HCNR201/200

Isolated Log Amplifier Using High-Linearity Optocouplers

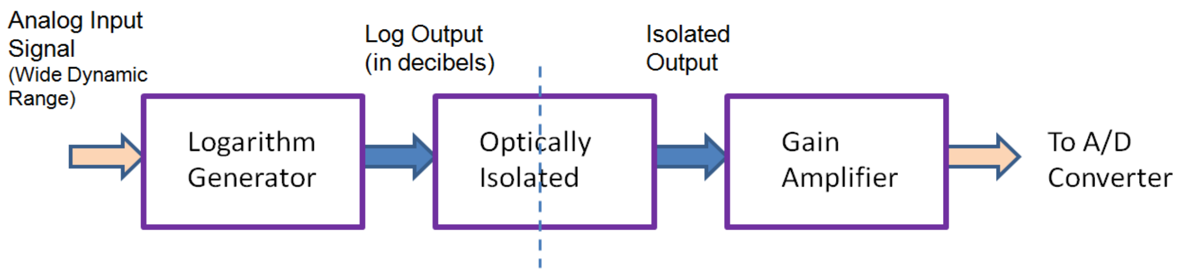
Introduction

Logarithmic amplifiers with its log functionality are useful for compressing wide dynamic range signals whereby the measured quantities are in decibels (dB) and they are used in a wide variety of applications such as video, medical, test and measurement system. Logarithmic amplifiers can be built to a compact, easy to use and cost effective circuits suitable for certain analog designs.

Because of high voltage presence in industrial applications, it is necessary to protect equipments and personnel operating the motors through galvanic isolation. HCNR201/200 can be used for current sensing and voltage monitoring in motor control drives, switching power supplies and inverter systems.

The HCNR201/200 analog optocouplers is commonly added to isolate the analog signal in the front end module of an application circuitry. The optocoupler will be placed between the analog input and the A/D converter to provide isolation of the analog input from the mixed signal ADC and other digital circuitries.

Figure 1: Optocoupler Placement

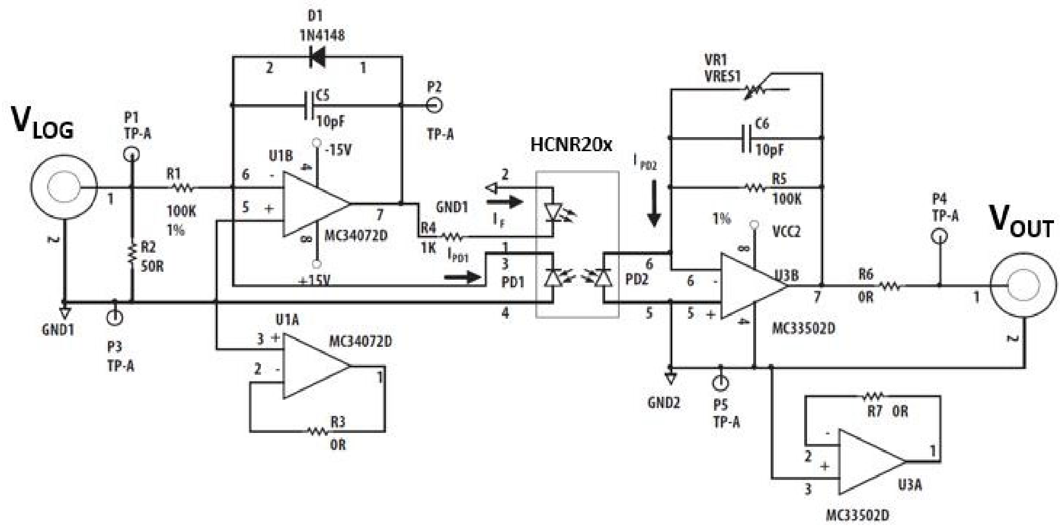


Optical Isolation using HCNR201/200

Isolation using Broadcom® optocouplers will protect the control part (such as the MCUs) from the high-voltage side of the IGBTs, in the case of malfunctioning of the IGBTs for motor drives.

The Broadcom high-linearity optocoupler, HCNR201/200, provides an excellent solution in isolating analog signals in various applications that require good stability, linearity, bandwidth, and low cost. The HCNR201/200 consists of one LED and two closely matched photodiodes (PD1 and PD2). Transfer gain is an important parameter for the HCNR201/200, and it determines how closely matched the two photodiodes are. HCNR201 has a tight transfer gain of 5%, and HCNR200 has a transfer gain of 15%. With the tight transfer gain governed by the photodiodes, Broadcom high-linearity optocouplers virtually eliminate the nonlinearities and drift characteristics of the LED, with HCNR201 achieving 0.07% non-linearity over temperature. An example of an isolated gain amplifier circuitry using the HCNR201/200 is shown in Figure 2, and the HCNR201/200 is connected in photovoltaic mode because the voltage across the photodiodes is essentially 0V

Figure 2: Example of Analog Isolation Circuitry Using HCNR201/200



Equation 1:

$V_{LOG} = I_{PD1} \times R_1$

Equation 2:

$V_{OUT} = I_{PD2} \times R_5$

Equation 3:

$(V_{OUT} / V_{LOG}) = K_3 \times (R_5 / R_1)$

K_3 is the transfer gain of HCNR20*x*. (The current flowing through PD2, I_{PD2} divided by the current flowing through PD1, I_{PD1}.)

To achieve gain of 1, R_5 and R_1 can be set to 100 kΩ. Therefore, if $R_1 = R_5$, the output signal will follow the input signal.

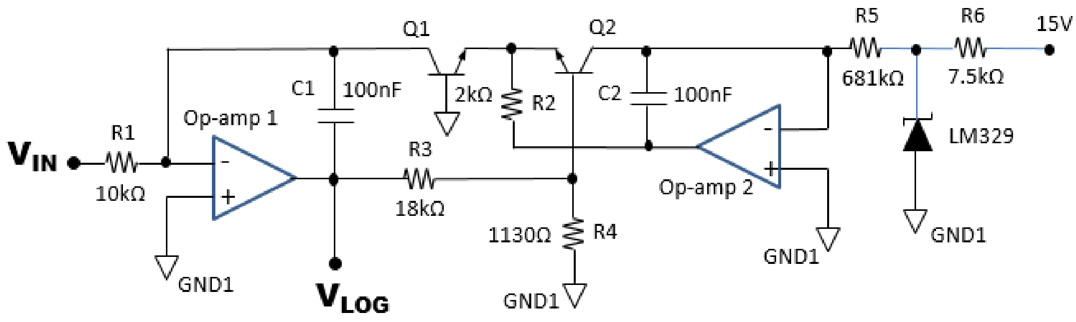
Logarithmic Generator

For applications involving signals with large dynamic range, it is difficult to handle both small and large amplitude signals. Thus, it requires a log amplifier for signal compression.

A simple circuit for logarithmic generator is shown in Figure 3. The circuit is constructed with a pair of matched transistors, Q1, Q2, and operational amplifiers. Transistors Q1 and Q2 serve as the feedback element for the inverting operational amplifer. The circuit output, V_{LOG} is the logarithmically of the input signal, V_{IN}.

With the zener diode, LM329, the collector current for Q2 is fixed; therefore, V_{BE2} is fixed. Only V_{BE1} is affected by the input signal, V_{IN}.

Figure 3: Logarithmic Generator Circuit



Output voltage, V_{LOG}, is proportional to the difference in the base emitter voltages of Q1 and Q2.

Equation 4:

$$V_{LOG} = ((R_3 + R_4) / R_4) \times (V_{BE2} - V_{BE1})$$

For different collector currents at Q1 and Q2, the V_{BE} difference is governed by the following equation.

Equation 5:

$$\Delta V_{BE} = (kT / q) \times \log_e(I_{CQ1} / I_{CQ2})$$

Substituting Equation 5 to Equation 4, with difference of V_{BE2} and V_{BE1} as ΔV_{BE} results in the following equation.

Equation 6:

$$V_{LOG} = -(kT / q) \times ((R_3 + R_4) / R_4) \times \log_e(I_{CQ1} / I_{CQ2})$$

I_{CQ1} and I_{CQ2} equations are shown in Equation 7 and Equation 8.

Equation 7:

$$I_{CQ1} = (V_{IN} / R_1)$$

Equation 8:

$$I_{CQ2} = (V_Z / R_5)$$

Substituting Equation 7 and Equation 8 into Equation 6 yields Equation 9.

Equation 9:

$$V_{LOG} = -(kT / q) \times ((R_3 + R_4) / R_4) \times \log_e((V_{IN} \times R_5) / (V_Z \times R_1))$$

With Vz of LM329 = 6.9V, and R_5 = 681 kΩ, R_1 = 10 kΩ, the logarithmic amplifier circuit gain is set by the R_3 and R_4 divider, $((R_3+R_4) / R_4)$ to a factor of 1V/decade.

kT / q is equal to 0.02586V, where k is the Boltzmann's constant, T is the temperature in Kelvin and q is the charge of an electron.

V_{BE1} is the base-emitter voltage for bipolar transistor, Q1 and V_{BE2} is the base-emitter voltage for bipolar transistor, Q2. I_{CQ1} is the collector current for bipolar transistor, Q1. I_{CQ2} is the collector current for bipolar transistor, Q2. V_Z is the zener diode voltage.

Results

Figure 4 shows the plot of output voltage vs input voltage for different DC input voltages ranging from 0.1 mV to 10V. Theoretical results are computed based on Equation 6. The actual measurement result is based on the evaluation board built from the cascaded isolated and logarithmic circuits in Figure 2 and Figure 3, respectively.

Figure 4: Vout vs. Vin Plot (DC Input Signal)

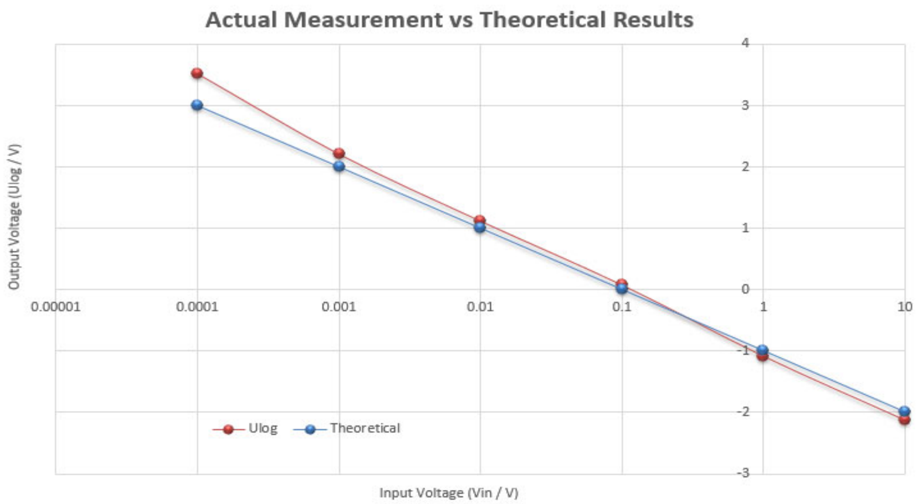
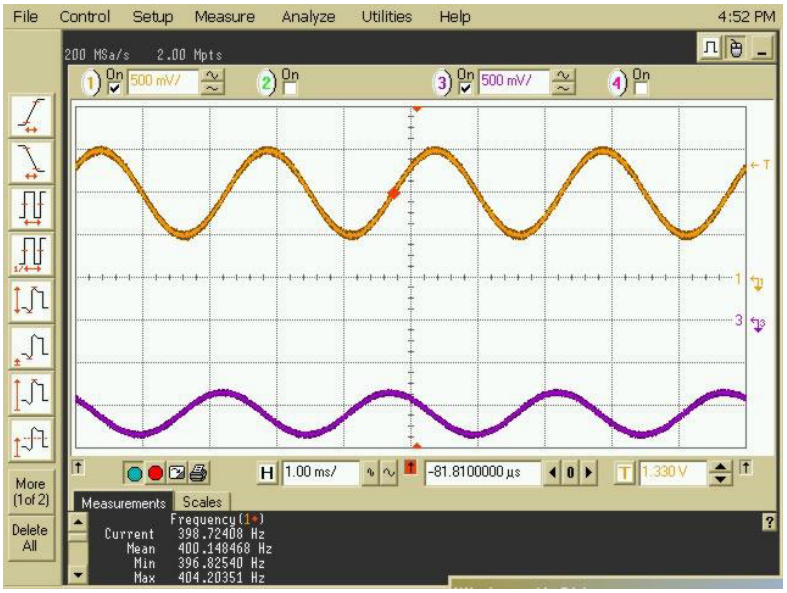


Figure 5 shows the output voltage signal (purple waveform) with 1 Vp-p AC input signal (orange waveform). The input AC signal is with 1 Vdc, so from the Figure 4 plot, the output is with –1 Vdc. Based on –3-dB cutoff frequency, the output signal will be at 0.5 Vp-p, which is at half of the input signal. The bandwidth (–3 dB) of this circuit is at 400 Hz.

Figure 5: Vout vs. Vin Plot (AC Input Signal)



Summary

Logarithmic amplifiers applications include digital communication systems, analytical, medical test and instrumentation, whereby safety isolation plays an important role as well.

These types of industrial applications measure the physical quantities over a wide dynamic range and use log amplifiers to match the dynamic output to the linear input range of the signal. HCNR201/200 high linearity optocouplers provide the optical isolation to ensure data integrity and to protect operators from high voltages.

References

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