Abstract

This application note introduces the implementation of zero crossing detector within many GreenPAK™ devices. Zero-voltage cross detection [ZVCD] can be used as a standalone concept for multiple applications, or it can be implemented within many prior designs to ensure higher accuracy or more robust functionality.

Several typical use cases of zero crossing detector will be highlighted within this document, with recommended corresponding GreenPAK devices.

Background

Zero-voltage cross detection is commonly used as an accurate method of detecting AC characteristics, such as frequency and phase. The zero-crossing point is ideally suited for measuring AC signals for several reasons. First, in any sinusoidal AC signal the zero-voltage crossing point has the greatest rate of change within the sinusoid, meaning that a comparator will be most quickly be able to establish a signal change at the zero crossing. Second, a reference to a common ground is the easiest reference to establish, since fewer perturbations exist to add noise to the voltage reference.

Zero crossing detector is implemented with AC signals to determine when the signal has passed its common ground point. The AC signal is compared to its DC offset reference (typically 0V) and triggers a signal whenever the AC signal has crossed the threshold. A Zener clamp is often used at the input of the comparator in conjunction with a resistor [Figure 1] to ensure that the comparator will have a clamped input if the AC signal is beyond its maximal input voltage.
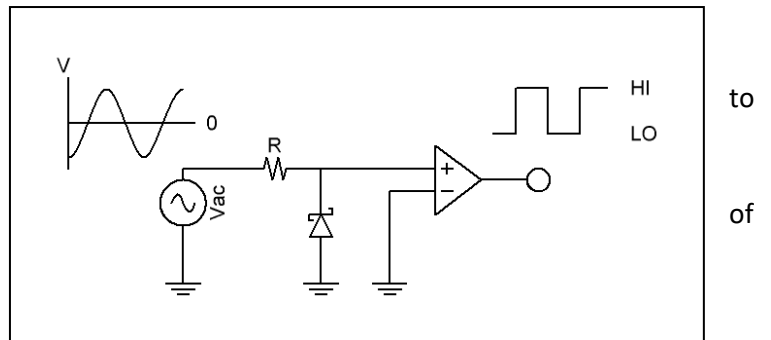

Figure 1 Basic ZCVD Schematic

The Zener clamp and resistor combination, used as the comparator input, have an added benefit; if the resistance is large enough, the comparator needs to extract only a small amount of current from the Vac voltage source. This is very useful for sampling a Vac value without noticeably reducing the power of the Vac node, which can be a necessity in many applications that require one or more supply voltages to be monitored.

Through additional logic and circuitry, the ZVCD signal is commonly utilized to detect information about the AC signal, such as frequency and phase.

Areas of Application

Frequency Detection

When an application may need to determine several frequencies ZVCD can be implemented. By measuring the period between ZVCD edges, and comparing to pre-determined frequencies, a frequency detection of an AC signal can be accurately obtained. This is essential in consumer electronics that may be used via outlets in multiple countries, some of which utilize 50Hz wall outlets and others 60Hz.

Additionally, frequency differentiation might be needed for a wider range of frequencies. For example, the input of a Musical Instrument Digital Interface, or MIDI, must be able to differentiate audio frequencies ranging from roughly 27.5Hz to 4.186kHz or higher. Using a ZVCD can be an accurate way of measuring consecutive, different frequencies.
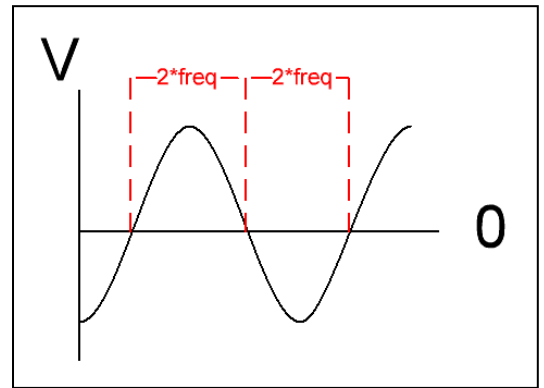

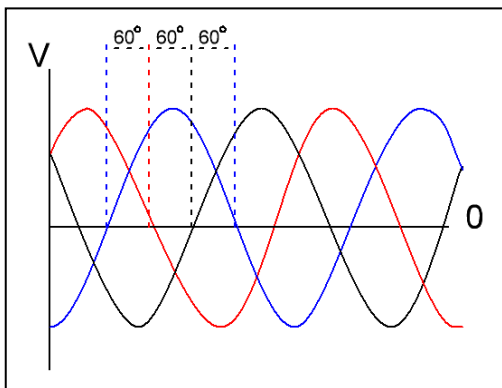**Figure 2 Frequency Detection**

Phase Detection

Figure 3 Three-Phase Detection

A ZVCD can be used to measure the phase of different AC signals. In devices such as 3-phase motors, it can be essential to ensure the AC sources have evenly-distributed phases; a noticeable offset of one AC source can cause a large variation of input voltage to the motor, and can drastically affect proper motor control or efficiency. By monitoring the phase difference between sources, a motor can shut off or re-orientate its voltage supplies to prevent failure or inconsistent speed. The threshold at which the motor must either shut off or recalibrate will vary by application, making GreenPAK ICs a useful asset for personalized phase detection.

Phase detection can also be used to monitor a signal's phase constant, aka its change in phase per unit length through a transmission line, by comparing the signal to a reference signal. This is useful for measuring the integrity of lengths of transmission lines used in various communications.

Zero-Voltage Switching

Many applications, such as ideal diode rectification and DC-DC soft-switching, require a switch or signal to activate at as close to the zero-voltage switching point as possible. In many cases this is to reduce power loss or large EMI perturbations. ZVCD allows for reduced MOSFET transition losses in DC-DC converters and regulated turn-on times during ideal diode rectification.

Using GreenPAK Family for ZVCD

One of the types of components found within almost every GreenPAK device are two or more analog comparators, which give a designer plenty of options when choosing the GreenPAK IC that fits the complexity and specificity of their ZVCD needs. The smallest device that can be used for ZVCD is the SLG46110V, which contains two analog comparators, additional logic, counters and an oscillator. As chips increase in the number of additional components available extra features may be implemented to improve the design, such as power saving or I2C and SPI interfacing to external processors.

This application note uses the SLG46110V as an introductory device to ZVCD, but extra components found within other GreenPAK devices may be suggested in the following sections should a designer wish to elaborate on their design.

Functional Requirement of ZVCD

GreenPAK devices have a nominal pin voltage range of 0V to a VDD value of 3.3V or 5V. To interpret an AC signal that typically crosses at the 0V point using the GreenPAK a DC offset shift should be implemented between the AC signal and the GreenPAK pin. Most simply, this can be accomplished by a 1:1 resistor divider between VDD and the AC signal [Figure 4], but other topologies are possible. These resistance values can also help limit the swing of the AC signal at the pin of the GreenPAK, which allows the GreenPAK to monitor large AC signals, such as 120V motor supplies. However, when large voltages are monitored a Zener clamp should also be added to prevent possible surges.

Zero crossing detection requires, at minimum, one or two comparators and a counter. The comparators check the incoming AC signal against a reference voltage, which can either come from the GreenPAK's assortment of available reference voltages or an external reference point. If a desired ZVCD voltage is greater than the available GreenPAK reference voltages the AC signal may instead be reduced by using the *IN+ gain* option within the comparator's property settings, and comparing the reduced AC value to a similarly-scaled reference [Figure 5].
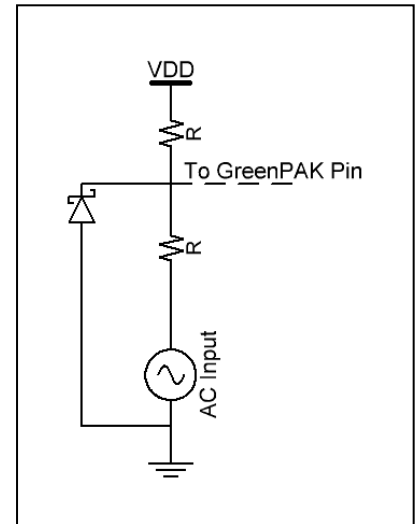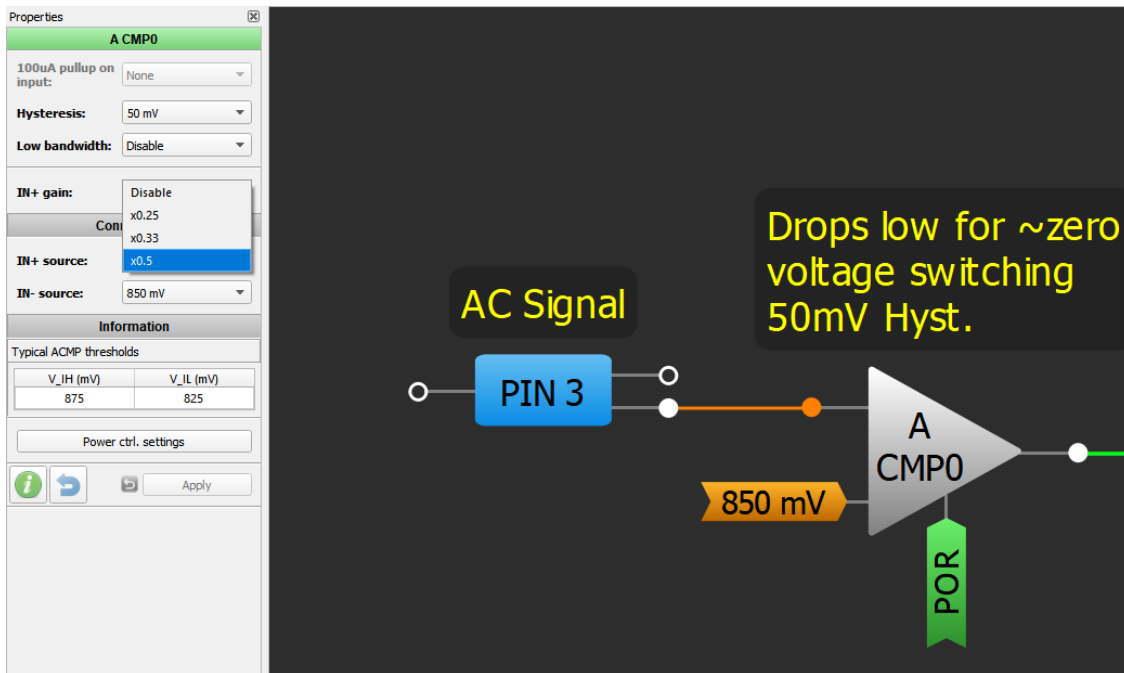

Figure 4 Basic DC Offset

Figure 5 Using the IN+ Gain to Measure a 1.7V Crossing

An alternative to supplying a zero-crossing reference voltage can be implemented if both the positive and negative terminals of a sinusoid can be monitored. In this case, the high-side and low-side of the AC supply can be connected to the terminals of the comparator, and the rate of change at the zero-crossing point is doubled, thereby increasing comparator switching speeds. A design that utilizes this method of zero-crossing is outlined in the next section, with a high-side and low-side comparison [Figure 6].

Example: Applying GreenPAK to Frequency Detection

A simple implementation of ZVCD is the detection of either a 50Hz or 60Hz frequency, under the assumption that an AC signal can only be one of the two frequencies. Once the zero-crossing point has been detected, a delay is set that is greater than a half-period of a 60Hz signal (8.33ms) and less than the half-period a 50Hz signal (10ms). In Figure 6, the delay was set at 9ms for an effective tolerance range.

This delay, in conjunction with additional logic, can be used to latch a D Flip-Flop when the AC signal is detected to be 50Hz and will also reset the Flip-Flop when the signal is detected to be 60Hz. A GreenPAK Designer file of the configuration is shown below [Figure 6].
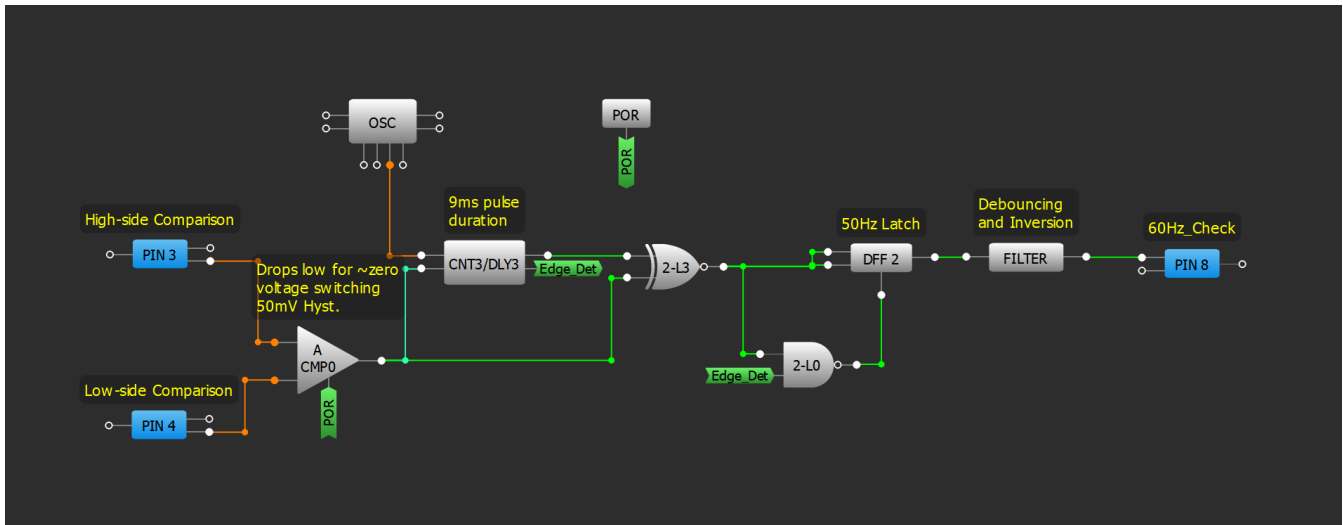
Figure 6 Rudimentary Home Outlet Freq Detection

Further SLG46110 blocks can be utilized for tasks such as detecting DC voltage, implementing frequency window detections to ensure a 50Hz/60Hz signal and more.

Implementing More Complicated GreenPAK Designs

The GreenPAK family offers a wide assortment of ICs, all with differing components and properties. Several other components within larger chips than the SLG464110 can notably add extra functionality for use with ZVCD.

Several GreenPAK designs include a frequency detect within their CNTx/DLYx blocks [Figure 7]. These functional blocks become HI when a signal input is not read in the input that is at or below the set period length. These blocks can economize frequency detection using zero-voltage crossing by reducing the number of functional components when compared with the SLG46110 example above.

Many GreenPAK ICs, such as the SLG46536, are I^{2}C compliant and able to read information from some of their counters. ZVCD can be used in these devices to go beyond a check for just several specified frequencies; by resetting a counter at the zero-voltage crossing, and counting until the next crossing, a frequency value depicted as a multiple of the counter's frequency can be obtained. This can be used in applications that must discern between numerous consecutive frequencies.
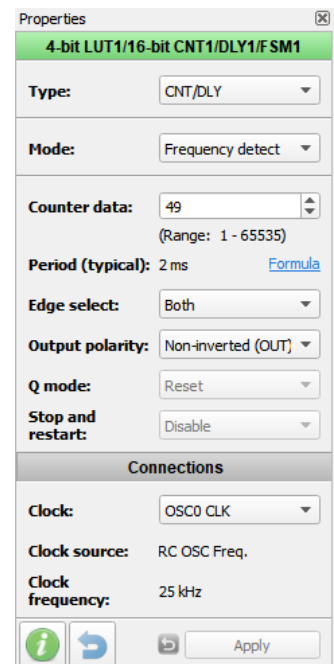

Figure 7 Freq Detect

Conclusion

Using zero crossing detector within many applications is an effective way of reading characteristics of an AC signal, without sacrificing accuracy or using many discrete parts. Several applications and methodologies have been outlined in this application note, but the only restrictions that exist for ZVCD are a lack of imagination or an application's market appeal. GreenPAK devices have become ideal platforms for ZVCD; by combining comparators, timers and associated logic on a small, affordable chip an inventor can now take advantage of frequency or phase detection, zero-voltage switching and more in an unprecedented manner.

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