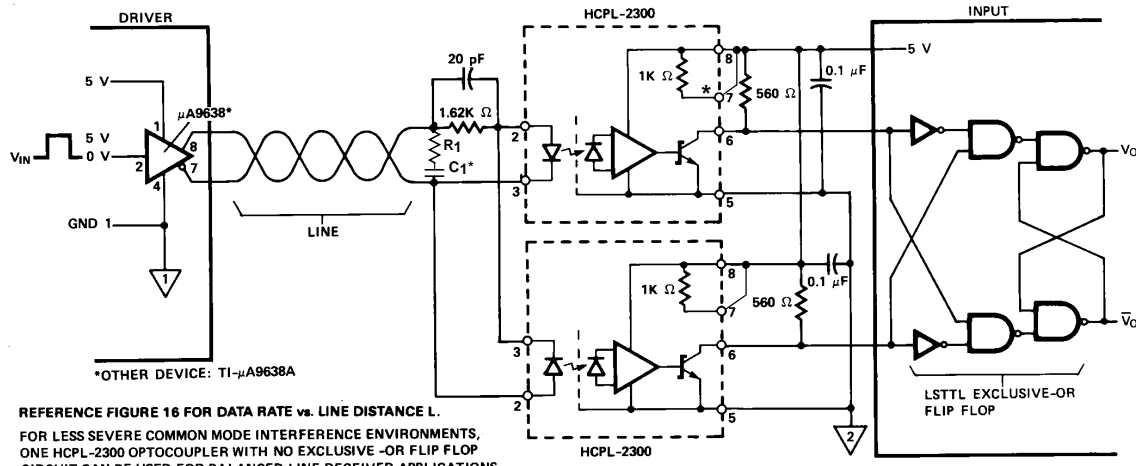
## Benefits

- Simple, low-cost, multidrop circuit for low signaling rates

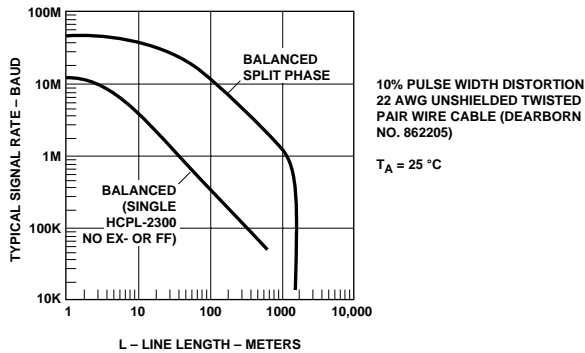
## Alternative HP Parts

- 1) HCPL-0700/01/30/31, HCPL-M700/1, HCNW138/9, and HCPL-2730/31 Low-Input Current Optocouplers
- 2) HCPL-57XX, HCPL-67XX, and 6N140 Hermetic Low-Input Current Optocouplers
- 3) HCPL-2300 High Speed, Low Input Current Optocoupler

# Isolated Balanced Line Receiver - Circuit No. 1



REFERENCE FIGURE 16 FOR DATA RATE vs. LINE DISTANCE L.  
 FOR LESS SEVERE COMMON MODE INTERFERENCE ENVIRONMENTS,  
 ONE HCPL-2300 OPTOCOUPLER WITH NO EXCLUSIVE -OR FLIP FLOP  
 CIRCUIT CAN BE USED FOR BALANCED LINE RECEIVER APPLICATIONS.  
 $V_O = V_{IN}$ .



## Description

A balanced RS-422 line driver differentially drives a twisted pair line. Two HCPL-2300s provide balanced signal direction for this line. The thresholds of the HCPL-2300 will be nearly equal, providing symmetrical signal detection level. Since the propagation delays of the two optocouplers are similar, the pulse-width distortion for this scheme will be quite low for considerable line lengths. The Exclusive-Or flip-flop circuit at the optocoupler output increases CMR protection to an extremely high level and balances the propagation delays. For less demanding noise environments, only one HCPL-2300 with no EX-OR flip-flop may be used. The maximum data rate, however, will be somewhat lower.

## Performance of Circuit

- Signaling rate: > 10 Mbd at 100 m line length
- Common mode rejection: > 15,000 V/μs

## Benefits

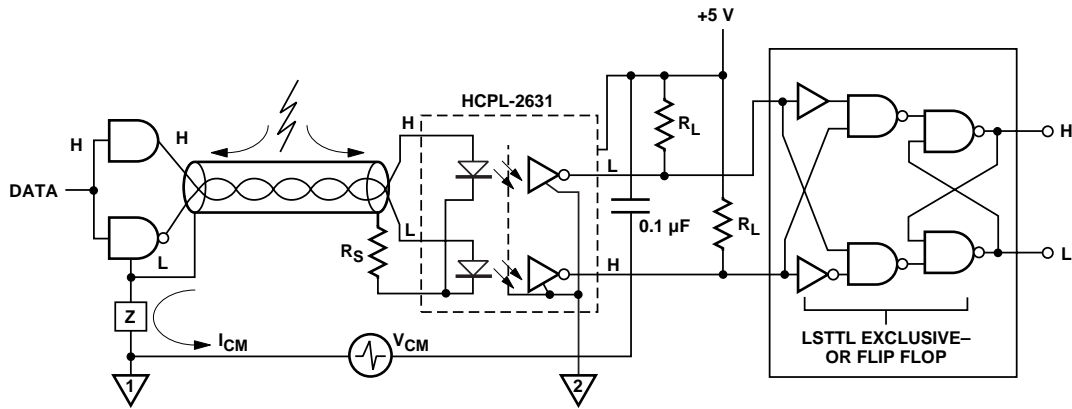
- Very high common-mode transient rejection
- Data transmission for up to 1 km distance

## Alternative HP Parts

HCPL-2602/12 High CMR Line Receiver



## Isolated Balanced Line Receiver - Circuit No. 2



### Description

This is a differential receiver using a dual-channel HCPL-2630 Optocoupler. The receiver circuit can handle data up to 10 Mbd for short line lengths. The capacitance of the twisted-pair wire introduces a propagation delay and, as a result, the data rate decreases with increasing line length. At the optocoupler output, an optional Exclusive-Or circuit can be used to increase CMR and to balance the propagation delays.

### Performance of Circuit

- Signaling rate: up to 10 MBd
- Optocoupler common mode rejection: 10,000 V/ $\mu s$

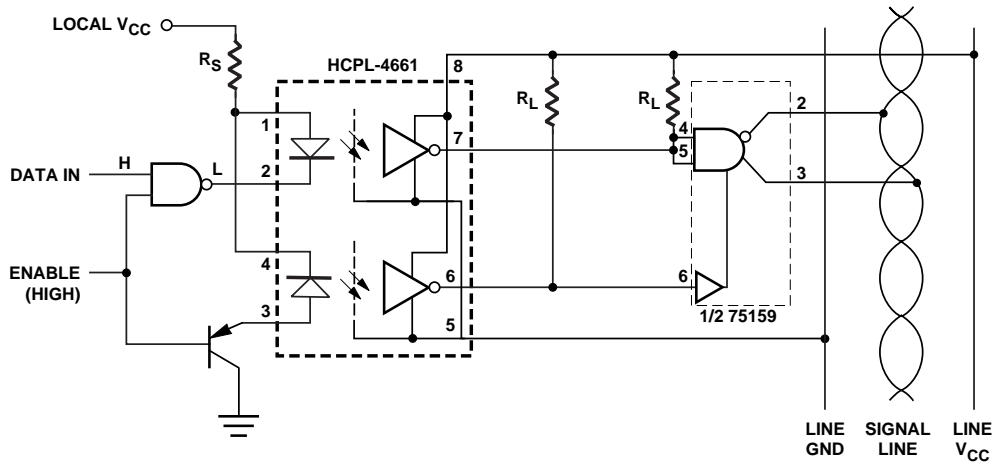
### Benefits

- Dual channel optocoupler reduces boardspace
- Balanced circuit increases CMR performance thereby eliminating or reducing transient interference

### Alternative HP Parts

- 1) HCPL-0631 Small Outline, Dual-Channel, High Speed Optocoupler
- 2) HCPL-4661 High-CMR, Dual-Channel Optocoupler
- 3) HCPL-56XX Hermetic High Speed Optocouplers

# Isolated Tri-State Line Driver



## Description

The above circuit converts a single-ended signal to a split-phase signal with a 75159 Tri-State Line Driver and dual-channel HCPL-4661 High CMR Optocoupler. When Input Enable goes low, the lower channel of the optocoupler operates the "strobe" input of the 75159 to make both outputs open.

## Performance of Circuit

- Optocoupler signaling rate: up to 10 MBd
- Optocoupler CMR: 15,000 V/ $\mu$ s at 1000 V peak (typical)

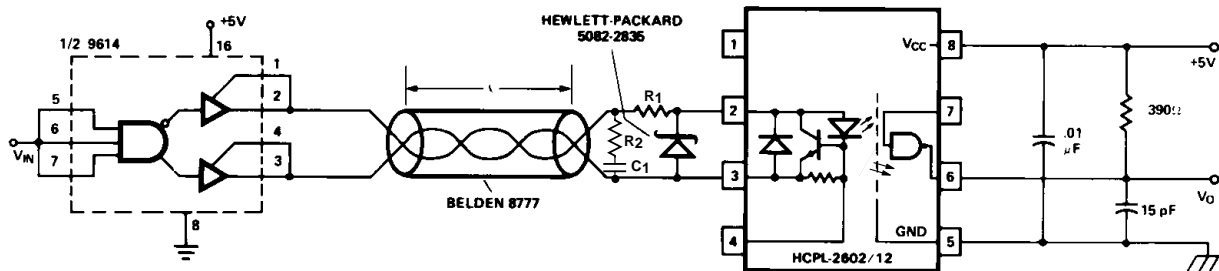
## Benefits

- Higher data rate than a current source pull-up
- High CMR performance reduces or eliminates transient noise

## Alternative HP Parts

- 1) HCPL-063N SO-8 High CMR Dual Channel Optocoupler
- 2) HCPL-2631 Dual Channel High Speed Optocoupler
- 3) HCPL-0631 Small Outline, Dual Channel Optocoupler
- 4) HCPL-56XX Hermetic High Speed Optocouplers

# Isolated Unbalanced Line Receiver



	WITHOUT SCHOTTKY DIODE			WITH SCHOTTKY DIODE						UNITS
	R = 0			R = 0		R = 33 Ω				
	<1	30	90	<1	30	90	<1	30	90	
tPHL	210	365	450	50	80	235	50	70	200	nsec
tPLH	35	46	60	35	45	60	36	45	80	nsec

PROPAGATION TIMES SHOWN EXCLUDE DRIVER AND LINE DELAYS.

## Description

The above illustration is an unbalanced line receiver using the integrated voltage-clamp input optocoupler, HCPL-2602. The circuit is unbalanced because the termination impedance is different for both “ends” of the differential signal received by the HCPL-2602. TTL data is converted to a differential signal via the differential line driver 9614, and transmitted over twisted-pair wire. The Schottky diode helps to improve the turn-on and turn-off delays.

## Performance of Circuit

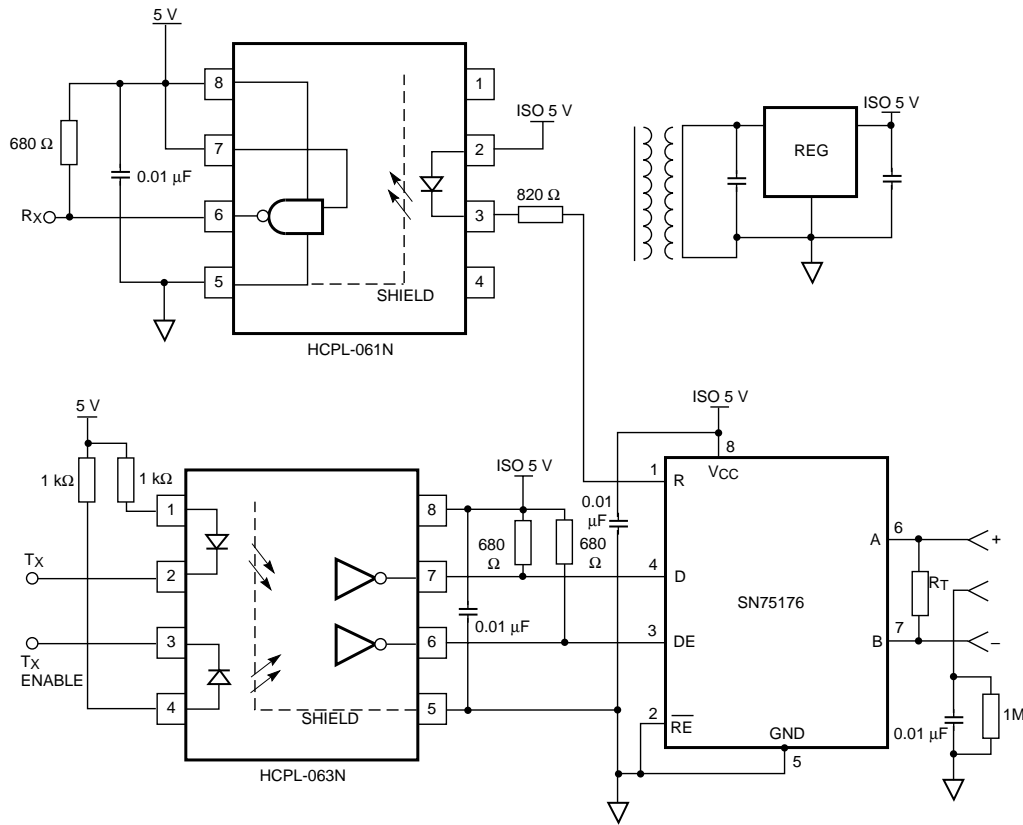
- Signaling rate: up to 2 MBd at 90 m (up to 10 MBd with polarity non-reversing driver)
- Optocoupler common-mode transient rejection: 10,000 V/μs (typical)

## Benefits

- Integrated line termination and voltage clamping saves board space
- Differential driver and optical isolated receiver reduce or eliminate transient noise interference

## Alternative HP Parts

- 1) HCPL-2611 High CMR, High Speed Optocoupler
- 2) HCPL-0601/0631 Small Outline, High Speed Optocoupler
- 3) HCNW2601 Widebody, High Speed Optocoupler



## Description

Profibus (Process Fieldbus) is essentially a twisted wire pair serial link very similar to RS-485 or 422. Profibus speed standard is either lower speed (1.5 MBd) or higher speed (12 MBd). In this application circuit the Profibus is shown to be isolated with HCPL-061N (single channel optoisolator) and HCPL-063N (dual channel optoisolator).

## Performance of Circuit

- Typical data rate (NRZ): Up to 10 Mbit/s
- Multipoint bus transmission line application
- Open collector output, HCMOS/TTL compatible
- Maximum propagation delay of optoisolator: 0.1 μsec
- Minimum common mode transient immunity: 15 kV/μsec at  $V_{CM} = 1000$  V
- Low minimum drive current: 3 mA

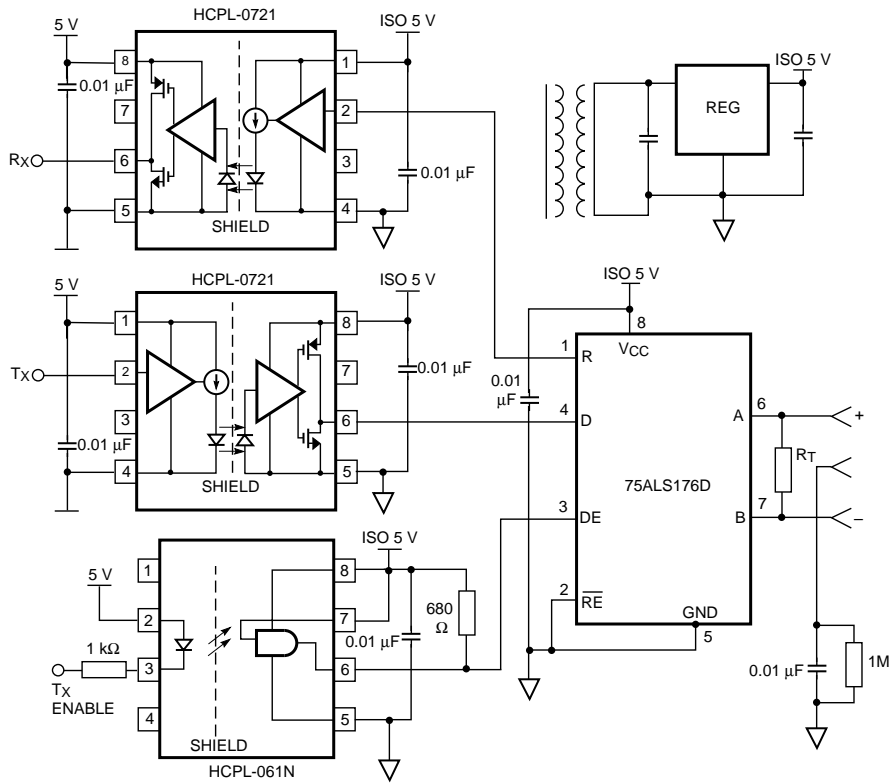
## Benefits

- Low input drive current maximizes LED lifetime/reliability
- Speed optimized for Profibus (1.5 MBd) and RS-422 (10 MBd)
- Performance guaranteed over temperature (-40 to 85°C)

## Alternative HP Parts

- 1) HCPL-0261 Single Channel Optocoupler
- 2) HCPL-56XX High CMR, Hermetically Sealed Optocoupler

# Isolated PROFIBUS/RS-485 12 MB/s Communication Application



## Description

Profibus (Process Fieldbus) is essentially a twisted wire pair serial link very similar to RS-485 or 422. Profibus speed standard is either lower speed (1.5 MBd) or higher speed (12 MBd). In this isolated multipoint transmission application circuit, two different optoisolators are utilized (HCPL-0721 and HCPL-061N).

## Performance of Circuit

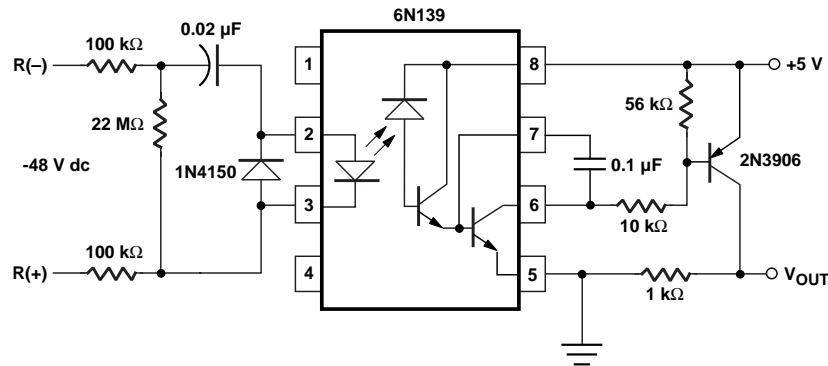
- Typical data rate (NRZ): Up to 12 Mbit/s
- Multipoint bus transmission line application
- Compatible with 5 V CMOS and TTL logic gates
- Maximum propagation delay of optoisolator: 0.04  $\mu$ sec
- Minimum common mode transient immunity: 10 kV/ $\mu$ sec at  $V_{CM} = 1000$  V

## Benefits

- Low input drive current maximizes LED lifetime/reliability
- Speed optimized for Profibus and RS-485
- Performance guaranteed over temperature (-40 to 85°C)

# Telecommunications Applications

## Telephone Ring Detection



### Description

The 6N136 Low-Input Current Optocoupler is used to detect standard telephone ring signals. At the optocoupler output, a 0.1  $\mu\text{F}$  base-collector capacitor provides a large enough Miller-capacitance so that a low-frequency ring signal (20 to 60 Hz) causes the output to remain low when ringing occurs.

### Performance of Circuit

- Can detect 20 to 60 Hz, 30 to 80  $V_{\text{RMS}}$  telephone ring signals

### Benefits

- Simple and inexpensive circuit for ring signal detection
- Meets worldwide regulatory isolation standards

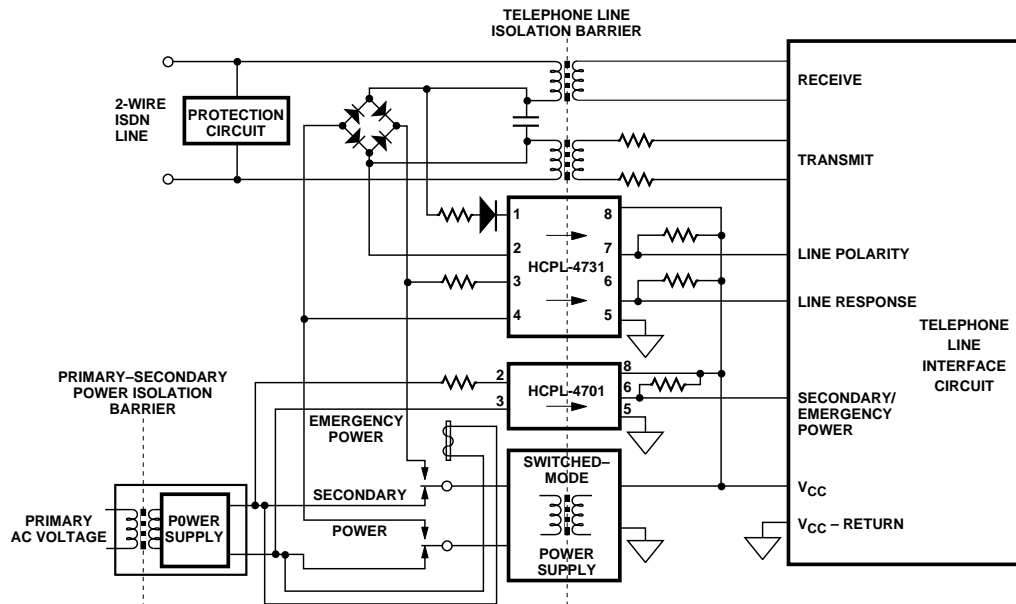
### References

6N139 Low-Input Current Optocoupler Technical Data

### Alternative HP Parts

- 1) HCPL-0701 Small Outline, Low-Input Current Optocoupler
- 2) HCPL-3700/60 Threshold Sensing Optocoupler
- 3) HCNW139 Low-Input Current Optocoupler

## ISDN Interface



### Description

The HCPL-4701 Low Power Optocoupler is suitable for standard telephone line interface functions such as: ring detection, line polarity, and power on/off detection. Integrated Services Digital Network (ISDN) applications severely restrict the input power that an optocoupler interface circuit can use, which makes the HCPL-4701 an ideal choice.

### Performance of Optocoupler

- Input current for turn-on: 40  $\mu\text{A}$
- Typical total power dissipation with  $I_F = 40 \mu\text{A}$ : < 3 mW
- Typical propagation delay: 65  $\mu\text{s}$

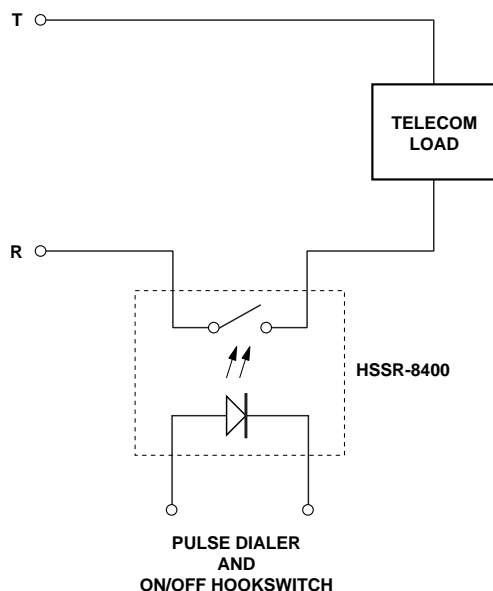
### Benefits

- Low power dissipation
- Compatible with 3 V Logic

### References

HCPL-4701 Lower Power Optocoupler Technical Data

# Telephone Pulse Dialing and On/Off Hookswitch Circuit



## Description

The HSSR-8400, optically coupled solid-state relay, can be used as an ON/OFF hookswitch and pulse dialer for telephone subscriber equipment such as modems and facsimile machines. The HSSR-8400's very low output on-resistance reduces signal distortion during voice transmission.

## Performance of Solid-State Relay

- Solid-state relay withstand voltage: 400 V
- Typical solid-state relay on-resistance: 6  $\Omega$
- Input turn-on current for solid-state relay: 5 mA

## Benefits

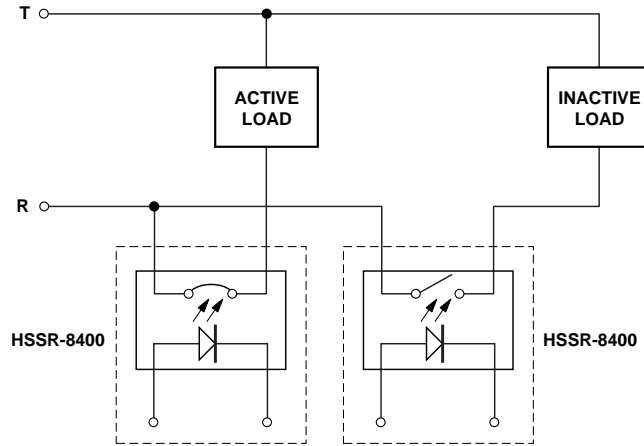
- Greater reliability compared to electro-mechanical relays
- Compact size
- Low power dissipation

## References

HSSR-8400 400 V Solid-State Relay



## Telephone Line Selection Circuit



### Description

Two HSSR-8400 optically coupled solid-state relays are used for selecting one of two telephone lines. One of the relays is turned on while the other is turned off. The HSSR-8400's very low output on-resistance reduces signal distortion during voice transmission. Telephone line selection circuits can be used in subscriber equipment such as computer modems and facsimile machines.

### Performance of Circuit

- Solid-state relay withstand voltage: 400 V
- Typical solid-state relay on-resistance: 6  $\Omega$
- Input turn-on current for solid-state relay: 5 mA

### Benefits

- Greater reliability compared to electro-mechanical relays
- Compact size
- Low power dissipation

### References

HSSR-8400 400 V Solid-State Relay

# Analog Isolation Applications with Linear Optocouplers

## Introduction

Optoisolators transfer analog and digital signals from one circuit section or module to another in the presence of a large potential difference or induced electrical noise between the ground or common points of these modules. Examples of analog isolation applications are interfaces to: A/D converters, sensing circuits such as thermocouples and transducers, patient monitoring equipment, motor speed and position measurement circuits, audio and video amplifiers, and power supply feedback.

## Basic Building Blocks for Analog Isolation

HP's HCNR200/1 and HCPL4562 constitute basic optical coupling building blocks for high linearity isolation applications. Figures 1 and 2 show the respective optical coupling mechanisms for these two optoisolators. Both these isolators use high-performance AlGaAs LEDs and photodiode combinations with higher speed and linearity compared to conventional optoisolators. The HCNR200/1 LED illuminates two closely matched photodiodes, one on the input side, and another on the output side. With a suitable applications circuit for the HCNR200/1, the nonlinearity and drift characteristics of the LED can be virtually eliminated. The output photodiode produces a photocurrent that is linearly related to the light output of the LED. The close matching of the photodiodes and advanced design of the package ensure the high linearity and stable gain

characteristics of the optoisolator.

The HCNR200/1 optoisolator can be used as a basic analog isolation building block for a wide variety of applications that require good stability, linearity, bandwidth and low cost. The HCNR200/1 is very flexible and, by appropriate design of the application circuit, is capable of operating in many different modes, including unipolar, bipolar, ac/dc, inverting and non-inverting.

The HCPL-4562 and HCNW4562 are recommended for very high bandwidth (up to 15 MHz) AC analog designs. If the output transistor is biased in the active region, the current transfer ratio relationship for the HCPL-4562 can be represented as:

$$I_C = K (I_F / I_{FQ})^n$$

where  $I_C$  is the collector current;  $I_F$  is the LED input current,  $I_{FQ}$  is LED input current at which K is measured; K is the collector current when  $I_F = I_{FQ}$ ; and n is the slope of  $I_C$  vs.  $I_F$  on logarithmic scale.

The exponent n varies with  $I_F$ , but over some limited range of  $\Delta I_F$ , n can be regarded as a constant. For ac-signal applications, the HCPL-4562 can be biased at an appropriate quiescent current where the ratio of the incremental photodiode current to incremental LED current is nearly constant. Figure 3 shows the linearity characteristics of the HCPL-4562.

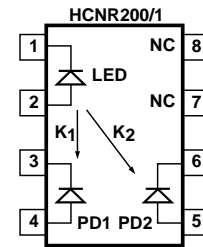


Figure 1. HCNR-200/1 High Linearity Analog Isolator

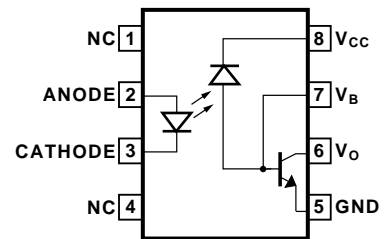


Figure 2. HCPL-4562 High Bandwidth Analog Isolator

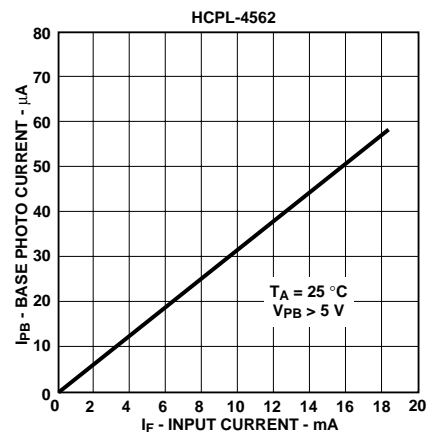
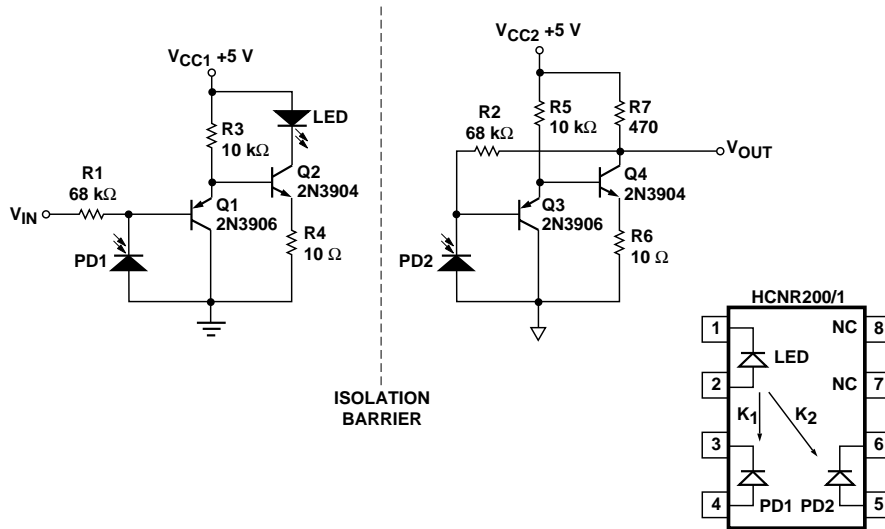


Figure 3. HCPL-4562 Base Photo Current vs. Input Current

# High Speed Isolation Amplifier



### Description

This is a high-speed, low-cost isolation amplifier for use in the feedback path of switch-mode power supplies or motor speed and position measurement. This circuit can be used in applications where high bandwidth, low-cost, and stable gain are required, but where accuracy is not critical.

### Performance of Optocoupler

- 1.5 MHz bandwidth
- Stable gain
- Low-cost support circuit
- Circuit couples only positive voltage signals

### Benefits

- Low cost solution for coupling positive voltage analog signals
- Simple way for sending power supply voltage feedback signal across isolation barrier

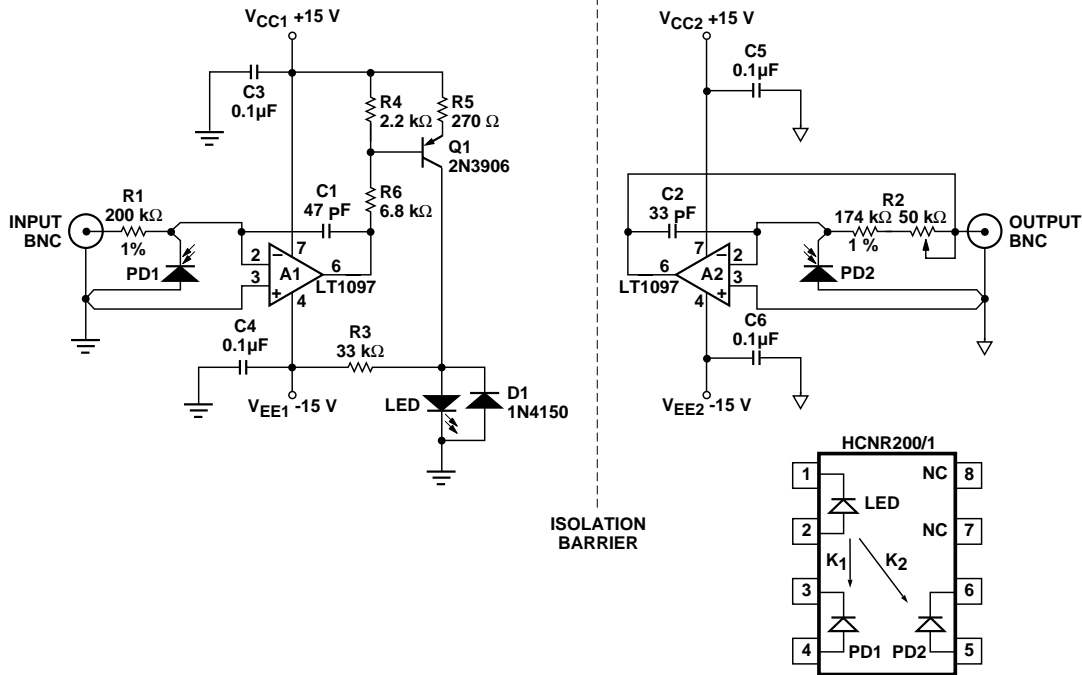
### References

HCNR200/1 Technical Data

### Alternative HP Parts

- 1) HCPL-7800A, HCPL-7800, HCPL-7840 Isolation Amplifier
- 2) HCPL-4562 Wideband Analog/Video Optocoupler
- 3) HCPL-785X Hermetically Sealed Isolation Amplifier

# Precision Isolation Amplifier for Unipolar Signals



## Description

This circuit uses the HCNR200/1 High-Linearity Analog Optocoupler to achieve high accuracy and wide dynamic range at a reasonable cost. This is accomplished by using low-cost, precision op-amps with very low input bias currents and offset voltages. The circuit couples only positive voltage analog signals.

## Performance of Circuit

- DC to 10 kHz bandwidth
- Stable gain
- 0.1% nonlinearity
- 1 mV to 10 V input/output voltage range

## Benefits

- Low-cost, high-accuracy solution for coupling analog signals
- Easy availability of support circuit components
- No offset adjustment is required

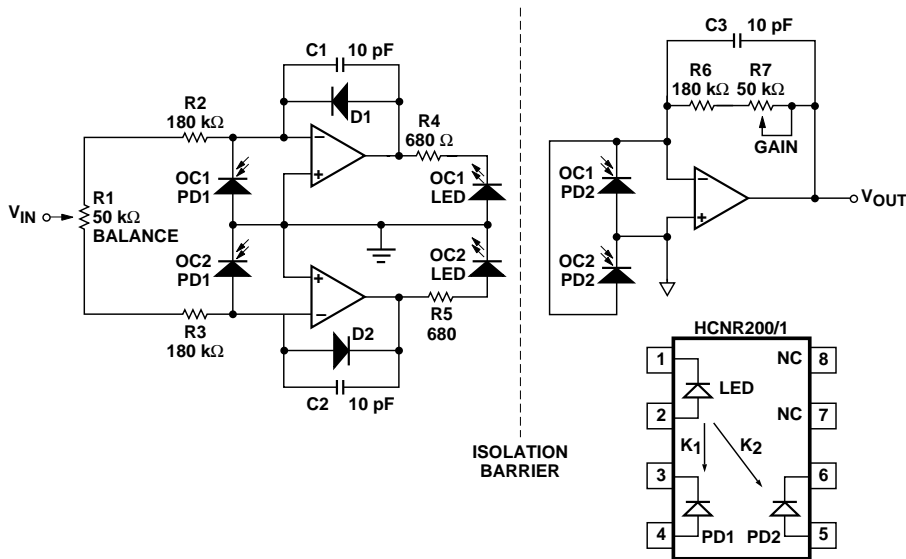
## References

HCNR200/1 Technical Data

## Alternative HP Parts

- 1) HCPL-7800A, HCPL-7800, HCPL-7840 Isolation Amplifier
- 2) HCPL-4562 Wideband Analog/Video Optocoupler
- 3) HCPL-785X Hermetically Sealed Isolation Amplifier

# Isolation Amplifier for Bipolar Signals - Circuit No. 1



## Description

This circuit shows how the HCNR200 High Linearity Optocoupler can be used for transmitting bipolar analog signals across an isolation boundary. This circuit uses two optocouplers: OC1 and OC2; OC1 handles the positive portions of the input signal and OC2 handles the negative portions. Diodes D<sub>1</sub> and D<sub>2</sub> help reduce cross-over distortion by keeping both amplifiers active during both positive and negative portions of the input signal.

## Performance of Circuit

- 0.01% nonlinearity
- Bandwidth: dc to 100 Hz
- Low transfer gain variation:  $\pm 5\%$  (K3 of HCNR201)

## Benefits

- Low drift
- Low crossover distortion within the dc to 100 Hz frequency band
- Good linearity
- Very low offset

## References

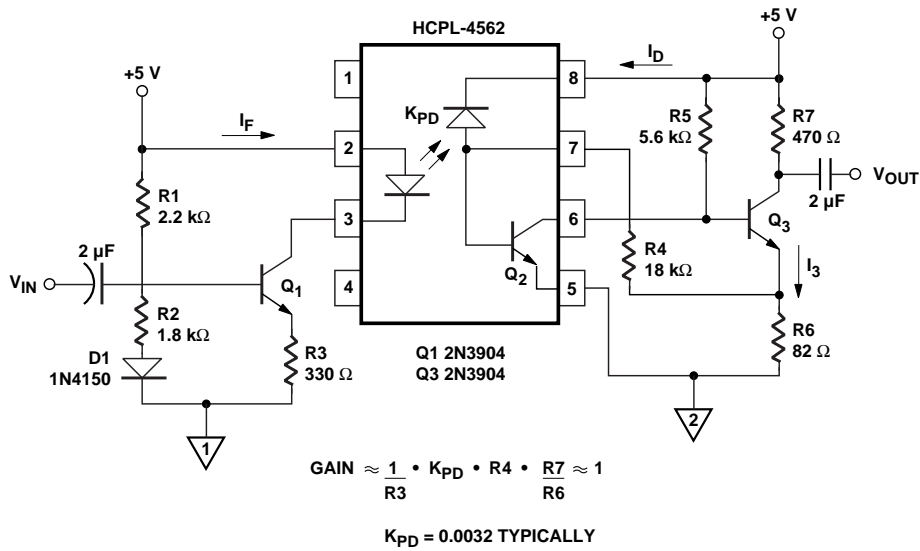
HCNR200/1 Technical Data

## Alternative HP Parts

- 1) HCPL-7800A, HCPL-7800, HCPL-7840 Isolation Amplifier
- 2) HCPL-785X Hermetically Sealed Isolation Amplifier



# AC-Coupled Isolation Amplifier



## Description

This circuit with the HCPL-4562 Wideband Analog/Video Optocoupler functions as an ac-coupled isolation amplifier that can be used for coupling audio or video signals. The input circuit biases the optocoupler LED at a quiescent current of about 6 mA, determined primarily by resistors R<sub>1</sub>, R<sub>2</sub>, and R<sub>3</sub>. Diode D<sub>1</sub> helps to stabilize the operating point over the operating temperature range. An ac-coupled signal will modulate the collector current of transistor Q<sub>1</sub> and the optocoupler LED. The output circuit consists of a simple transresistance (current-in, voltage-out) amplifier followed by a common-emitter amplifier stage.

## Performance of Circuit

- Typical bandwidth: 13 MHz
- Nominal gain of circuit: 1
- Isolation-mode rejection: 46 dB at 1 kHz
- Overall nonlinearity: 0.5%
- Optocoupler input current range: 4 mA-8 mA

## Benefits

- Simple solution for coupling audio and video signals

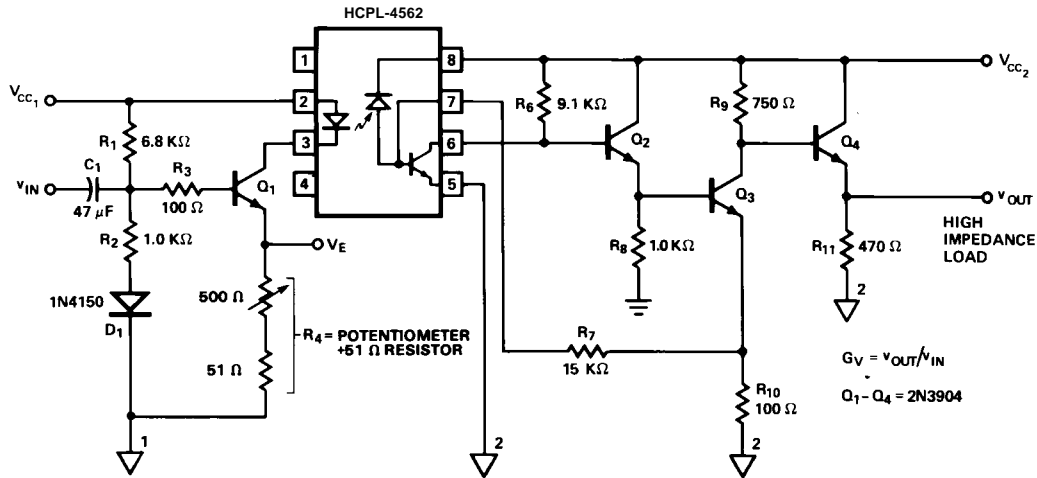
## References

- 1) HCPL-4562 Wideband Analog/Video Optocoupler Technical Data
- 2) Application Note 951-2, "Linear Applications of Optocouplers"

## Alternative HP Parts

- 1) HCPL-2502, 6N135, 6N136 High Speed Transistor Output optocouplers
- 2) HCNW4562 Widebody Wideband Analog/Video Optocoupler
- 3) HCPL-55XX, 4N55, HCPL-6530/1 Hermetic High Speed Optocoupler
- 4) HCPL-05XX Small-Outline High Speed Optocoupler

# Isolated Video Interface



## Description

This circuit, with the HCPL-4562 Wideband Analog/Video Optocoupler, is optimized for video signal coupling. The peaked response of the detector circuit helps extend the frequency range over which the gain is relatively constant. The number of gain stages, the overall circuit topology, and the dc bias points are all chosen to maximize the bandwidth.

## Performance of Circuit

- Typical bandwidth: 15 MHz
- Typical Gain variation: -1.1 dB at 5 MHz with reference at 0.1 MHz
- Isolation Mode Rejection: 122 dB at 120 Hz

## Benefits

- Cost-effective, high performance video interface circuit

## References

HCPL-4562 Wideband Analog/Video Optocoupler Technical Data

## Alternative HP Parts

HCNW4562 Widebody Wideband Analog/Video Optocoupler





# Inverter Design Using Gate Drive and Current Sense Optocouplers

## System Overview

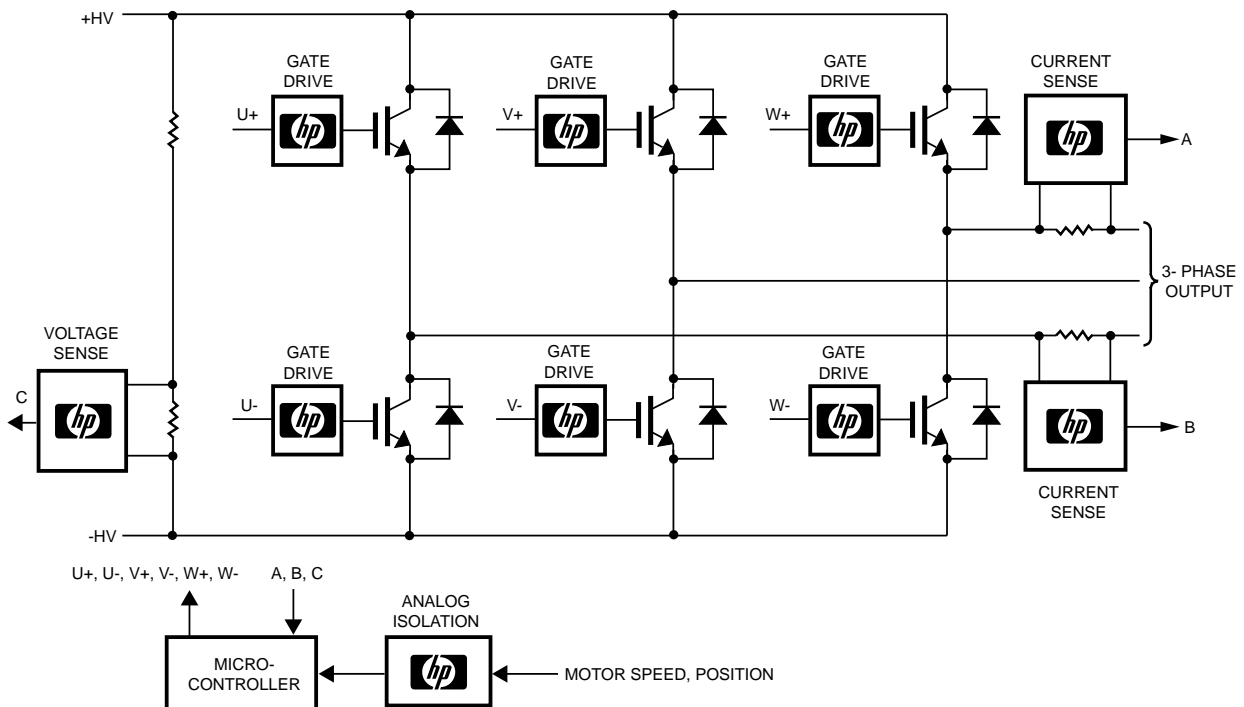
A typical motor drive and power control system shown in Figure 1 requires isolation between the high voltage devices (IGBT/MOSFET) and the low voltage devices (micro-controller). In addition to meeting the severe requirements for the isolation function, HP optocouplers provide customized functionality such as direct gate drive for IGBTs or power MOSFETs, and analog isolation for motor current sensing, voltage sensing, speed measurement, and position measurement.

## Isolated Gate Drive and IPM Interface

Many motor drive and power control systems use pulse width modulation switching of power devices to generate a three phase variable voltage and variable frequency power source. High performance motor drives require precision timing for turning on and turning off the power devices on the inverter. The micro-controller that controls the turn-on and turn-off of these power devices needs to be isolated from the high voltage inverter side. HP offers a variety of optocouplers that have built-in gate drive capability. For solutions that require only a

simple isolation interface, HP provides Intelligent Power Module (IPM) interface optocouplers. All of HP's gate drive and IPM interface optocouplers meet stringent industrial requirements with critical performance:

- Minimum Common Mode Rejection: 10 kV/μs slew rate at 1,500 V peak transients
- Wide Operating Temperature Range: -40°C to +85°C
- Over Current Protection and Fault Feedback (HCPL-316J)
- Safety Standards Certifications: UL, CSA, VDE
- Fast Switching Speeds: 500 ns range (see detailed part number specifications)
- Wide Supply Voltage Range: 15 V to 30 V



**Figure 1. Isolation Circuits for Power Control – System Overview**

## Isolated Current and Voltage Sensing

HP provides several analog isolation amplifier products for isolated precision current and voltage sensing for monitoring motor performance. HP also offers a digital output isolation amplifier for direct connection to a micro-controller. Compared to Hall-Effect sensors, HP's isolation amplifiers have excellent gain and offset characteristics, especially very low offset drift over a wide temperature range. In addition, they provide a compact, low-cost, and reliable solution for motor drive designers that need to accurately measure motor voltage and current. Some of the key performance features include:

- 12-bit linearity (HCPL-7860)
- over current detection (HCPL-788J)
- $\pm 200$  mV input range
- $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  operating temperature range
- $15\text{ kV}/\mu\text{s}$  isolation transient immunity
- Safety Standards Certifications: UL, CSA, VDE

## Analog Signal Isolation for Speed and Position Measurement

HP offers a low cost, high accuracy, isolated amplifier solution for the measurement of speed and position in a motor. With the use of HP's HCNR201 and low cost operational amplifiers, circuit designers have the flexibility of designing analog isolation amplifiers that have low input bias currents, high bandwidth, stable gain, and very high linearity.

## Common Mode Rejection

The detector shield in the optocoupler prevents CMR failure

due to capacitive coupling from the input side of the optocoupler, through the package, to the detector IC. However, this shield does not eliminate the capacitive coupling between the LED and the optocoupler output pins and output ground as shown in Figure 2. This capacitive coupling causes perturbations in the LED current during common mode transients and becomes the major source of CMR failures for a shielded optocoupler. The main design objective of a high CMR LED drive circuit becomes keeping the LED in the proper state (on or off) during common mode transients. The recommended application circuits for HP's gate drive applications can achieve  $15\text{ kV}/\mu\text{s}$  CMR while minimizing component complexity.

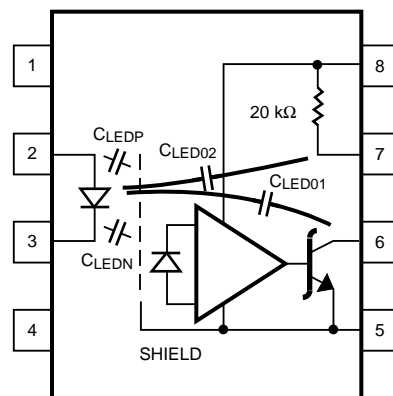


Figure 2. AC Equivalent for a Digital Optocoupler

Another cause of CMR failure for a shielded optocoupler is direct coupling to the optocoupler output pins through  $C_{LED01}$  and  $C_{LED02}$  in Figure 2. Many factors influence the effect and magnitude of the direct coupling including: the use of an internal or external output pull-up resistor, the position of the LED

current setting resistor, the connection of the unused input package pins, and the value of the capacitor at the optocoupler output (CL). The recommended gate drive and IPM interface application circuits for HP optocouplers have been optimized to reduce the likelihood of CMR failure.

## IPM Dead Time and Propagation Delay Specifications

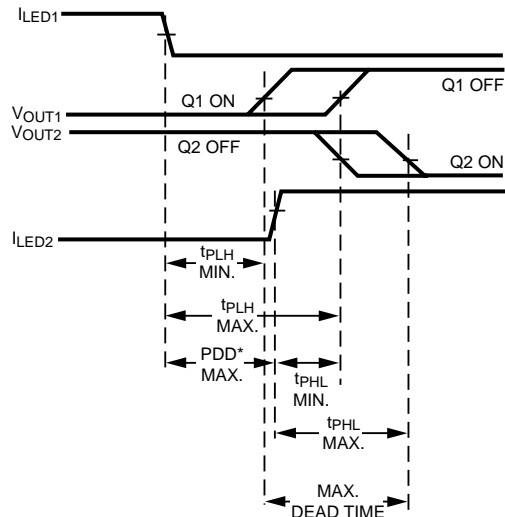
Many of HP's gate drive and IPM interface optocouplers include a Propagation Delay Difference (PDD) specification intended to help designers minimize "dead time" in their power inverter designs. Dead time is the time periods during which both the high and low side power transistors ( $Q_1$  and  $Q_2$ ) of a power module are off. Any overlap in  $Q_1$  and  $Q_2$  conduction will result in large currents flowing through the power devices between the high and low voltage motor rails.

To minimize dead time the designer must consider the propagation delay characteristics of the optocoupler as well as the characteristics of the IGBT gate drive circuit. Considering only the delay characteristics of the optocoupler (the characteristics of the IGBT gate drive circuit can be analyzed in the same way) it is important to know the minimum and maximum turn-on ( $t_{PHL}$ ) and turn-off ( $t_{PLH}$ ) propagation delay specifications, preferably over the desired operating temperature range.

The limiting case of zero dead time occurs when the input to  $Q_1$  turns off at the same time that the input to  $Q_2$  turns on. This case

determines the minimum delay between LED<sub>1</sub> turn-off and LED<sub>2</sub> turn-on, which is related to the worst case optocoupler propagation delay waveforms, as shown in Figure 3. A minimum dead time of zero is achieved in Figure 3 when the signal to turn on LED<sub>2</sub> is delayed by (t<sub>PLH max</sub> - t<sub>PHL min</sub>) from the LED<sub>1</sub> turn off. Note that the propagation delays used to calculate PDD are taken at equal temperatures since the optocouplers under consideration are typically mounted in close proximity to each other. (Specifically, t<sub>PLH max</sub> and t<sub>PHL min</sub> in the Figure 3 equations are not the same as the t<sub>PLH max</sub> and t<sub>PHL min</sub> over the full operating temperature range, specified in the data sheet.) This delay is the maximum value for the propagation delay difference specification that is specified at 450 ns for the HCPL-4506 over an operating temperature range of -40°C to +100°C. Delaying the LED signal by the maximum propagation delay difference ensures that the minimum dead time is zero, but it does not tell a designer what the maximum dead time will be. The maximum dead time occurs in the highly unlikely case where one optocoupler with the fastest t<sub>PLH</sub> and another with the slowest t<sub>PHL</sub> are in the same inverter leg. The maximum dead time in this case becomes the sum of the spread in the t<sub>PLH</sub> and t<sub>PHL</sub> propagation delays as shown in Figure 3. The maximum dead time is also equivalent to the difference

minimum propagation delay difference specifications. The maximum dead time (due to the optocouplers) for the HCPL-4506 is 600 ns over an operating temperature range of -40°C to +100°C



MAXIMUM DEAD TIME (DUE TO OPTOCOUPLER)  
 = (t<sub>PLH MAX.</sub> - t<sub>PLH MIN.</sub>) + (t<sub>PHL MAX.</sub> - t<sub>PHL MIN.</sub>)  
 = (t<sub>PLH MAX.</sub> - t<sub>PHL MIN.</sub>) + (t<sub>PLH MIN.</sub> - t<sub>PHL MAX.</sub>)  
 = PDD\* MAX. - PDD\* MIN.  
 PROPAGATION DELAY DIFFERENCE (PPD) MAX.  
 = (t<sub>PLH</sub> - t<sub>PHL</sub>) MAX. = (t<sub>PLH MAX.</sub> - t<sub>PHL MIN.</sub>)  
 NOTE: THE PROPAGATION DELAYS USED TO CALCULATE THE PDD AND MAXIMUM DEAD TIME ARE TAKEN AT EQUAL TEMPERATURES.

Figure 3. Propagation Delay and Dead Time

### Bootstrap Power Supply Circuit for Power Control Systems

Figure 4 shows a bootstrapped output power supply circuit that has the following benefits:

- eliminates the need for an isolated power supply or a dc-to-dc converter,
- lower cost solution compared to transformer based power supply,
- less printed circuit board space.

This circuit includes a bootstrap circuit for providing output power to the HCPL-316J gate drive optocouplers, thereby

eliminating the need for isolated power supplies or dc-to-dc converters. It can be modified to suit other HP gate drive optocouplers and current/voltage sensing isolation amplifiers.

Component values were chosen for a 350 V rail =  
 $HV+ - HV - (240 V \times 1.414)$ .  
 When the lower IGBT is turned on,  $V_{C1H}$  charges up (through  $D_{1H}$ ) to a voltage of:

$$\begin{aligned}
 V_{C1H} &= HV+ - [HV- + V_{SATM2} + V_{CC2H} + V_F(D_{1H})] \\
 &= 350 V - 3 V - 18 V - 1 V \\
 &= 328 V
 \end{aligned}$$

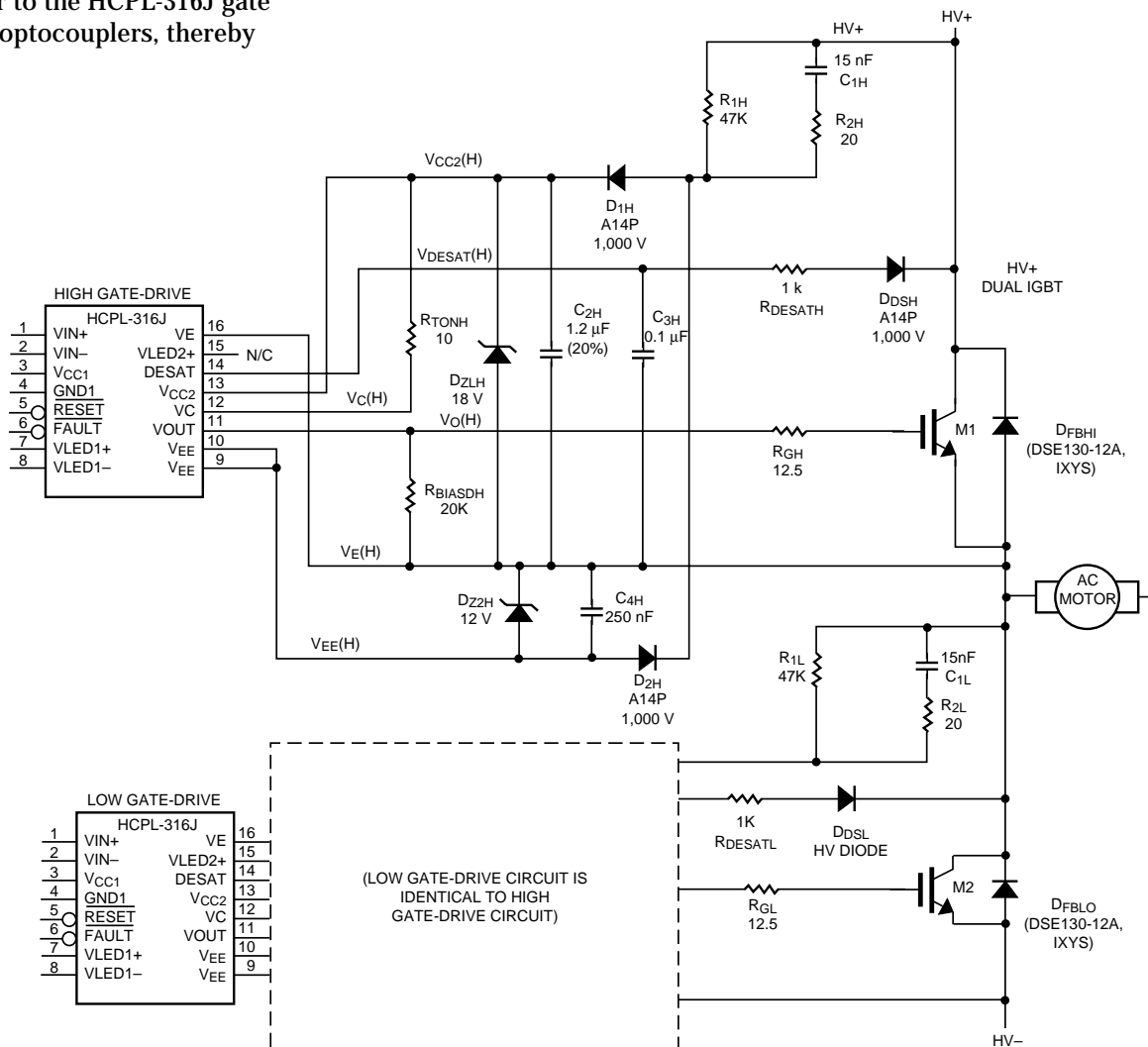


Figure 4. Bootstrap Circuit for Power Control System

where  $V_{SATM2}$  is the saturation or “on” voltage across the collector-emitter of IGBT M2;  $V_{F(D1H)}$  is the voltage across diode  $D_{D1H}$ ; and  $HV+$ ,  $HV-$  are the rail voltages.

When M2 (low IGBT) switches off and M1 (upper IGBT) switches on,  $V_{E(H)}$  pulls up to  $HV+ - V_{SATM1}$ . This causes  $C_{4H}$  to become charged through  $D_{2H}$ . Charge sharing between  $C_{1H}$  and  $C_{4H}$  results in the voltage across  $C_{4H}$  which (in the absence of clamping diode  $D_{Z2H}$ ) can be approximated by:

$$C_{4H} \times \Delta V_{C4H} = C_{1H} \times 328 V$$

$$\rightarrow \Delta V_{C4H} = 19.6 V$$

where  $\Delta V_{C4H}$  = the voltage drop across  $C_{4H}$ . The negative gate bias then is held at 12 V by clamping Zener  $D_{Z2H}$ .

### Shunt Resistor Selection for Current Sensing

The current-sensing shunt resistor should have low resistance to minimize power dissipation, low inductance to minimize di/dt induced voltage spikes which could adversely affect operation, and reasonable tolerance to maintain overall circuit accuracy. Choosing a particular value for the shunt is usually a compromise between minimizing power dissipation and maximizing accuracy. Smaller shunt resistance decrease power dissipation, while larger shunt resistance can improve circuit accuracy by utilizing the full input range of the isolated modulator.

Hewlett-Packard recommends Dale Electronics’ two-terminal shunt resistors for low cost

applications. These resistors are suitable for measuring current up to 28  $A_{RMS}$ . See comparison table below.

Several four-terminal shunts from Isotek suitable for sensing currents in motor drives up to 71  $A_{RMS}$  (71 hp or 53 kW) are shown in the comparison table below; the maximum current and motor power range for each of the PBV-series shunts are indicated. For shunt resistance from 50 mW down to 10 mW, the maximum current is limited by the input voltage range of the isolated modulator. For the 5 mW and 2 mW shunts, a heat sink may be required due to the increased power dissipation at higher currents.

#### Low Cost Two Terminal Resistor Selection Guide (Supplier: Dale Electronics, Tel: 402-564-3131)

Shunt Resistor Part Number	Shunt Resistance (mΩ)	Price Range (US\$)	Tolerance (%)	Temp. Coefficient (ppm/°C)	Max. RMS Current (A)	Motor Power Range 120 Vac - 440 Vac	
						(hp)	(kW)
LV-5.005	5	\$0.40 - 1.00	1	<300	28.3	8 - 28	6 - 21
LVR-3.01	10	\$0.38 - 0.76	1	<300	14.1	4 - 14	3 - 10
LVR-3.02	20	\$0.38 - 0.76	1	<300	7	2 - 7	1.4 - 5
LVR-3.05	50	\$0.38 - 0.76	1	<300	2.8	0.8 - 3	0.6 - 2
WSC-2.02*	20	\$0.38 - 0.76	1	<300	7.1	2 - 7	1.4 - 5

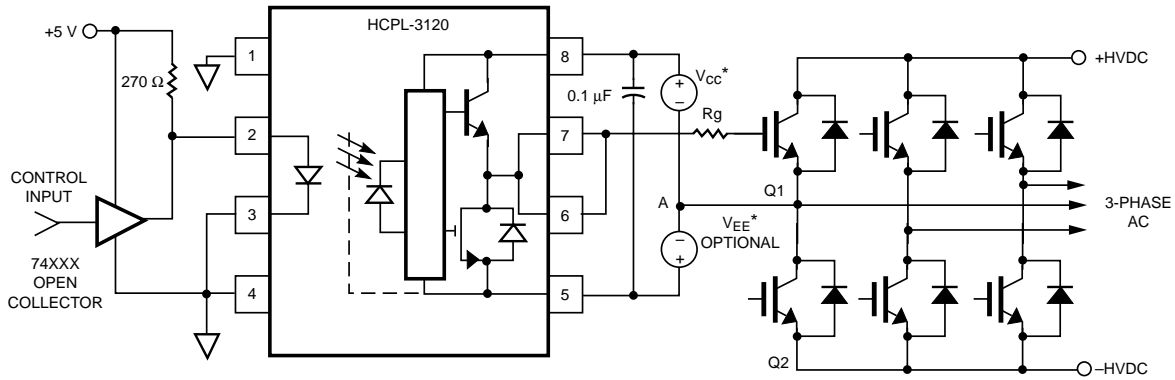
\* Surface Mount

#### High Performance Four-Terminal Shunt Resistor Selection Guide (Supplier: Isotek, Tel: 508-673-2900)

Shunt Resistor Part Number	Shunt Resistance (mΩ)	Unit Price @ 2500 Qty. (US\$)	Tolerance (%)	Temp. Coefficient (ppm/°C)	Max. RMS Current (A)	Motor Power Range 120 Vac - 440 Vac	
						(hp)	(kW)
PBV-R050-0.5	50	\$3.74	0.5	<30	3	0.8 - 3	0.6 - 2
PBV-R020-0.5	20	\$3.74	0.5	<30	7	2 - 7	1.4 - 5
PBV-R010-0.5	10	\$3.74	0.5	<30	14	4 - 14	3 - 10
PBV-R005-0.5	5	\$4.09	0.5	<30	25 [28]	7-25 [8-28]	5-19 [6-21]
PBV-R002-0.5	2	\$4.09	0.5	<30	39 [71]	11 - 39 [19 - 71]	8 - 29 [14 - 53]

Note: Values in brackets are with a heatsink for the shunt.

# Isolated Integrated Gate Driver for IGBT/MOSFET



\*RECOMMENDED SUPPLY VOLTAGES

SINGLE SUPPLY	V <sub>CC</sub> = +18V	V <sub>EE</sub> = 0V
DUAL SUPPLY	V <sub>CC</sub> = +15V	V <sub>EE</sub> = -5V

$$R_g = \frac{V_{CC} - V_{EE} - V_{OL}}{I_{ON}}$$

## Description

The HCPL-3120 drives the IGBTs or MOSFETs directly in this circuit and provides full regulatory approved isolation between the power and control circuits. The output power supply can be derived from rail to rail supply by using a bootstrap circuit illustrated in the “Inverter Design using Gate Drive and Current Sense Optocoupler” section. The value of R<sub>g</sub> in the above circuit is chosen to control the peak gate charge and discharge current as well as the output power dissipation.

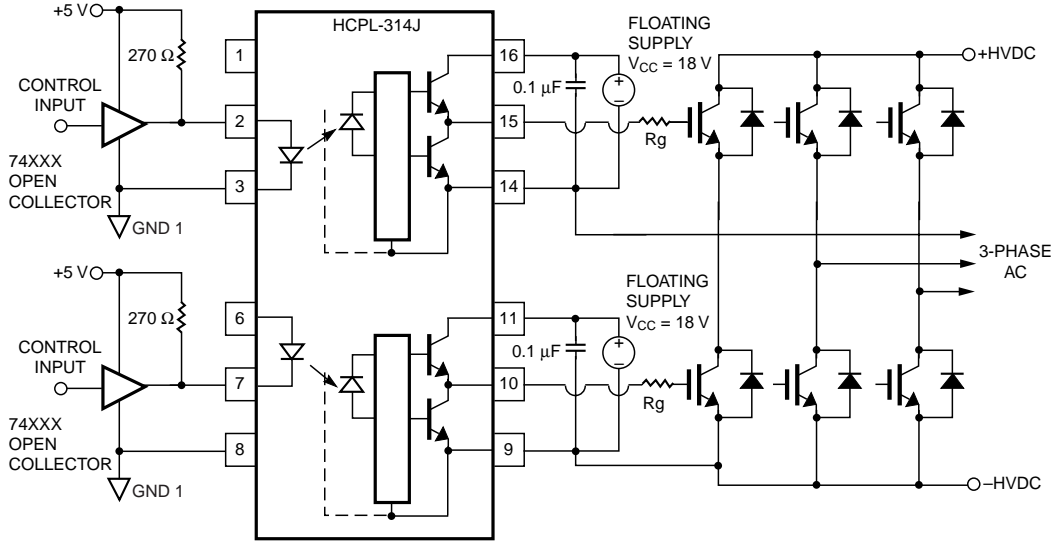
## Performance of Circuit

- Peak output current of 2.0A improves driving efficiency.
- Superior common mode transient noise immunity: 15 kV/μs@V<sub>cm</sub> = 1500 V.
- Low I<sub>cc</sub> current and wide V<sub>cc</sub> range: 15 V - 30 V over -40°C to 100°C.
- Low V<sub>OL</sub> of 0.5 V eliminates the need for negative Supply Voltage (V<sub>ee</sub>).
- World wide regulatory approval.
- Fast under voltage lockout response: 0.6 μs.

## Alternative HP Parts

- 1) HCPL-3150 0.5 Amp Isolated IGBT Gate Driver
- 2) HCPL-J314 0.4 amp Isolated IGBT Gate driver
- 3) HCPL-314J 0.4 Amp Dual IGBT Gate Driver
- 4) HCPL-315J 0.5 Amp Dual IGBT Gate Driver
- 5) HCPL-316J 2.0 Amp Isolated Gate Driver with Integrated Desaturation Detection and Feedback.

# Dual Channel Isolated Integrated Gate Driver for IGBT/MOSFET



## Description

The HCPL-314J drives 2 IGBTs or MOSFETs directly in this circuit and provides full regulatory approved isolation between the power and control circuits. The output power supply can be derived from rail to rail supply by using a bootstrap circuit illustrated in the “Inverter Design using Gate Drive and Current Sense Optocoupler” section. The value of  $R_g$  in the above circuit is chosen to control the peak gate charge and discharge current as well as the output power dissipation.

## Performance of Circuit

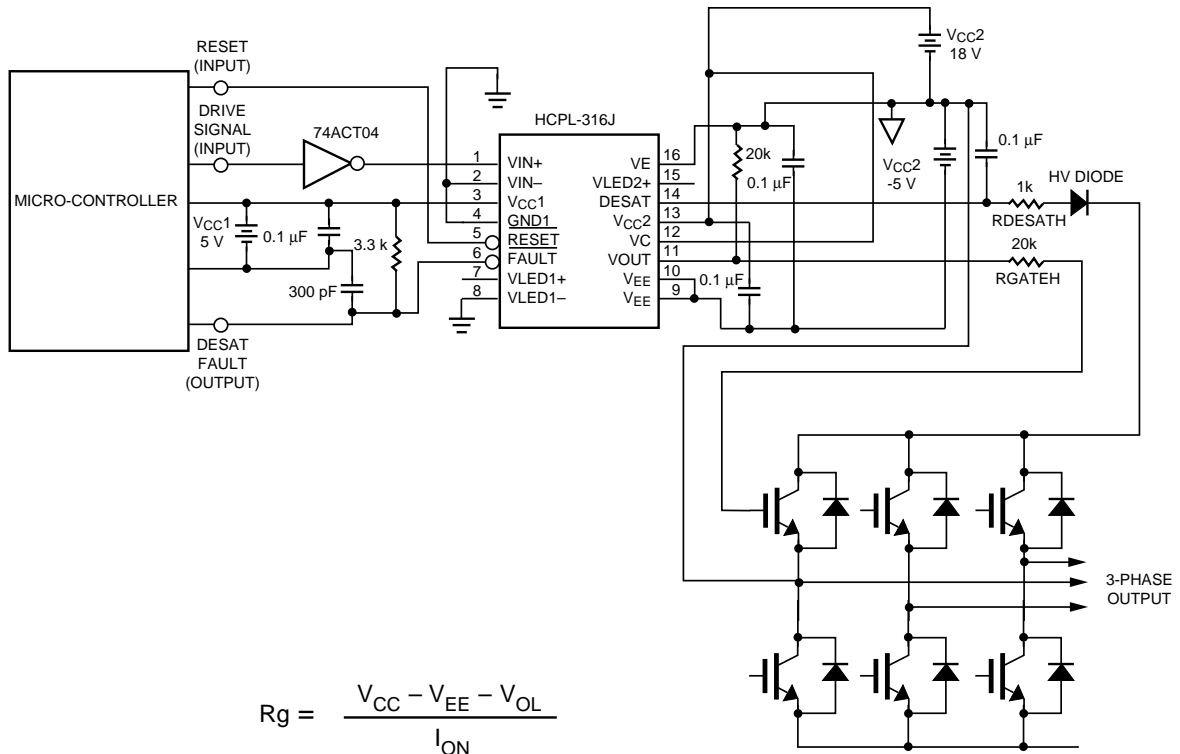
- Dual in 1 package saves assembly costs.
- Peak output current of 0.4 A best suited for low and medium power IGBTs.
- Superior common mode transient noise immunity:  $10 \text{ kV}/\mu\text{s}@V_{cm} = 1500 \text{ V}$ .
- Low  $I_{cc}$  current and wide  $V_{cc}$  range: 10 V - 30 V over  $-40^\circ\text{C}$  to  $100^\circ\text{C}$ .
- Low  $V_{OL}$  of 1V eliminates the need for negative supply voltage ( $V_{ee}$ ).
- Worldwide regulatory approval.

## Alternative HP Parts

- 1) HCPL-315J 0.5 Amp Dual IGBT Gate Driver
- 2) HCPL-3150 0.5 Amp Isolated IGBT Gate Driver
- 3) HCPL-J314 0.4 amp Isolated IGBT Gate driver
- 4) HCPL-3120 2.0 Amp IGBT Gate Driver
- 5) HCPL-316J 2.0Amp Isolated Gate Driver with Integrated Desaturation Detection and Feedback.



# Isolated Gate Drive for IGBT/MOSFET with Integrated Desaturation Protection and Fault Feedback



## Description

The HCPL-316J drives IGBTs or MOSFETs directly and provides additional IGBT desaturation protection. The Vce of the IGBT is monitored by Desat pin and the IGBT will be slowly turned off if Vdesat exceeds a threshold of 7 V. A fault feedback signal is propagated to the input side to notify the micro-controller of the detected fault condition. This FAULT output remains low until the part is reset. The 100 pF blanking capacitor shown in the diagram above will delay the rise of V<sub>Desat</sub> for a period of around 4 µs to allow the IGBT sufficient time to turn on and the collector to settle to a low V<sub>Desat</sub>.

## Performance of Circuit

- Gate Drive Current : 2.0 A
- Common mode Transient Rejection: 15 kV/µs@V<sub>CM</sub> = 1.5 kV
- IGBT gate protection response time: 3 µs.
- IGBT fault signal propagation delay: 10 µs.

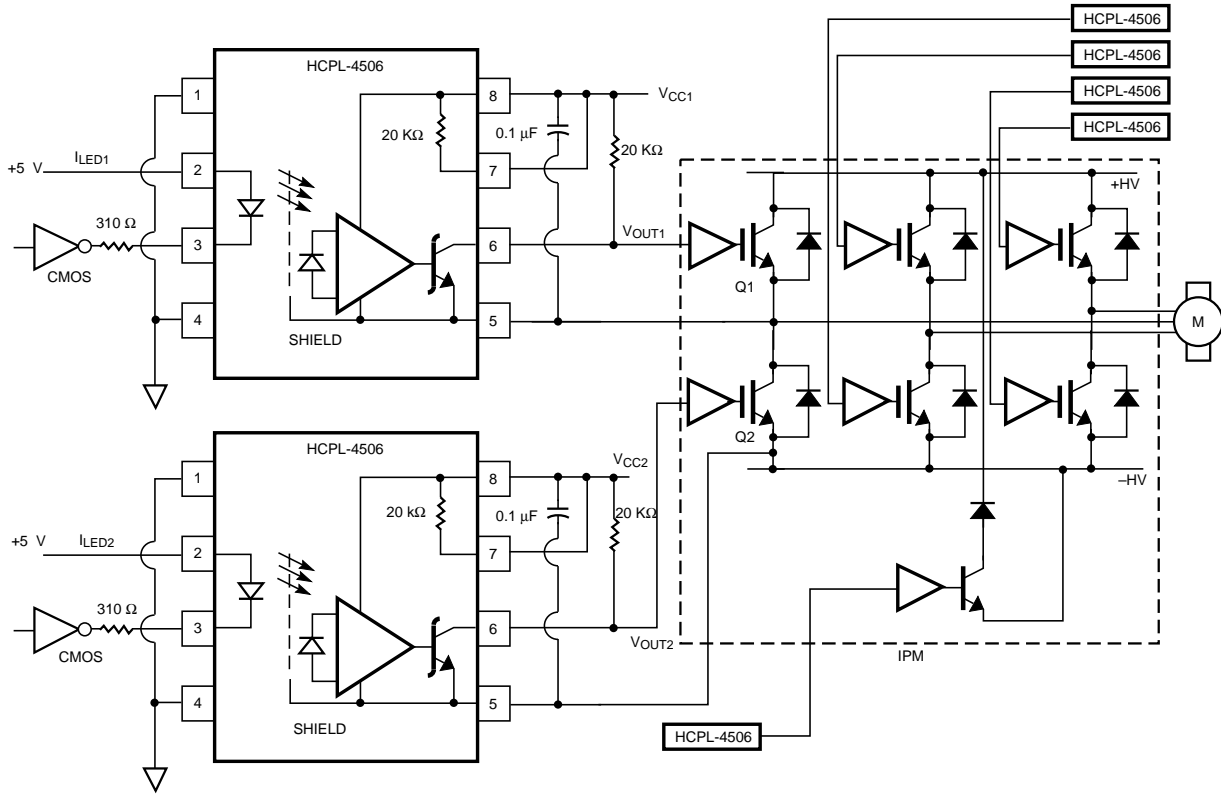
## Benefits:

- Reduced assembly costs
- CMOS/TTL compatible
- Local IGBT soft shutdown
- Worldwide regulatory approval

## Alternative HP Parts

- 1) HCPL-315J 0.5 Amp Dual IGBT Gate Driver
- 2) HCPL-3150 0.5 Amp Isolated IGBT Gate Driver
- 3) HCPL-J314 0.4 amp Isolated IGBT Gate driver
- 4) HCPL-314J 0.4 Amp Dual IGBT Gate Driver
- 5) HCPL-3120 2.0Amp Isolated Gate Driver.

# Isolated Interface for Intelligent Power Module Gate Drive



## Description

The HCPL-4506 provides isolation between the controller and the IPM (Intelligent Power Module). This optoisolator provides world wide safety certification (UL, CSA, VDE, BSI). The HCPL-4506 optocouplers can reject common mode transients that have slew rates as high as 15 kV/μs and peak voltage up to 1500 V. Furthermore, this optocoupler has guaranteed Pulse Width Distortion and Propagation Delay Difference specifications that allow the circuit designer to reduce switching dead time and improve inverter efficiency.

## Performance of Optocoupler

- Minimum 15 kV/μs transient immunity
- Maximum propagation delay: 500 ns
- Maximum propagation delay difference between any two HCPL-4506s: 450 ns
- Specification guaranteed over -40°C to 100°C operating temperature range.

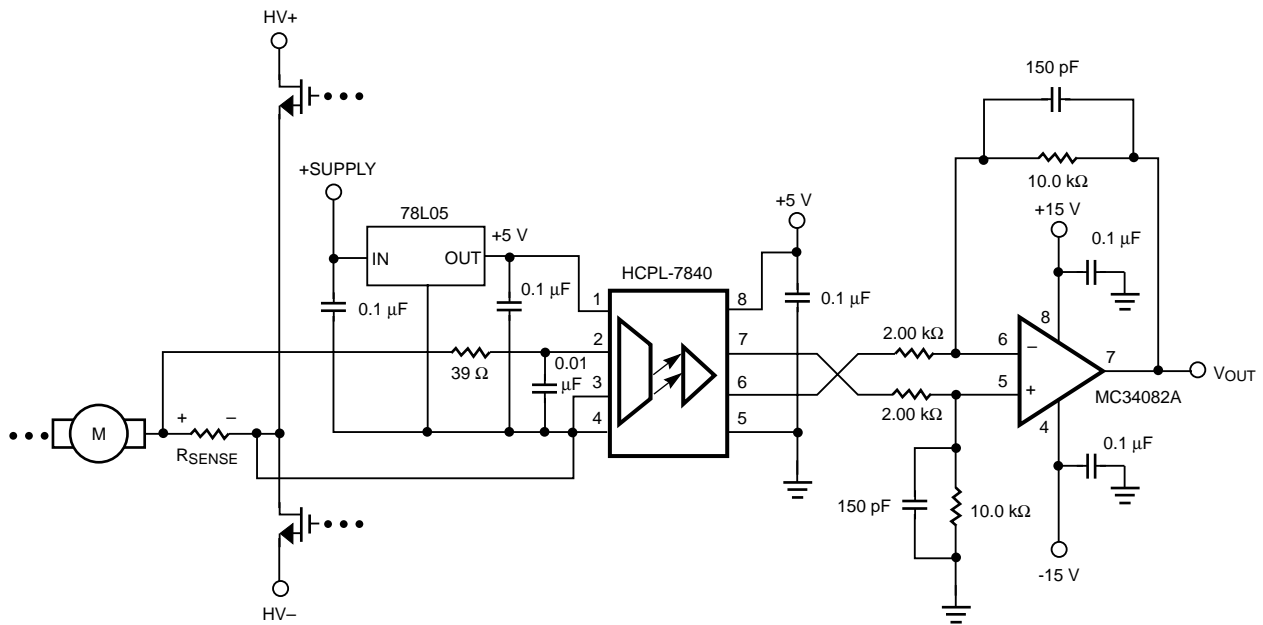
## Benefits

- World wide regulatory approval.
- Reduced deadtime

## Alternative HP Parts

- 1) HCNW4506 widebody,  $V_{IORM} = 1414$  V, HCPL-J456,  $V_{IORM} = 891$  V, HCPL-0456, SO8 package.
- 2) HCPL-4504, CNW4504, HCPL-J454, HCPL-0454.
- 3) HCPL-4503, HCNW4503, HCPL-0453.

# Low Cost Isolated Phase Current Sensing with Analog Output



### Description

The HCPL-7840 Isolation Amplifier can be used for isolating the motor current sensing element from the control circuit while at the same time transmitting precision analog signals. This circuit requires a low cost shunt resistor for monitoring the motor current. The voltage across the sensing resistor is fed to the HCPL-7840 input pins 2 and 3. A floating power supply (which in many applications could be the same one used to drive the high side power transistors) is regulated to 5 V using a simple three-terminal voltage regulator, 78L05. The differential output from the HCPL-7840 isolation amplifier is converted to a ground-referenced single-ended output voltage with a simple differential amplifier circuit (MC34082A and associated components).

### Performance of Circuit

- Sense current: Up to 200 A
- Optocoupler bandwidth: Up to 100 kHz
- Optocoupler nonlinearity: 0.2%
- Optocoupler input offset voltage: 0.2 mV (typical)
- Optocoupler common-mode rejection: 15 kV/μs

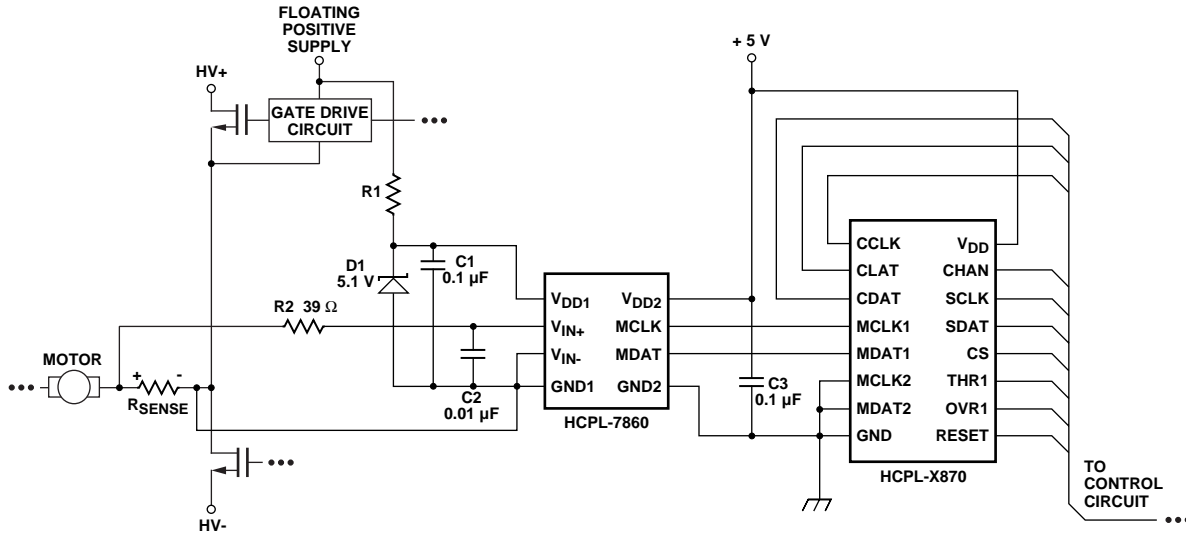
### Benefits

- Small size and lower profile circuit compared to Hall-Effect device current sensing circuits.
- Industry standard low profile components are used in this circuit.
- High precision measurement while maintaining common mode transient immunity.

### Alternative HP Parts

- 1) HCPL-7800A: 1% part-to-part gain tolerance, HCPL-7800: 3% part-to-part gain tolerance.
- 2) HCPL-788J: single ended output isolation amplifier with integrated over current detection.
- 3) HCPL-7860 and HCPL-7870/ HCPL-0870: isolated 15 bit A/D converter.

# Isolated A/D Converter for Phase Current Sensing



## Description

The HCPL-7860 Isolated Modulator and the HCPL-x870 Digital Interface IC together form an isolated programmable two-chip analog-to-digital converter. The isolated modulator allows direct measurement of motor phase currents in power inverters while the digital interface IC can be programmed to optimize the conversion speed and resolution.

## Performance of Circuit

- Resolution due to linearity: 12 bits at  $t_{\text{DELAY}} = 18 \mu\text{s}$ , 14 bits at  $t_{\text{DELAY}} = 94 \mu\text{s}$
- Common-mode transient rejection:  $dV/dt = 15 \text{ kV}/\mu\text{s}$  @  $V_{\text{CM}} = 1500 \text{ V}$
- Signal-to-Noise:  $\text{SNR} = 62 \text{ dB}$  (minimum)
- Regulatory Isolation Ratings:  $V_{\text{ISO}} = 3750 \text{ V}$  (per UL 1577),  $V_{\text{IORM}} = 848 \text{ V}$ ;  $V_{\text{IOTM}} = 6000 \text{ V}$
- Input Offset Drift:  $4 \mu\text{V}/^\circ\text{C}$  (typical)
- Reference Voltage Tolerance:  $\pm 4\%$  ( $\pm 1\%$  within shipment tube)

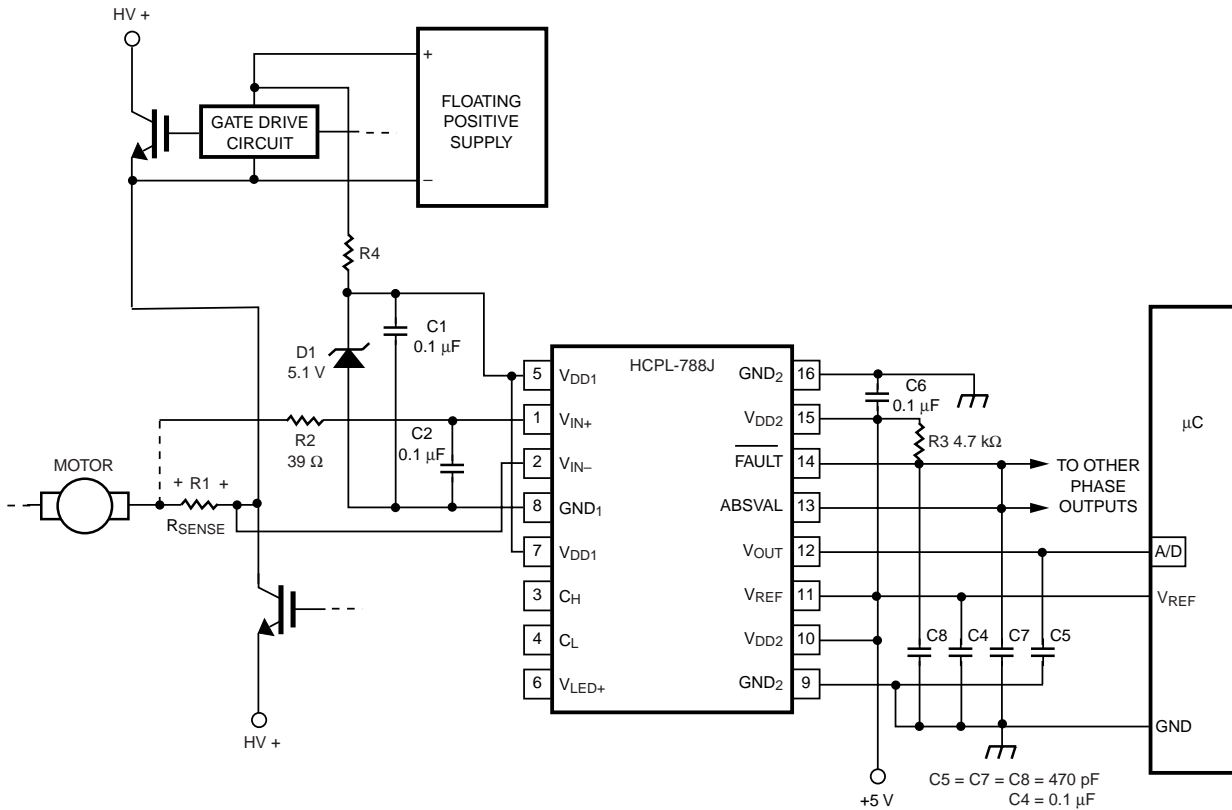
## Benefits

- Integrated analog-to-digital converter means fewer components required.
- High common-mode transient rejection ensures no corruption of data.
- Low gain temperature-coefficient and offset voltage ensure high accuracy measurements.

## References

- 1) HCPL-7860/x870 Technical Data
- 2) High precision current sensing resistor suppliers: Dale in USA; Isabellenhutte in Germany; and PCN in Japan

# Low Cost Isolated Phase Current Sensing with Analog Output and Over Current Detection



## Description

The HCPL-788J can be used for isolating the motor current sensing element from the control circuit while at the same time transmitting precision analog signals and over current fault signal. This circuit requires a high precision-sensing resistor for monitoring the motor current. The voltage across the sensing resistor is fed to the HCPL-788J input pins 2 and 3. The single-ended output allows it to interface directly with the A/D port of the micro-controller. The sensing resistor is available from several suppliers, which are listed in the “Inverter Design using Gate Drive and Current Sense Optocoupler” section.

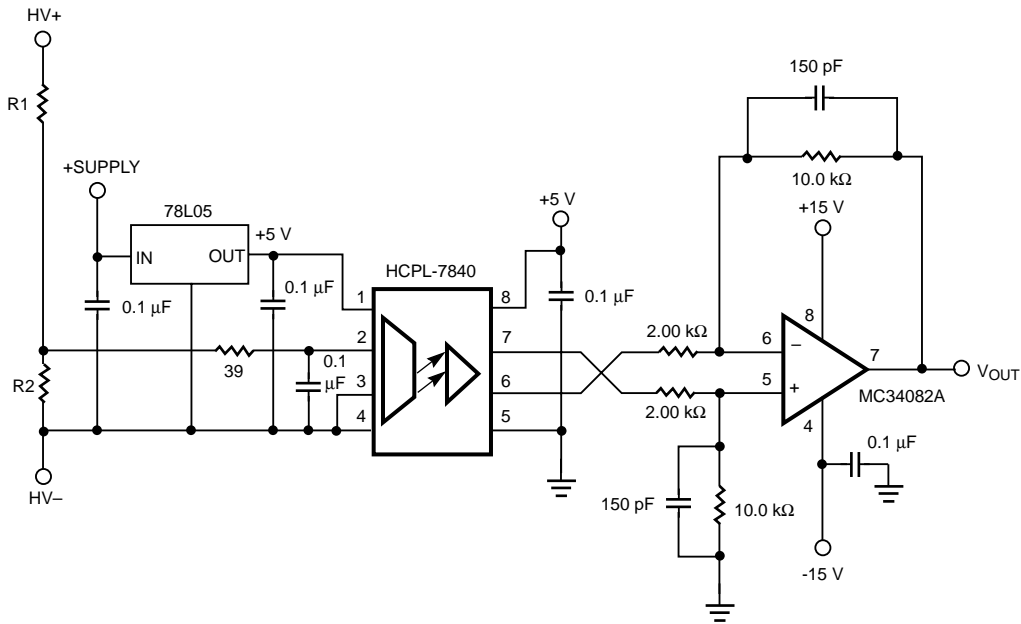
## Performance of Circuit

- Overcurrent fault response: 3  $\mu$ s typical
- Sense current up to 100 A or more
- Bandwidth: 30 kHz typical
- Nonlinearity: 0.06% typical
- Input offset voltage: 3 mV max. over temp.
- Common-mode rejection: 10 kV/ $\mu$ s@ $V_{CM} = 15$  kV min.

## Benefits

- No additional fault detection circuitry needed
- Direct interface with micro-controller
- Smaller size and lower profile compared to Hall-Effect device based current sensing circuits
- High precision measurement while at the same time maintaining transient immunity

# Isolated Inverter Rail Voltage Sensing using an Isolation Amplifier



## Description

The HCPL-7840 isolation amplifier can be used for sensing the rectified dc power supply voltage in a power inverter. An isolated 5 V power supply regulated to 5 V using a simple three-terminal voltage regulator powers the HCPL-7840 input circuit. The resistor divider network is used so that the full scale voltage at the HCPL-7840 input is 200 mV. The impedance of the resistor divider must be less than 1 kΩ so that the input resistance (500 kΩ) and input bias current (1 mA) of the isolation amplifier do not affect the accuracy of the measurement. To obtain higher bandwidths, the input bypass capacitor (across HCPL-7840's pins 2 and 3) can be reduced, but it should not be reduced much below 1000 pF to maintain gain accuracy of the isolation amplifier.

## Performance of Circuit

- 15 kV/μs transient rejection
- 0.05% nonlinearity
- 5% gain tolerance

## Benefits

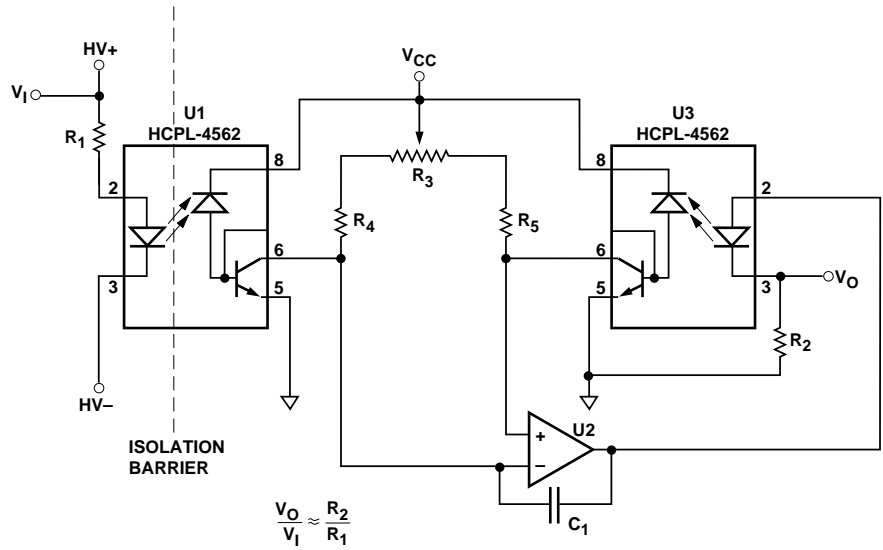
- Few components
- High electrical noise immunity

## HP Alternative Parts

## References

- 1) HCPL-7860/x870 Technical Data
- 2) High precision current sensing resistor suppliers: Dale in USA; Isabellenhutte in Germany; and PCN in Japan

# Isolated Inverter Rail Voltage Sensing using a Linear Optocoupler



### Description

The HCPL-4562 Linear Optocoupler is used in a servo circuit to sense the rectified dc power supply voltage of a power inverter. The series resistor  $R_1$  limits the current that drives the input LED of optocoupler U1. The forward current through the LED of the HCPL-4562 optocoupler is proportional to the dc high voltage power supply rail.

When the circuit is balanced with the potentiometer R3, the output voltage  $V_O$  is proportional to the high voltage dc power supply as shown by the equation:

$$V_O / V_I = R_2 / R_1$$

### Performance of Circuit

- 122 dB isolation mode rejection ratio
- 0.25% nonlinearity
- $\pm 0.3\%/^{\circ}\text{C}$  gain variation temperature coefficient

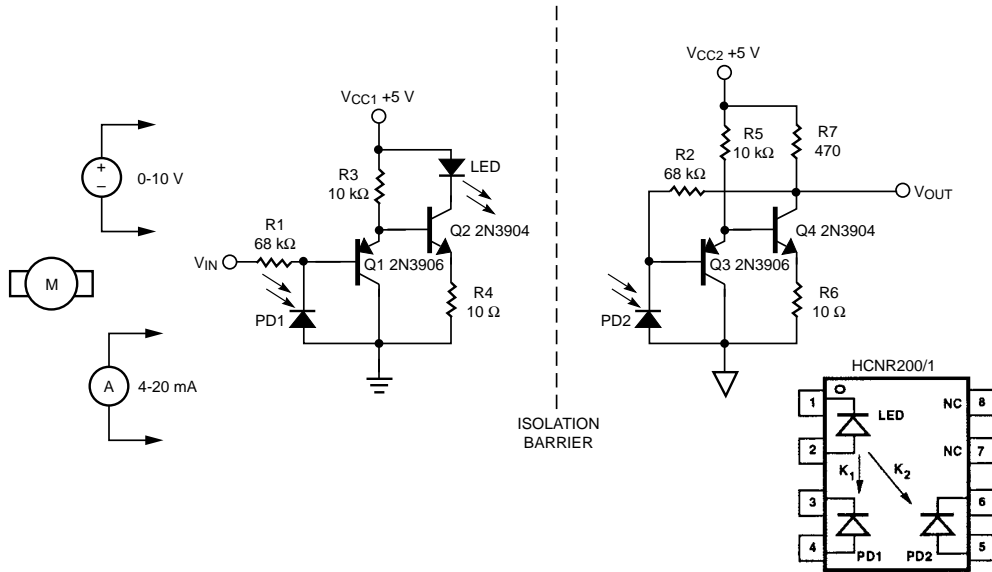
### Benefits

- No isolated 5 V input power supply is required for optocoupler U1
- Simple circuit

### Alternative HP Parts

- 1) HCPL-7800A: 1% part-to-part gain tolerance
- 2) HCPL-7800: 3% part-to-part gain tolerance

# Low Cost Isolation Amplifier for Motor Speed and Position Measurement



## Description

This is a high-speed, low-cost isolation amplifier that can be used for the measurement of motor speed and position. The analog signal coming from the motor is assumed to be 0 to 10 V, or 4 to 20 mA. This circuit can be used in applications where high bandwidth, low-cost, and stable gain are required, but where accuracy is not critical. This circuit is a good example of how a designer can trade off accuracy to achieve improvements in bandwidth and cost. The circuit has a bandwidth of about 1.5 MHz with stable gain characteristics and requires few external components. R1 is selected to achieve an LED current of about

7 - 10 mA at the nominal input operating voltage according to the following equation:

$$I_F = (V_{IN} / R_1) / K_1$$

where K1 (i.e.,  $I_{PD1} / I_F$ ) of the optocoupler is typically about 0.5%. R2 is then selected to achieve the desired output voltage according to the equation,  $V_{OUT} / V_{IN} = R_2 / R_1$ . The purpose of R4 and R6 is to improve the dynamic response (i.e., stability) of the input and output circuits by lowering the local loop gains. R3 and R5 are selected to provide enough current to drive the bases of Q2 and Q4. And R7 is selected so that Q4 operates at about the same collector current as Q2.

## Performance of Circuit

- 1.5 MHz bandwidth
- Stable gain
- Low-cost support circuit
- Circuit couples only positive voltage signals

## Benefits

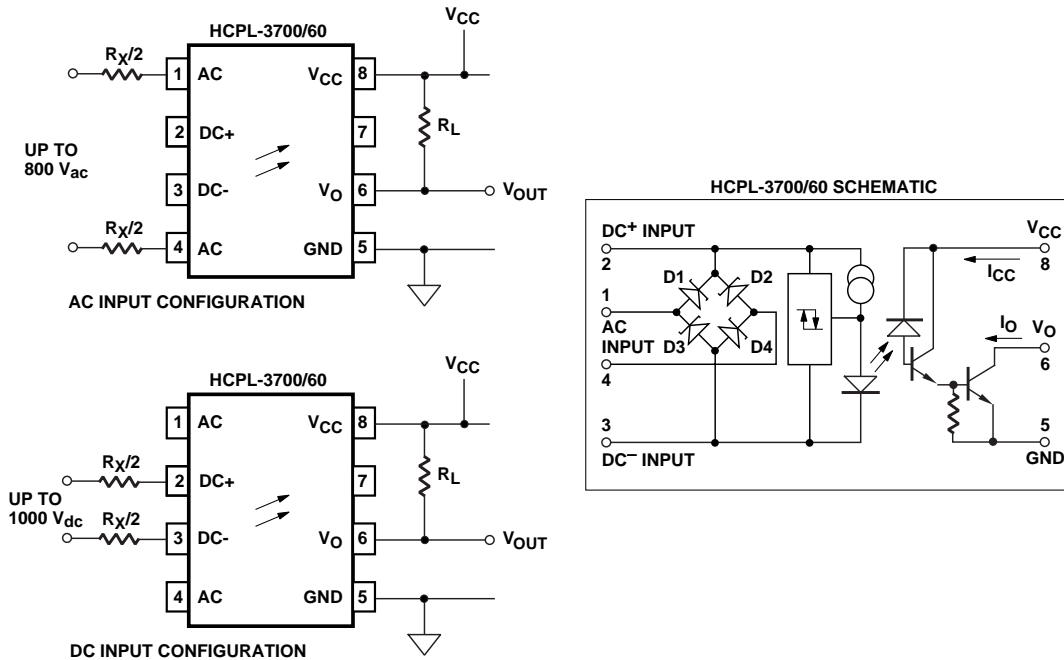
- Low cost solution for coupling positive voltage analog signals
- Simple way for isolating motor speed and position analog signals





# Industrial Applications

## AC/DC Voltage Threshold Sensing



### Description

The HCPL-3700/60 Threshold-Sensing Optocoupler can be used for sensing the ac/dc power on/off condition. At the optocoupler input, only a pair of series resistors  $R_X/2$  are required to limit the current. The ac signal can be filtered with a capacitor at either the input or the output of the optocoupler. For more information refer to HP Application Note AN 1004, "Threshold Sensing for Industrial Control Systems." The value of  $R_X$  determines the threshold sensing voltage.

### Performance of Circuit

- HCPL-3760 optocoupler threshold input current: 1.3 mA (typical)
- Typical optocoupler propagation delay: 10  $\mu$ s
- Optocoupler common mode transient immunity: 600 V/ $\mu$ s (typical)
- Maximum input voltage: up to 1000 Vdc, or 800 Vac

### Benefits

- HCPL 3700/60's built-in diode bridge and hysteresis circuit reduces component count
- HCPL-3760's low threshold sensing current reduces power dissipation
- Threshold voltage can be adjusted by external resistor  $R_X$

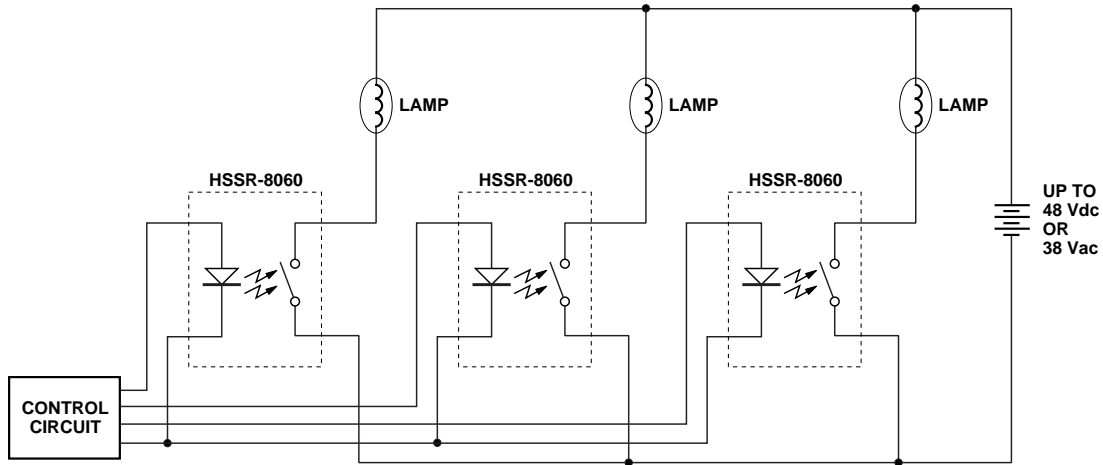
### References

- 1) HP Application Note AN 1004, "Threshold Sensing for Industrial Control Systems"
- 2) HCPL-3700/60 Threshold Sensing Optocoupler Technical Data

### Alternative HP Parts

HCPL-576X: Hermetically Sealed Threshold Sensing Optocoupler

## Low Power - AC/DC Industrial Switching



### Description

The HSSR-8060 Solid State Relay (SSR) can be used for switching low-voltage incandescent lamps in industrial equipment. This SSR can be controlled with TTL or CMOS 5V logic, and requires only 5 mA for turn-on. For dc switching, the HSSR-8060 output can pass up to 1.5 A steady-state current, and 7.0 A transient current.

### Performance of Solid State Relay

- Maximum output withstand voltage: 60 V peak, either polarity
- Typical output on-resistance: 0.4  $\Omega$  for ac connection; 0.1  $\Omega$  for dc connection (refer to HSSR-8060 Solid-State Relay Technical Data for an explanation of ac and dc connections.)
- Maximum output steady state current: 1.5 A for dc connection; 0.75 A for ac connection

### Benefits

- Greater reliability compared to electro-mechanical relays
- Compact size
- With a low input turn-on current of 5 mA and low output on-resistance there is less power dissipation

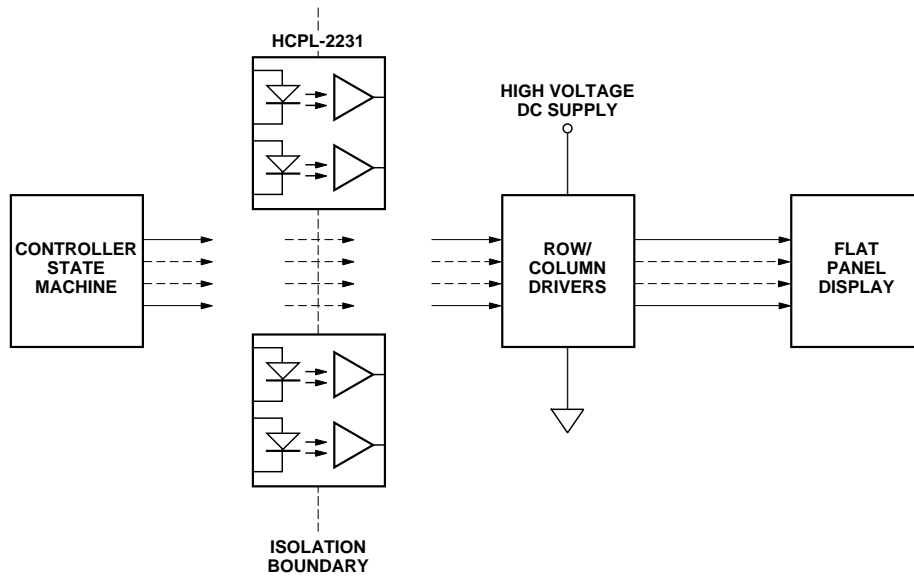
### References

- 1) HP Application Note, "Low On-Resistance Solid State Relays"
- 2) HSSR-8060 Solid-State Relay Technical Data

### Alternative HP Parts

- 1) HSSR-711X Hermetically Sealed Solid State Relay
- 2) HSSR-8400, 400 V Solid-State Relay

# Optical Isolation In Flat-Panel Displays



## Description

The HCPL-2231 dual-channel, high-speed, optocoupler isolates the low-voltage logic circuit from the high-voltage Flat-Panel Display row/column drivers. Examples of Flat-Panel Display technologies requiring such high voltage technologies are Electro-Luminescence, Fluorescence, and Plasma technologies. The optocoupler serves the functions of level shifting and safety isolation.

## Performance of Optocoupler

- Maximum propagation delay time: 300 ns
- Input turn-on current: 1.6 mA
- Common-mode transient rejection: 10,000 V/ $\mu$ s at 1000 V peak for the HCPL-2232

## Benefits of Optocoupler

- Compact size and easy interface compared to pulse transformers
- Low input current allowing CMOS interface
- Low component count (HCPL-2231/2 requires no pull-up resistor)

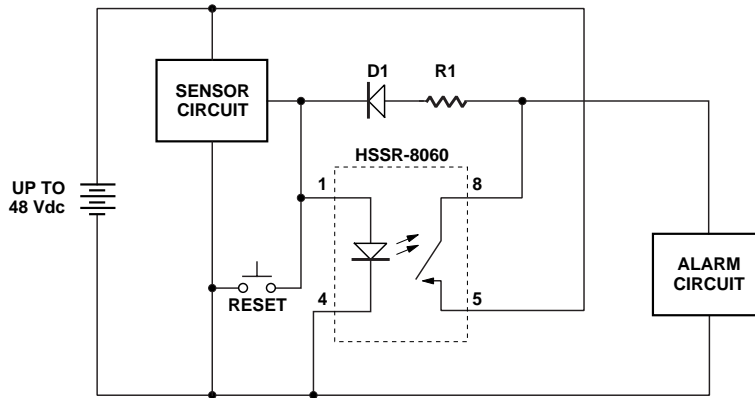
## References

HCPL-2231/2 Low Input Current Optocoupler Technical Data

## Alternative HP Parts

- 1) HCPL-0201/11 Small Outline Low Input Current Optocoupler
- 2) HCPL-52XX Hermetically Sealed Low Input Current Optocoupler
- 3) HCNW-2201/11 Widebody Low Input Current Optocoupler
- 4) HCPL-2430/1 20 MBd Logic-Gate Optocoupler

# Low Power Alarm Control Circuit



## Description

In battery-powered alarm systems, the alarm circuit needs to be disconnected from the battery when not in use. The HSSR-8060 Solid State Relay reconnects the alarm circuit to the battery only when the sensor circuit is energized.

## Performance of Solid State Relay

- Typical output on-resistance =  $0.4 \Omega$  for ac-connection;  $0.1 \Omega$  for dc-connection (refer to HSSR-8060 Solid-State Relay Technical Data for an explanation of ac and dc connections.)
- Maximum output steady-state current: 1.5 A for dc-connection; 0.75 A for ac-connection
- Maximum output withstand voltage: 60 V peak (either polarity for ac-connection)

## Benefits of Solid State Relay

- Greater reliability compared to electro-mechanical relays
- Compact size
- Less power dissipation (low input turn-on current, and low output on-resistance)

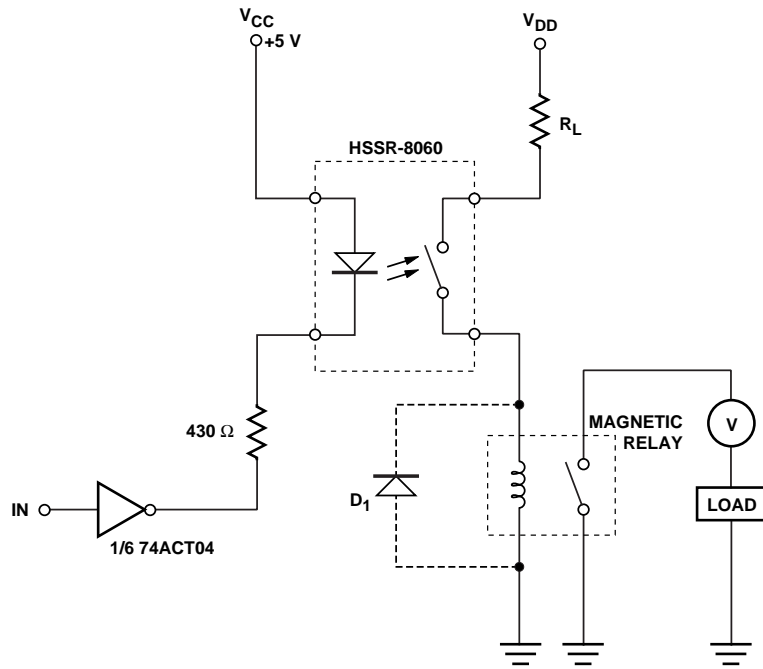
## References

- 1) HP Application Note 1046, "Low On-resistance Solid State Relays"
- 2) HSSR-8060 Solid State Relay Technical Data

## Alternative HP Parts

HSSR-8400, 400 V Solid State Relay

# Relay Coil Driver



## Description

The HSSR-8060 Solid State Relay (SSR) can be used for driving the coil of a large electro-mechanical relay. This SSR can be controlled with TTL or CMOS 5 V logic, and requires only 5 mA for turn-on. Diode  $D_1$  across the coil of the electro-magnetic relay protects the SSR output by limiting the back EMF of the coil during turn-off. The HSSR-8060 can switch up to 7.0 Amp transient current when the output is in the dc-connection.

## Performance of Solid State Relay

- Maximum output withstand voltage: 60 V peak (either polarity for ac-connection)
- Typical on-resistance = 0.1  $\Omega$  for dc-connection
- Maximum steady-state current: 1.5 A for dc-connection; 0.75 A for ac-connection (refer to HSSR-8060 Solid-State Relay Technical Data for an explanation of ac and dc connections.)

## Benefits of Solid State Relay

- Greater reliability compared to electro-mechanical relays
- Compact size
- Less power dissipation (low input turn-on current, and low output on-resistance)

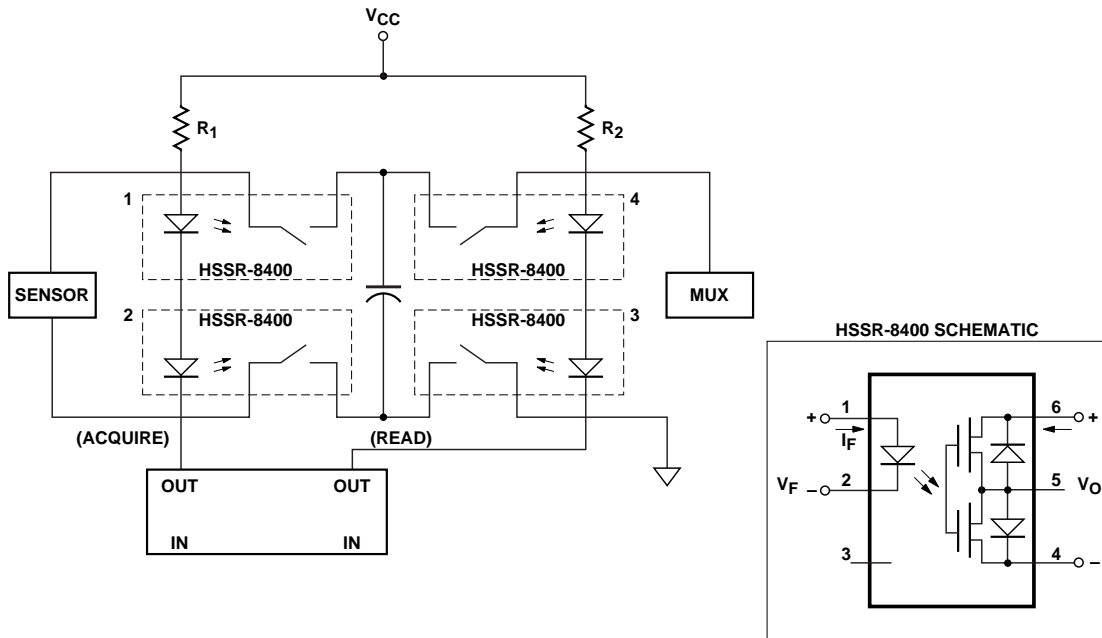
## References

- 1) HP Application Note 1047 and 1046, "Low on-resistance Solid State Relays"
- 2) HSSR-8060 Solid State Relay Technical Data

## Alternative HP Parts

- 1) HSSR-711X Hermetically Sealed Solid State Relay
- 2) HSSR-8400, 400 V Solid State Relay

# Voltage Signal Sensing - Flying Capacitor Technique



## Description

The HSSR-8400 optically-coupled, solid-state relay (SSR) can be used for measuring voltages on industrial sensors such as thermocouples. When SSRs 1 and 2 are closed, the voltage is acquired from the sensor and stored across the capacitor. After SSRs 1 and 2 open and SSRs 3 and 4 close, the voltage across the capacitor is read by the multiplexer.

## Performance of Solid State Relay

- Output withstand voltage: 400 V
- Typical output leakage current: 0.6 nA at  $V_O = 400\text{ V}$
- Typical SSR switching time: turn-on time =  $0.5\ \mu\text{s}$ ; turn-off time =  $0.013\ \mu\text{s}$

## Benefits of Solid State Relay

- Greater reliability compared to electro-mechanical relays
- Compact size
- Lower power dissipation

## References

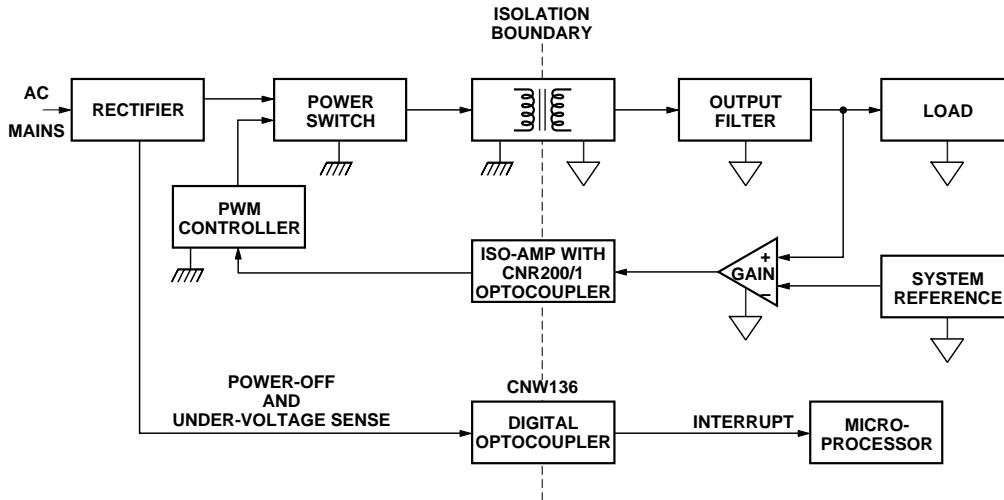
HSSR-8400 Solid State Relay Technical Data

## Alternative HP Parts

HSSR-8060, 60 V Solid State Relay

# Power Supply Applications

## Optical Isolation In A Switching Power Supply - Circuit No. 1



### Description

Switching power supplies often need to couple digital and analog signals between the primary and secondary circuits. The above schematic shows an analog error signal representing the difference between the output voltage and the reference voltage being fed back to the primary side using a HCNR200/1 Analog Optocoupler. The analog error signal helps the pulse-width modulation (PWM) controller determine the exact pulse-width to make the filtered output voltage match the system reference voltage. In a similar manner, the HCNW136 Digital Optocoupler can be used to monitor the primary side power-off and under-voltage condition.

### Performance of Optocoupler

- HCNR200/1 has 0.01% non-linearity and up to 1 MHz bandwidth
- HCNW135 has 0.2  $\mu$ s typical propagation delay time
- Both HCNR200/1 and HCNW136 optocouplers meet worldwide regulatory insulation guidelines

### Benefits

- Accurate monitoring and control of secondary output voltage
- Power off condition detectable at an early stage enabling the microprocessor to save critical information

### References

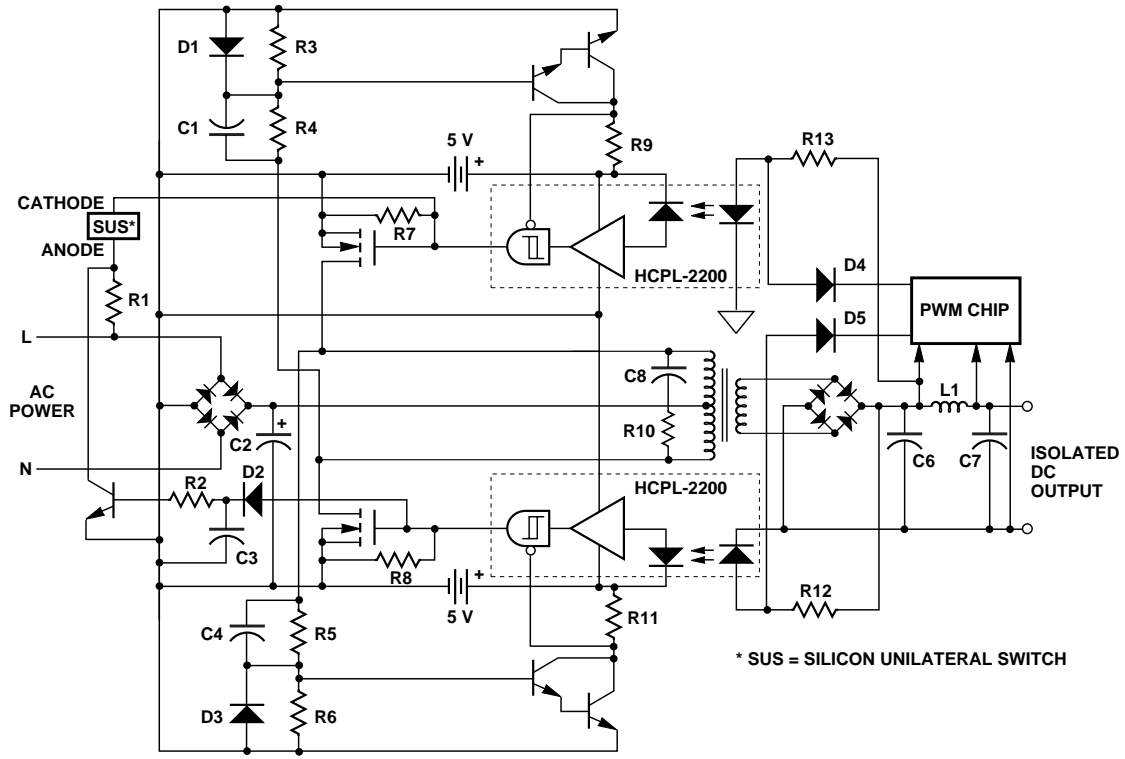
- 1) HCNR200/1 Analog Optocoupler Technical Data
- 2) HCNW136 High Speed Optocoupler Technical Data

### Alternative HP Parts

- 1) HCPL-7800 Isolation Amplifier
- 2) HCPL-4503, HCNW4503 High CMR Digital Optocoupler
- 3) HCNW2601/11 Widebody, High Speed Digital Optocoupler



# Optical Isolation In A Switching Power Supply - Circuit No. 2



## Description

The above figure shows a push-pull switching power supply that utilizes the HCPL-2200 optocoupler to drive switching transistors. The above circuit uses a silicon unilateral switch (SUS) to bootstrap start the power supply when power is first applied. The inhibit function in the HCPL-2200 optocoupler has been used to good advantage to provide a common-mode conduction interlock function that will not allow both the switching transistors to turn on at the same time.

## Performance of Optocoupler

- Maximum propagation delay: 300 ns
- Input turn-on current: 1.6 mA
- Common-mode transient rejection: 1000 V/ $\mu$ s

## Benefits

- The power switches are protected from common-mode conduction failures caused by EMI
- Regulation range is increased since no deadtime is required
- Design is tolerant to propagation delay changes due to lot-to-lot component variations

## References

HCPL-2200 High CMR Optocoupler Technical Data

## Alternative HP Parts

- 1) HCPL-2219 Very High CMR Optocoupler
- 2) HCNW2601/11 Widebody High CMR Optocoupler

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# Application Notes and Technical Articles

The following application notes and technical articles are available on HP's web site at

**[http://www.hp.com/HP-COMP/isolator/app\\_index.html](http://www.hp.com/HP-COMP/isolator/app_index.html)**

They can also be obtained from your local Hewlett-Packard sales office or authorized HP distributor.

## Application Notes

- AN 1023 (Pub. 3/85)  
**Radiation Immunity of Hewlett-Packard Optocouplers**
- AN 1024 (Pub. 3/85)  
**Ring Detection with the HCPL-3700 Optocouplers**
- AN 1036 (Pub. 11/96)  
**Small Signal Solid State Relays**
- AN 1043 (Pub. 2/97)  
**Common-Mode Noise: Sources and Solutions**
- AN 1046 (Pub. 11/96)  
**Low On-Resistance Solid State Relays**
- AN 1047 (Pub. 5/92)  
**Low On-Resistance Solid-State Relays for High-Reliability Applications**
- AN 1059 (Pub. 2/93)  
**High CMR Isolation Amplifier for Current Sensing Applications**
- AN 1063 (Pub. 7/93)  
**A Designer's Guide to HCPL-7600 Series, Low Input-Current, High Speed Optocouplers**
- AN 1074 (Pub. 11/96)  
**Optocoupler Input-Output Endurance Voltage**
- AN 1078 (Pub. 11/96)  
**Designing with Hewlett-Packard Isolation Amplifiers**
- AN 1087 (Pub. 11/96)  
**Thermal Data for Optocouplers**

## Technical Articles

1. AN SO-16:  
**Isolated IGBT Gate Driver with Integrated Desaturation Protection and Fault Feedback**
2. **Motor Drive and Inverter Design Using Optocouplers**
3. **An Isolated A/D Converter for Drive Systems**
4. **Optocouplers in Motor Drives and Inverters**
5. **A Smart Current Sensor for Low Cost Inverters**