Hello and welcome to Simple Circuits!

In this edition, I would like to explore an optical isolation technique for monitoring applications that provides circuit protection and isolation from external sensor ground loops and transients.

Optical digital signal input isolation is usually very straightforward. Linear optical analog isolation is slightly more complex.

Perhaps before we explore this concept in greater detail we should ask ourselves why we might want to isolate the equipment from a field sensor in the first place.

**Why Isolate?**

The signals from field sensors and transducers such as temperature, pressure, voltage, current, load, etc. are not typically dangerous in and of themselves. Power surges or lightning strikes however can induce large transients on signal cables or raise the ground potential to the point of voltage stress failure in the electronic device.

Transient suppression circuitry can provide some protection from transients but can be ineffective if the earth ground is raised due to a ground fault. This is especially true if the electronic device connects to a telecommunication facility like a telephone line or antenna which is grounded at a different point in the facility.

CSA and UL specifically require products such as answering machines, modems and auto dialers to demonstrate a minimum isolation voltage rating of 1500 VAC from ground to the incoming telephone line.

Telephone lines can be particularly susceptible to transients from lightning, nearby construction projects, etc. and it would be very dangerous for users to be engaged with such products when such a transient came down the line.

*Note: This does not mean that it is now perfectly safe to use such products during a lightning storm, but there is an added layer of protection for both the user and the product.*

I have personally seen many incoming telephone line circuit board traces vaporized off of auto dialer printed circuit boards. The CPU and process electronics however, remained intact and no fire resulted from the incident.

There are also several applications where sensor isolation from process electronics is crucial, such as in bio-medical instrumentation (heart monitors, etc.). Even small electric currents passing through the human body can have serious and detrimental effects on hospital patients connected to sensing devices.

The potential for danger to patients is so great that even the wiring schemes of the electrical outlets within hospital rooms are considerably more complex than most people realize.

**Analog Vs. Digital Isolation**

Let me begin by introducing the concept of true isolation from field devices.

The true isolation of an input sensor (and any circuitry required to support the sensor), will require a separate and isolated power supply to power the field device. This includes a separate ground or common reference.

By not using an isolated power supply and ground reference, this circuit provides a transient path through the pull up resistor(s) and common to all the electronic components on the PCB.

Proponents of such a circuit suggest that if the power supply ground for the equipment is in any way commoned with the incoming sensor ground, then isolation is already compromised.

In many instances however, where something as simple as a wall adapter is used to power the equipment, earth ground isolation is achieved through the step-down transformer inside the wall adapter.

Figure 2 demonstrates a proper method of isolation for the same circuit, including a fully isolated onboard power supply.
ply. The added power supply drives up the cost to build the circuit, but the protection is there, and incoming transients will not damage internal circuitry, providing the associated breakdown voltages of the power supply and opto-isolator are not exceeded.

Although digital isolation is typically straightforward, analog signal isolation requires extra consideration if we are to accurately reproduce incoming signal levels.

**Analog Isolation**
There are several techniques which can be implemented for the isolation of analog signals, and their usefulness depends on the application.

One technique employs a front end analog to digital converter with a serial interface. The sensor and A/D converter would be driven from the isolated power supply, with the digitized signal then serially streamed through a standard optocoupler to the CPU for processing.

The drawback to such a technique comes from the fact that many analog signals are used for real time feedback control of external processes. These applications require a high speed or large bandwidth to ensure that feedback is not unduly delayed.

When the incoming signal is required to function in such a capacity, the delays of the conversion time of the A/D, in addition to the streaming time of the serialized data are prohibitive.

**An Alternate Analog Isolation Strategy**
The LOC110, manufactured by Clare (an IXYS Company), provides an excellent method to isolate and reproduce incoming analog signals, while minimizing delays when used in control applications.

It is essentially an optocoupler in which two matched output phototransistors are driven by the same optical infrared LED.

(Note: The LOC110 provides 3750 volts of isolation and will operate down to -40°C.)

The LOC110 can be applied using two circuit configurations:

1) A high bandwidth, lower linearity mode (Photoconductive Mode)
2) A lower bandwidth, high linearity mode (Photovoltaic Mode)

**Photoconductive Mode**
In order to drive the input diode of the LOC110, application notes (AN-107), published by Clare, indicate that drive currents of 10mA to 15mA are desirable.

In order to achieve this level of drive current, an input buffer op amp, which also functions as part of a negative feedback and linearization drive circuit, is employed.

The Clare application note takes the reader through a mathematically derived process in which 3 types of gain are taken into consideration when applying the circuit.

1) Servo Gain (K1) – Servo Gain is a constant which is determined by the values of the input diode current limiting resistor and the feedback resistor from the servo photodiode feedback output. (K1=I1/IF – Please see Figure 3)
2) Forward Gain (K2) – Forward Gain is used to derive the transfer gain of the circuit – please see Transfer Gain.
3) Transfer Gain – The Transfer Gain is important because it dictates the actual amplification gain of the entire circuit.

In summary, the application note demonstrates the desired drive characteristics for the input diode and that the Ratio of R2 to R1 defines the gain of the entire signal conditioning circuit. This makes the device very straightforward to implement into applications.

**Photovoltaic Mode**
In the photovoltaic mode, a different control feedback configuration is used for the input buffer amplifier.

In this instance, the output phototransistors function as current generators.

---

**Figure 3** Isolation Amplifier (Photoconductive Operation)

In summary, the application note demonstrates the desired drive characteristics for the input diode and that the Ratio of R2 to R1 defines the gain of the entire signal conditioning circuit. This makes the device very straightforward to implement into applications.

---

**WILCOX SALES COMPANY**

**PS/4-10 Series**

Anchored Pedestrian Signal

Since 1974 Wilcox Sales Company has been providing audible pedestrian signals to public agencies throughout the North American Continent. With the PS/4-10 Series, ease of installation, simplicity of use, and long-lasting durability are just a few of the comments people constantly use to describe our products.

**Features**
- Two distinct tones: Koo-Koo-North South; Peep-Peep-East West
- Ambient noise volume override – 3 distinct dB noise thresholds
- Customizable messages
- NEMA TS-2 environmental requirements
- We stock all three standard colors; Traffic Signal Green, Safety Yellow, & Black

**Family owned and made in the U.S.A. since 1974**

Wilcox Sales Company
1420 N. Claremont Bl #203A
Claremont, Ca 91711
Phone: 909.624.6674
Fax: 909.624.0725
E-mail: wilcoxps@verizon.net
Alt Email: wilcoxps@gmail.com

---
The servo feedback control phototransistor is essentially placed across the two inputs of the input buffer op amp.

This keeps the phototransistor at a 0V bias, as photogenerators display some voltage dependence on linearity, and the objective is to eliminate this issue, thereby improving linearity.

As can be seen in Figure 4, the input amplifier is operating as an inverting amplifier. The incoming voltage is fed through a resistor into the negative input of the op amp. It is also applied to the collector of the feedback phototransistor.

![Figure 4 Isolation amplifier (Photovoltaic Operation)](image)

The output of the inverting input amplifier, sinks current through the input diode of the optocoupler, whose anode is pulled up to VCC through a current limiting resistor.

As the input signal is increased, the inverting op amp begins to sink greater current through the input diode, which in turn drives the feedback phototransistor into higher conduction. The photocurrent through the servo control output transistor is linearly proportional to the input signal.

As the feedback phototransistor conducts, it bleeds off current from the inverting input of the op amp, thereby lowering the input signal to the op amp, providing the negative feedback control.

The output photodiode drives an inverting amplifier, which inverts and amplifies the already linearized output signal such that it is properly polarized, and tracks the input signal as current flows away from the inverting input, into the collector of the output phototransistor.

You will note that I have not attempted to review the math involved in the preceding circuit analyses, only the operation of the circuits themselves. This is because Clare has produced an excellent application note (AN-107). Not only is the math very simple and straightforward, but it is thoroughly covered in the App note, which is available for download off the internet.

**Repeatability and Circuit Calibration**

Any time a manufacturer produces an electronic component, they strive for specification consistency from part to part. This is not always easy to achieve, especially with components such as opto-isolators, where even the smallest physical difference can lead to varying performance characteristics within a circuit.

In order to compensate for differences in the LOC110, Clare actually tests and pre-sorts the LOC110 into batches, reflecting different transfer gain characteristics from various production runs.

Six ranges of transfer gain are available for purchase for the LOC110. Even with factory pre-sorting, small amounts of circuit calibration will still likely be required.

Calibration can be accomplished by trimming the amplification gain resistors of the circuit.

**Additional Applications:**

I have not had the opportunity to cover many applications of the LOC110 within the scope of this article. The LOC110 can also be used for modem DAA (Data Access Arrangement) circuits, where the device can replace the cumbersome isolation transformer of years past.

The LOC110 can also be used in switch mode power supply designs, cardiac monitoring, isolating voltage to current converters, and RTD temperature measuring circuits, etc. You will find LOC11x series devices for sale on the internet for under $2.00 USD, and they also come with two completely independent opto-couplers in the same package (LOC21x series).

An assortment of external amplifiers can be used with the LOC110 including the LM358, LM201, LM1558 and LMC6484. For high precision/accuracy applications, the AD824 has also been used. http://www.analog.com/static/imported-files/data_sheets/AD824.pdf

**Conclusion**

I would like to thank David Hickle, President of Xtel International for his assistance in the writing of this article and Clare for permission to use graphics (Figures 3 and 4) from the LOC110 App Note, AN-107.

The LOC series of opto-isolators provide low cost, small form factor, and superior performance over traditional transformer interface designs, and are readily available from several suppliers.

As always, I have tried to be as accurate as possible within the scope of my column, however, there are several aspects to this device which I have not had the opportunity to review. Please read the entire data sheet and application note before implementing this component into a design.

Until next time,

Take care out there!