SIEMENS

IL300
LINEAR OPTOCOUPLER

FEATURES
- Couples AC and DC signals
- 0.01% Servo Linearity
- Wide Bandwidth, >200 KHz
- High Gain Stability, $\pm 0.005\%/C$
- Low Input-Output Capacitance
- Low Power Consumption, < 15mw
- Isolation Test Voltage, 5300 VAC_{RMS}, 1 sec.
- Internal Insulation Distance, >0.4 mm
  for VDE
- Underwriters Lab File #E52744
- VDE Approval #0884 (Optional with Option 1, Add -X001 Suffix)
- IL300G Replaced by IL300-X006

APPLICATIONS
- Power Supply Feedback Voltage/ Current
- Medical Sensor Isolation
- Audio Signal Interfacing
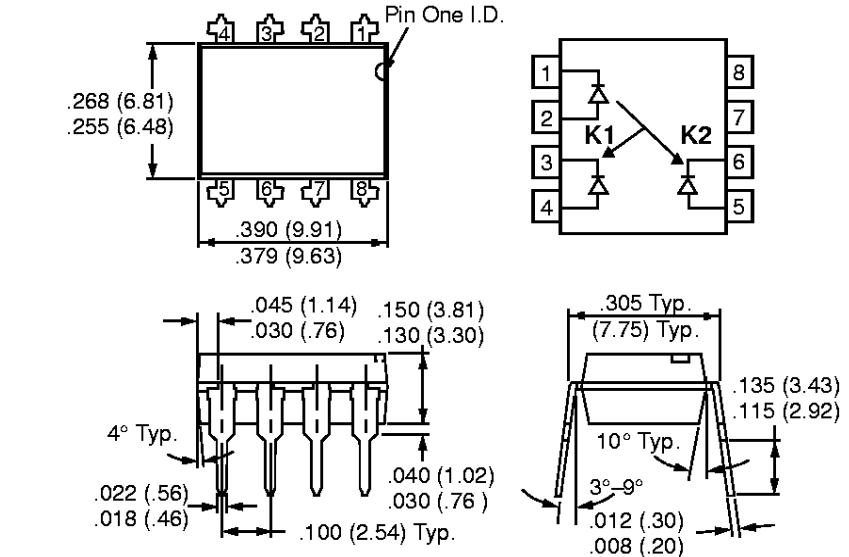- Isolate Process Control Transducers
- Digital Telephone Isolation

DESCRIPTION

The IL300 Linear Optocoupler consists of an AlGaAs IRLED irradiating an isolated feedback and an output PIN photodiode in a bifurcated arrangement. The feedback photodiode captures a percentage of the LED's flux and generates a control signal (IP_1) that can be used to servo the LED drive current. This technique compensates for the LED's non-linear, time, and temperature characteristics. The output PIN photodiode produces an output signal (IP_2) that is linearly related to the servo optical flux created by the LED.

The time and temperature stability of the input-output coupler gain (K3) is insured by using matched PIN photodiodes that accurately track the output flux of the LED.

A typical application circuit (Figure 1) uses an operational amplifier at the circuit input to drive the LED. The feedback photodiode sources current to R1 connected to the inverting input of U1. The photocurrent, IP1, will be of a magnitude to satisfy the relationship of ($IP1=V_{IN}/R1$).
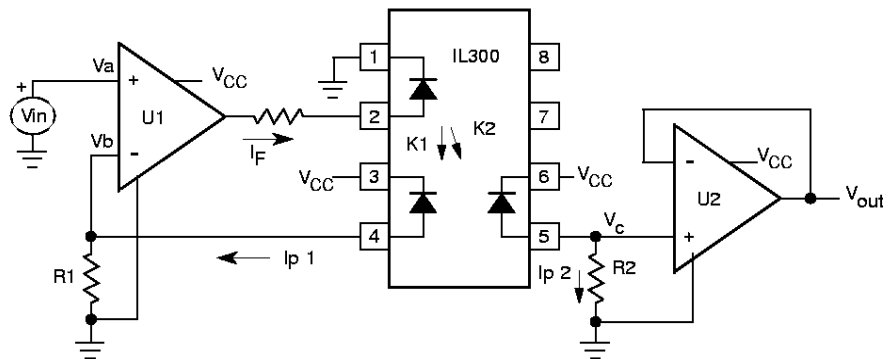

Dimensions in inches (mm)

DESCRIPTION (continued)

The magnitude of this current is directly proportional to the feedback transfer gain (K1) times the LED drive current ($V_{IN}/R1=K1 \cdot I_F$). The op-amp will supply LED current to force sufficient photocurrent to keep the node voltage (Vb) equal to Va

The output photodiode is connected to a non-inverting voltage follower amplifier. The photodiode load resistor, R2, performs the current to voltage conversion. The output amplifier voltage is the product of the output forward gain (K2) times the LED current and photodiode load, R2 ($V_O=I_F \cdot K2 \cdot R2$).

Therefore, the overall transfer gain (V_O/V_{IN}) becomes the ratio of the product of the output forward gain (K2) times the photodiode load resistor (R2) to the product of the feedback transfer gain (K1) times the input resistor (R1). This reduces to $V_O/V_{IN}= (K2 \cdot R2)/(K1 \cdot R1)$. The overall transfer gain is completely independent of the LED forward current. The IL300 transfer gain (K3) is expressed as the ratio of the ouput gain (K2) to the feedback gain (K1). This shows that the circuit gain becomes the product of the IL300 transfer gain times the ratio of the output to input resistors [$V_O/V_{IN}=K3 (R2/R1)$].

Figure 1. Typical application circuit

IL300 Terms

KI—Servo Gain

The ratio of the input photodiode current (I_{P1}) to the LED current(I_F). i.e., $K1 = I_{P1}/I_F$

K2—Forward Gain

The ratio of the output photodiode current (I_{P2}) to the LED current (I_F), i.e., $K2 = I_{P2}/I_F$

K3—Transfer Gain

The Transfer Gain is the ratio of the Forward Gain to the Servo gain, i.e., $K3 = K2/K1$.

∆K3—Transfer Gain Linearity

The percent deviation of the Transfer Gain, as a function of LED or temperature from a specific Transfer Gain at a fixed LED current and temperature.

Photodiode

A silicon diode operating as a current source. The output current is proportional to the incident optical flux supplied by the LED emitter. The diode is operated in the photovoltaic or photoconductive mode. In the photovoltaic mode the diode functions as a current source in parallel with a forward biased silicon diode.

The magnitude of the output current and voltage is dependant upon the load resistor and the incident LED optical flux. When operated in the photoconductive mode the diode is connected to a bias supply which reverse biases the silicon diode. The magnitude of the output current is directly proportional to the LED incident optical flux.

LED (Light Emitting Diode)

An infrared emitter constructed of AlGaAs that emits at 890 nm operates efficiently with drive current from 500 µA to 40 mA. Best linearity can be obtained at drive currents between 5 mA to 20 mA. Its output flux typically changes by –0.5%/°C over the above operational current range.

Absolute Maximum Ratings

	Symbol	Min.	Max.	Unit
Emitter				
Power Dissipation (T_A=25°C)	P_{LED}		160	mW
Derate Linearly from 25°C			2.13	mW/°C
Forward Current	If		60	mA
Surge Current (Pulse width <10µs)	Ipk		250	mA
Reverse Voltage	V_R		5	V
Thermal Resistance	Rth		470	°C/W
Junction Temperature	T_J		100	°C
Detector				
Power Dissipation	P_{DET}		50	mA
Derate linearly from 25°C			0.65	mW/°C
Reverse Voltage	V_R		50	V
Junction Temperature	T_J		100	°C
Thermal Resistance	Rth		1500	°C/W
Coupler				
Total Package Dissipation at 25°C	P_T		210	mW
Derate linearly from 25°C			2.8	mW/°C
Storage Temperature	T_S	–55	150	°C
Operating Temperature	T_{OP}	–55	100	°C
Isolation Test Voltage		5300		VAC$_{RMS}$
Isolation Resistance V_{IO}=500 V, T_A=25°C V_{IO}=500 V, T_A=100°C		10^{12} 10^{11}		Ω Ω

Characteristics (T_A=25°C)

	Symbol	Min.	Typ.	Max.	Unit	Test Condition
LED Emitter						
Forward Voltage	V_F		1.25	1.50	V	I_F=10 mA
V_F Temperature Coefficient	$\Delta V_F/\Delta°C$		-2.2		mV/°C	
Reverse Current	I_R		1	10	μA	V_R=5 V
Junction Capacitance	C_J		15		pF	V_F=0 V, f=1 MHz
Dynamic Resistance	$\Delta V_F/\Delta I_F$		6		Ω	I_F=10 mA
Switching Time	t_R t_F		1 1		μs μs	ΔI_F=2 mA, I_{Fq}=10 mA ΔI_F=2 mA, I_{Fq}=10 mA
Detector						
Dark Current	I_D		1	25	nA	V_{det}=-15 V, I_F=0 μA
Open Circuit Voltage	V_D		500		mV	I_F=10 mA
Short Circuit Current	I_{SC}		70		μA	I_F=10 mA
Junction Capacitance	C_J		12		pF	V_F=0 V, f=1 MHz
Noise Equivalent Power	NEP		4×10^{14}		W/√Hz	V_{det}=15 V
Coupled Characteristics						
K1, Servo Gain (I_{P1}/I_F)	K1	0.0050	0.007	0.011		I_F=10 mA, V_{det}=-15 V
Servo Current, see Note 1, 2	I_{P1}		70		μA	I_F=10 mA, V_{det}=-15 V
K2, Forward Gain (I_{P2}/I_F)	K2	0.0036	0.007	0.011		I_F=10 mA, V_{det}=-15 V
Forward Current	I_{P2}		70		μA	I_F=10 mA, V_{det}=-15 V
K3, Transfer Gain (K2/K1) See Note 1, 2	K3	0.56	1.00	1.65	K2/K1	I_F=10 mA, V_{det}=-15 V
Transfer Gain Linearity	$\Delta K3$		±0.25		%	I_F=1 to 10 mA
Transfer Gain Linearity	$\Delta K3$		±0.5		%	I_F=1 to 10 mA, T_A=0°C to 75°C
Photoconductive Operation						
Frequency Response	BW (-3 db)		200		KHz	I_{Fq}=10 mA, MOD=±4 mA, R_L=50 Ω,
Phase Response at 200 KHz			-45		Deg.	V_{det}=-15 V
Rise Time	t_R		1.75		μs	
Fall Time	t_F		1.75		μs	
Package						
Input-Output Capacitance	C_{IO}		1		pF	V_F=0 V, f=1 MHz
Common Mode Capacitance	C_{cm}		0.5		pF	V_F=0 V, f=1 MHz
Common Mode Rejection Ratio	CMRR		130		dB	f=60 Hz, R_L=2.2 KΩ

Notes

1. Bin Sorting:

   K3 (transfer gain) is sorted into bins that are ±5%, as follows:

   Bin A=0.557–0.626
   Bin B=0.620–0.696
   Bin C=0.690–0.773
   Bin D=0.765–0.859
   Bin E=0.851–0.955
   Bin F=0.945–1.061
   Bin G=1.051–1.181
   Bin H=1.169–1.311
   Bin I=1.297–1.456
   Bin J=1.442–1.618

   K3=K2/K1. K3 is tested at I_F=10 mA, V_{det}=–15 V.

2. Bin Categories: All IL300s are sorted into a K3 bin, indicated by an alpha character that is marked on the part. The bins range from "A" through "J".

   The IL300 is shipped in tubes of 50 each. Each tube contains only one category of K3. The category of the parts in the tube is marked on the tube label as well as on each individual part.

3. Category Options: Standard IL300 orders will be shipped from the categories that are available at the time of the order. Any of the ten categories may be shipped. For customers requiring a narrower selection of bins, four different bin option parts are offered.

   IL300-DEFG: Order this part number to receive categories D,E,F,G only.

   IL300-EF: Order this part number to receive categories E, F only.

   IL300-E: Order this part number to receive category E only.

   IL300-F: Order this part number to receive category F only

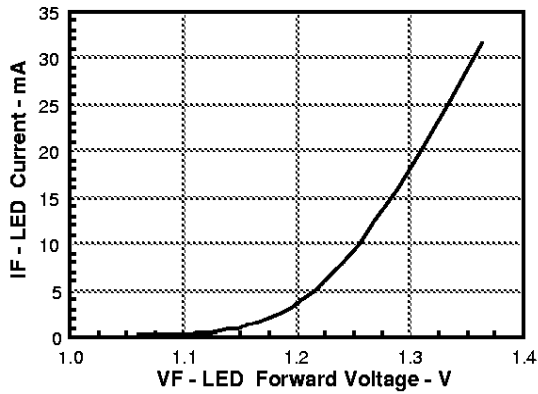Figure 2. LED forward current vs. forward voltage

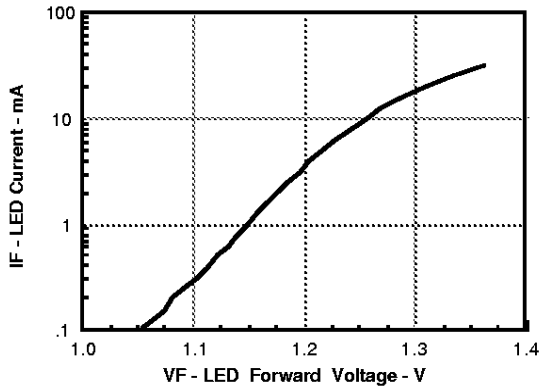Figure 3. LED forward current vs. forward voltage

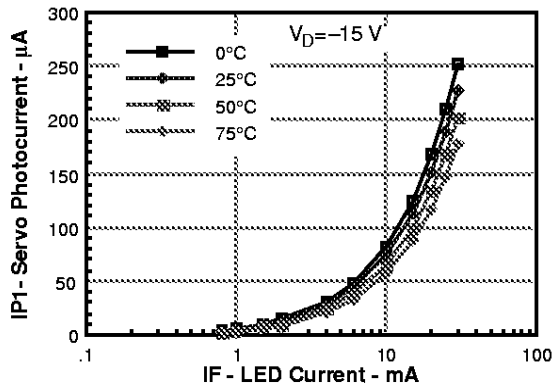Figure 4. Servo photocurrent vs. LED current and temperature

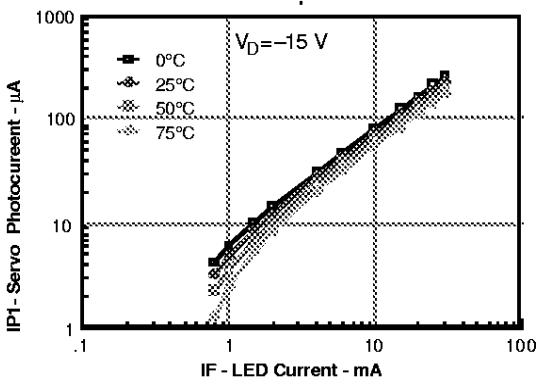Figure 5. Servo photocurrent vs. LED current and temperatureFigure

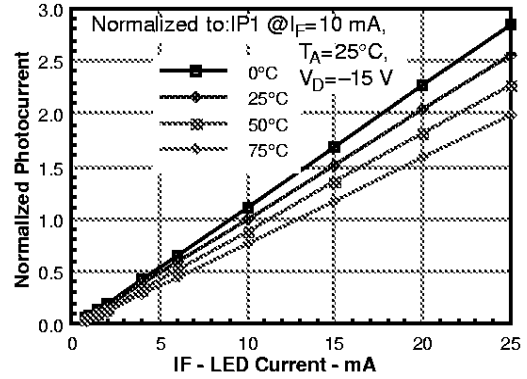Figure 6. Normalized servo photocurrent vs. LED current and temperature

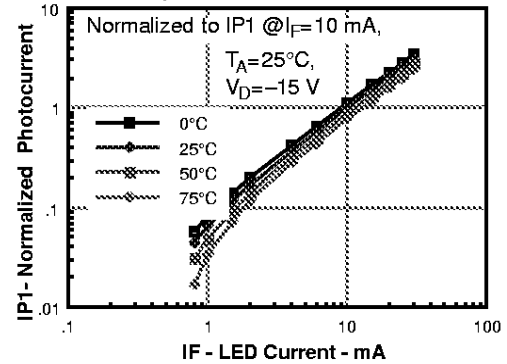Figure 7. Normalized servo photocurrent vs. LED current and temperature

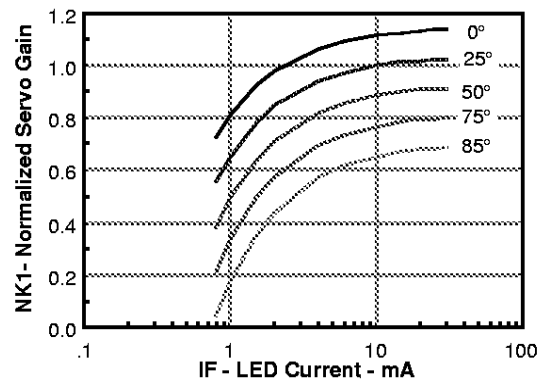Figure 8. Servo gain vs. LED current and temperature
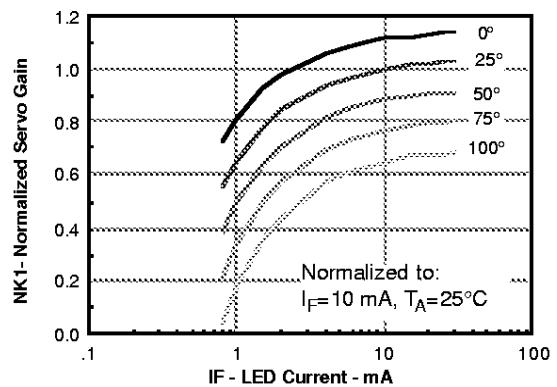

Figure 9. Normalized servo gain vs. LED current and temperature

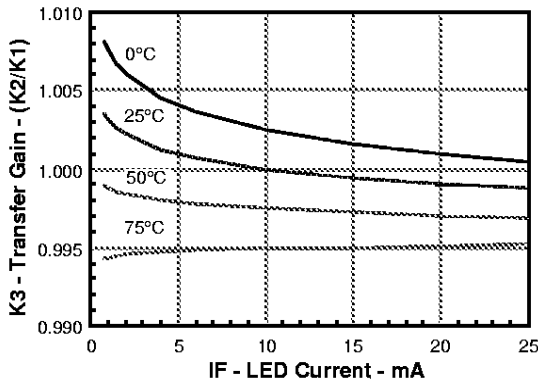## Figure 10. Transfer gain vs. LED current and temperature

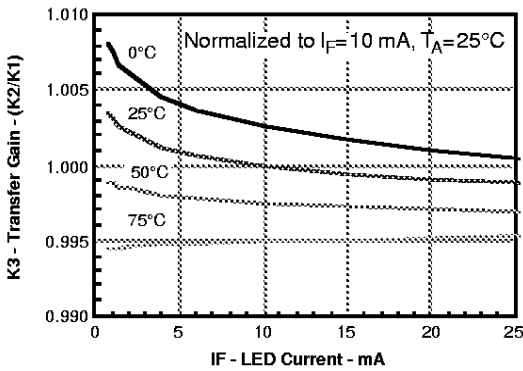## Figure 11. Normalized transfer gain vs. LED current and temperature

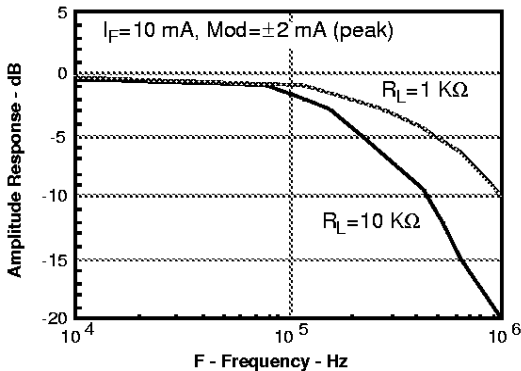## Figure 12. Amplitude response vs. frequency

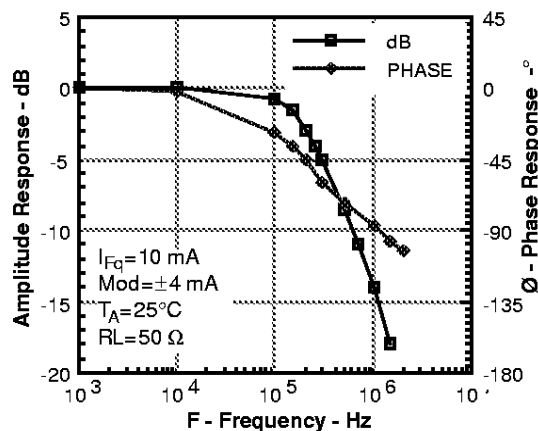## Figure 13. Amplitude and phase response vs. frequency

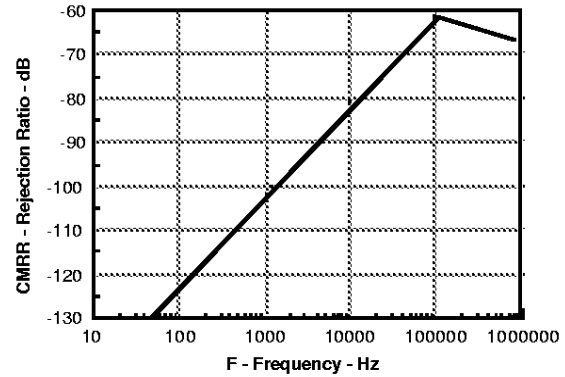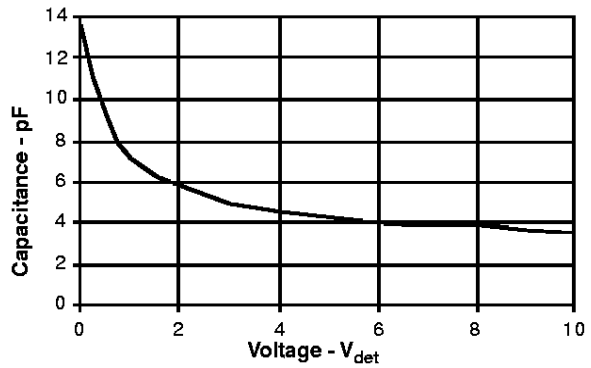## Figure 14. Common mode rejection

Figure 15. Photodiode junction capacitance vs. reverse voltage

Application Considerations

In applications such as monitoring the output voltage from a line powered switch mode power supply, measuring bioelectric signals, interfacing to industrial transducers, or making floating current measurements, a galvanically isolated, DC coupled interface is often essential. The IL300 can be used to construct an amplifier that will meet these needs.

The IL300 eliminates the problems of gain nonlinearity and drift induced by time and temperature, by monitoring LED output flux.

A PIN photodiode on the input side is optically coupled to the LED and produces a current directly proportional to flux falling on it . This photocurrent, when coupled to an amplifier, provides the servo signal that controls the LED drive current.

The LED flux is also coupled to an output PIN photodiode. The output photodiode current can be directly or amplified to satisfy the needs of succeeding circuits.

Isolated Feedback Amplifier

The IL300 was designed to be the central element of DC coupled isolation amplifiers. Designing the IL300 into an amplifier that provides a feedback control signal for a line powered switch mode power is quite simple, as the following example will illustrate.

See Figure 17 for the basic structure of the switch mode supply using the Siemens TDA4918 Push-Pull Switched Power Supply Control Chip. Line isolation and insulation is provided by the high frequency transformer. The voltage monitor isolation will be provided by the IL300.

The isolated amplifier provides the PWM control signal which is derived from the output supply voltage. Figure 16 more closely shows the basic function of the amplifier.
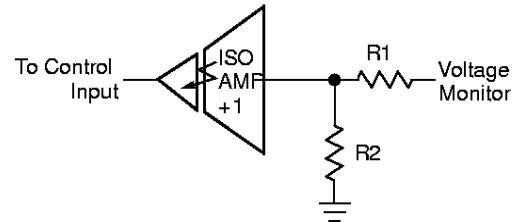
The control amplifier consists of a voltage divider and a non-inverting unity gain stage. The TDA4918 data sheet indicates that an input to the control amplifier is a high quality operational amplifier that typically requires a +3V signal. Given this information, the amplifier circuit topology shown in Figure 18 is selected.

The power supply voltage is scaled by R1 and R2 so that there is +3 V at the non-inverting input (Va) of U1. This voltage is offset by the voltage developed by photocurrent flowing through R3. This photocurrent is developed by the optical flux created by current flowing through the LED. Thus as the scaled monitor voltage (Va) varies it will cause a change in the LED current necessary to satisfy the differential voltage needed across R3 at the inverting input.

The first step in the design procedure is to select the value of R3 given the LED quiescent current (I_{Fq}) and the servo gain (K1). For this design, I_{Fq}=12 mA. Figure 4 shows the servo photocurrent at I_{Fq} is found to be 100 µA. With this data R3 can be calculated.

$$R3 = \frac{V_b}{I_{PI}} = \frac{3V}{100\mu A} = 30K\Omega$$

Figure 16. Isolated control amplifier

For best input offset compensation at U1, R2 will equal R3. The value of R1 can easily be calculated from the following.

$$R1 = R2\left(\frac{V_{MONITOR}}{V_a} - 1\right)$$

$$20K\Omega = 30K\Omega\left(\frac{5V}{3V} - 1\right)$$

The value of R5 depends upon the IL300 Transfer Gain (K3). K3 is targeted to be a unit gain device, however to minimize the part to part Transfer Gain variation, Siemens offers K3 graded into ±5 % bins. R5 can determined using the following equation,

$$R5 = \frac{V_{OUT}}{V_{MONITOR}} \cdot \frac{R3(R1 + R2)}{R2K3}$$

Or if a unity gain amplifer is being designed (V*MONITOR*=V*OUT*, R1=0), the euation simplifies to:

$$R5 = \frac{R3}{K3}$$

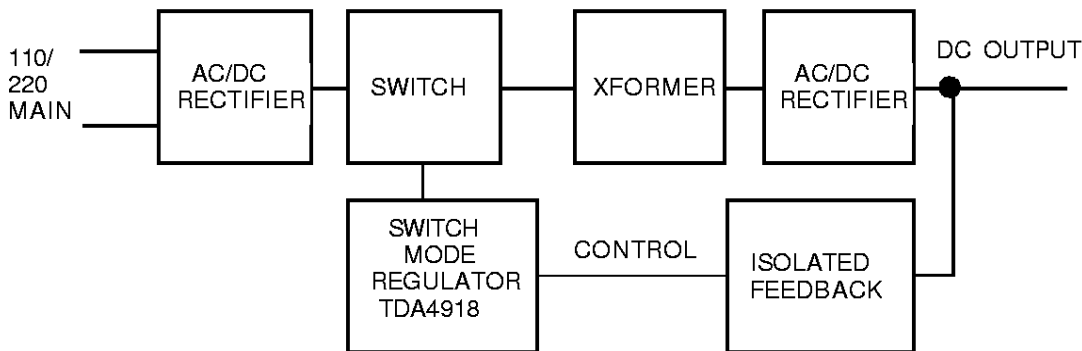## Figure 17. Switch mode power supply

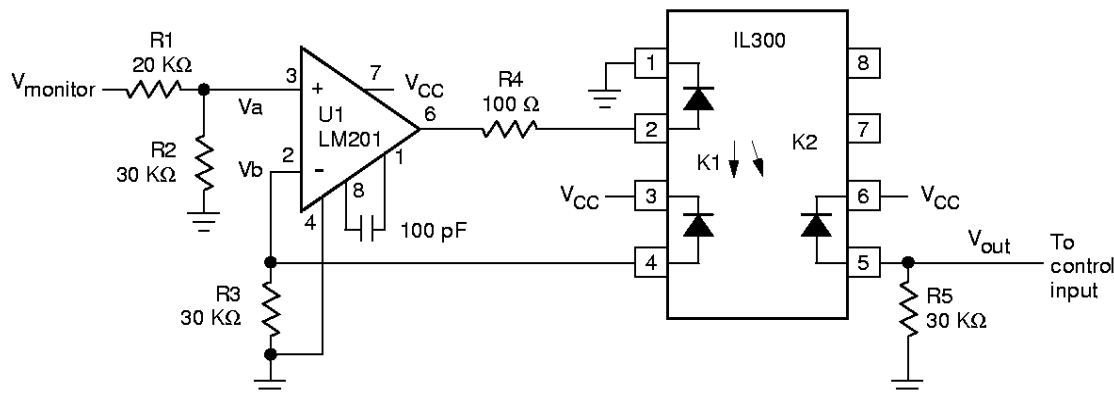## Figure 18. DC coupled power supply feedback amplifier

Table 1 gives the value of R5 given the production K3 bins.

Table 1. R5 selection

Bins	Min.	Max.	K3 Typ.	R5 Resistor KΩ	1% KΩ
A	0.560	0.623	0.59	50.85	51.1
B	0.623	0.693	0.66	45.45	45.3
C	0.693	0.769	0.73	41.1	41.2
D	0.769	0.855	0.81	37.04	37.4
E	0.855	0.950	0.93	32.26	32.4
F	0.950	1.056	1.00	30.00	30.0
G	1.056	1.175	1.11	27.03	27.0
H	1.175	1.304	1.24	24.19	24.0
I	1.304	1.449	1.37	21.90	22.0
J	1.449	1.610	1.53	19.61	19.4

The last step in the design is selecting the LED current limiting resistor (R4). The output of the operational amplifier is targeted to be 50% of the Vcc, or 2.5 V. With an LED quiescent current of 12 mA the typical LED (V_F) is 1.3 V. Given this and the operational output voltage, R4 can be calculated.

$$R4 = \frac{V_{opamp} - V_F}{I_{Fq}} = \frac{2.5V - 1.3V}{12mA} = 100\Omega$$

The circuit was constructed with an LM201 differential operational amplifier using the resistors selected. The amplifier was compensated with a 100 pF capacitor connected between pins 1 and 8.

The DC transfer charateristics are shown in Figure 19. The amplifier was designed to have a gain of 0.6 and was measured to be 0.6036. Greater accurracy can be achieved by adding a balancing circuit, and potentiometer in the input divider, or at R5. The circuit shows exceptionally good gain linearity with an RMS error of only 0.0133% over the input voltage range of 4 V–6 V in a servo mode; see Figure 20.

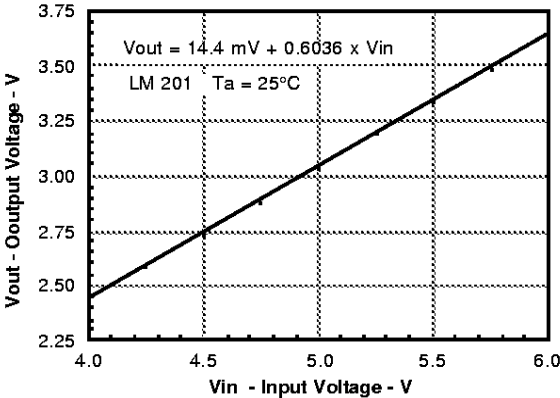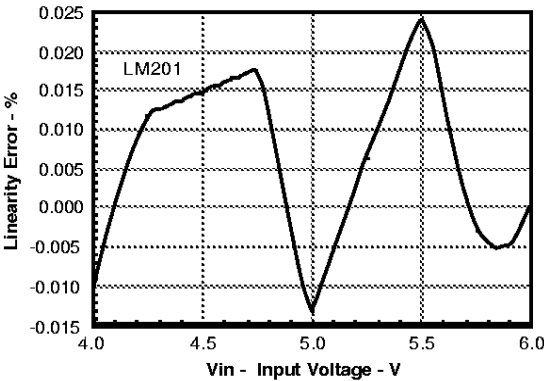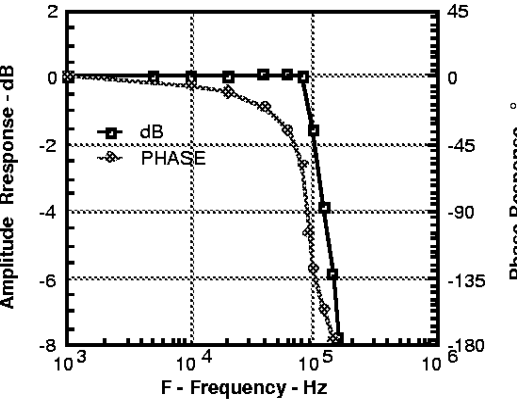**Figure 19. Transfer gain**

Figure 20. Linearity error vs. input voltage

The AC characteristics are also quite impressive offering a -3 dB bandwidth of 100 KHz, with a -45° phase shift at 80 KHz as shown in Figure 21.

Figure 21. Amplitude and phase power supply control

The same procedure can be used to design isolation amplifiers that accept biploar signals referenced to ground. These amplifiers circuit configurations are shown in Figure 22. In order for the amplifier to respond to a signal that swings above and below ground, the LED must be prebiased from a separate source by using a voltage reference source (Vref1). In these designs, R3 can be determined by the following equation.

$$R3 = \frac{V_{ref1}}{I_{P1}} = \frac{V_{ref1}}{K1 I_{Fq}}$$
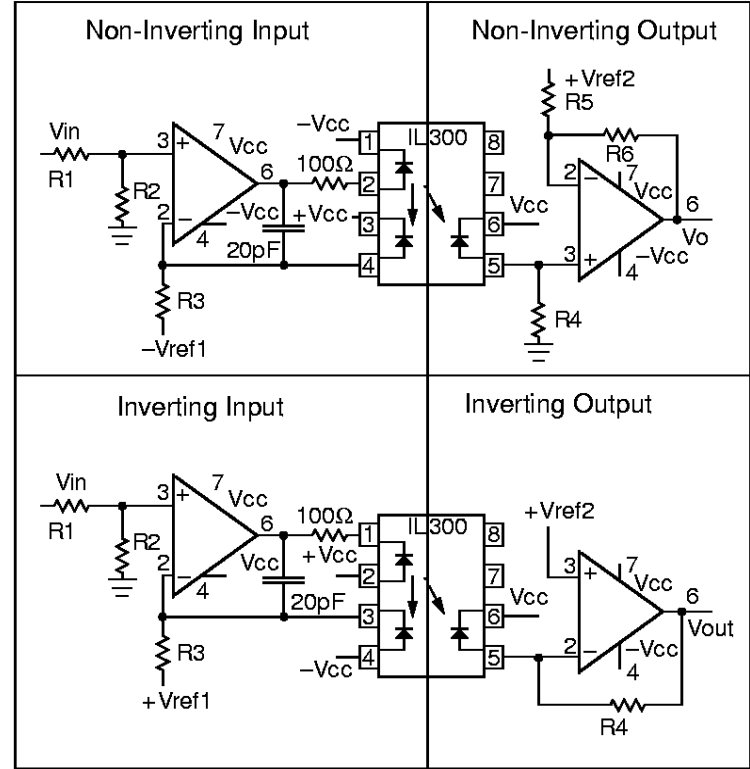
Figure 22. Non-inverting and inverting amplifiers

Table 2. Optolinear amplifiers

Amp[ifier	Input	Output	Gain	Offset
Non-Inverting	Inverting	Inverting	$\dfrac{V_{OUT}}{V_{IN}} = \dfrac{K3\ R4\ R2}{R3\ (R1+R2)}$	$V_{ref2} = \dfrac{V_{ref1}\ R4\ K3}{R3}$
	Non-Inverting	Non-Inverting	$\dfrac{V_{OUT}}{V_{IN}} = \dfrac{K3\ R4\ R2\ (R5+R6)}{R3\ R5\ (R1+R2)}$	$V_{ref2} = \dfrac{-V_{ref1}\ R4\ (R5+R6)\ K3}{R3\ R6}$
Inverting	Inverting	Non-Inverting	$\dfrac{V_{OUT}}{V_{IN}} = \dfrac{-K3\ R4\ R2\ (R5+R6)}{R3\ R5\ (R1+R2)}$	$V_{ref2} = \dfrac{V_{ref1}\ R4\ (R5+R6)\ K3}{R3\ R6}$
	Non-Inverting	Inverting	$\dfrac{V_{OUT}}{V_{IN}} = \dfrac{-K3\ R4\ R2}{R3\ (R1+R2)}$	$V_{ref2} = \dfrac{-V_{ref1}\ R4\ K3}{R3}$

These amplifiers provide either an inverting or non-inverting transfer gain based upon the type of input and output amplifier. Table 2 shows the various configurations along with the specific transfer gain equations. The offset column refers to the calculation of the output offset or Vref2 necessary to provide a zero voltage output for a zero voltage input. The non-inverting input amplifier requires the use of a bipolar supply, while the inverting input stage can be implemented with single supply operational amplifiers that permit operation close to ground.

For best results, place a buffer transistor between the LED and output of the operational amplifier when a CMOS opamp is used or the LED I_{Fq} drive is targeted to operate beyond 15 mA. Finally the bandwidth is influenced by the magnitude of the closed loop gain of the input and output amplifiers. Best bandwidths result when the amplifier gain is designed for unity.