



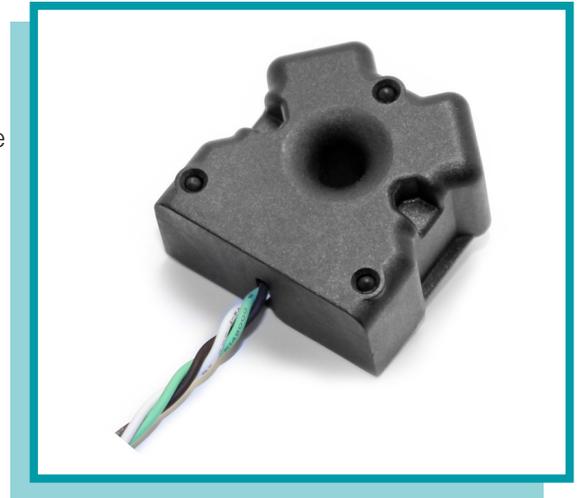
## USING THE PULSE SIDEWINDER ROGOWSKI COIL TO MEASURE AC CURRENT

### Introduction

Wide dynamic range, increased efficiency and immunity to the effects of saturation are just some of the benefits offered when selecting a Rogowski Coil based current sensing solution. The purpose of this article is to describe the output signal of the Pulse Rogowski Coil, address the fact that the output signal looks different than the output signal of a CT or shunt and to detail several practical methods for using the Pulse Sidewinder Rogowski Coil for AC current measurement application.

### Rogowski Coil Basics

When an AC current flows through a conductor, a magnetic field is created that is sensed by the Pulse Sidewinder Rogowski Coil, and a voltage output is produced from the sensor that is proportional to the time rate of change of the AC current.



$$V_{out} = dl(t)/dT (-M)$$

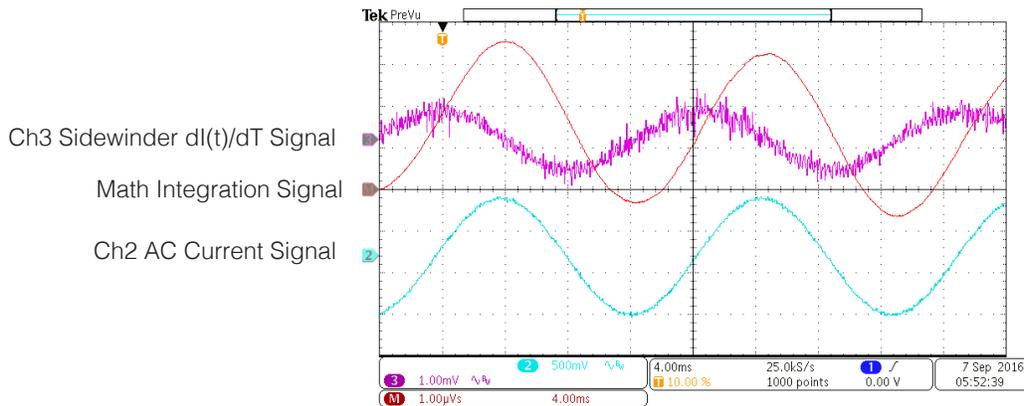
If the AC input current waveform is a sine wave,  $I(t) = \text{sine}(\omega t)$ , then the derivative of the waveform is  $dl(t)/dT = -\omega * \cos(\omega t)$ , bringing the  $\omega$  factor out as a multiplier. The magnitude of the output increases as the frequency increases. The change from a sine wave to a cosine wave also appears as a -90 degrees phase shift. However, if the output is integrated, then the multiplier and the phase shift are eliminated and the original AC current waveform is reproduced.

### Sidewinder Output Waveforms

It is possible to view the voltage output of the Sidewinder on an oscilloscope, and this output will be the derivative of the original current waveform.

The below image shows three waveforms, the first is the input current as measured by the voltage dropped across a shunt resistor (in blue), next is the output of the sensor (in purple) and finally the result of the integrating math function (in red). By using the Math Function, 'Integrate' of a digital oscilloscope such as the **Tektronix MDO 3034**, the original AC waveform can be reproduced.

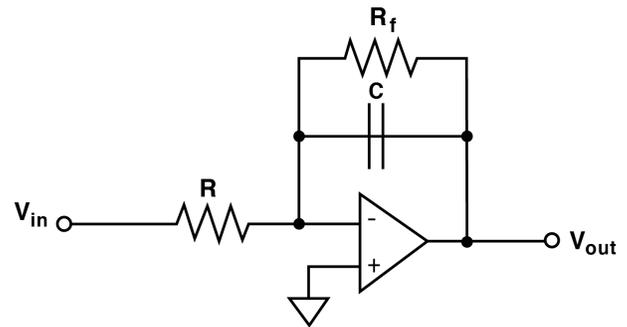
The output waveform of the Sidewinder sensor (in purple) does not look like the expected output from a CT or a shunt, because it is the  $dl(t)/dT$  of the input waveform. The uneven waveform is due to the input signal that is not a pure 60Hz sine wave. It contains many high frequency ripple signals, riding on top of the 60Hz sine wave, and they can be seen with close examination of the Ch2 waveform in the image above. These high frequency ripple signals are sensed by the Sidewinder sensor, and the  $dl(t)/dT$  of these produces the waveform that has a very large amount of ripple. The -90 degree phase shift of the Sidewinder output is also noticeable. However, when the output is integrated with the Math function, the original input waveform is reproduced. The linearity and the phase accuracy of the integrated output can now be verified.



## Integrating Operational Amplifier

There are several techniques to integrating the Sidewinder signal in a practical circuit, without an oscilloscope Math function. An integrating operational amplifier circuit is one approach, and the following simple circuit can be used with the Sidewinder.

The sensor is connected to the  $V_{in}$  of this above circuit, and the integrated output is directly proportional to the input current. The transfer function is a product of the Sidewinder coil constant  $M$ , and the integrator gain.



When  $R_f \gg R$ , the output is

$$V_{out}(t) = -\frac{1}{RC} \int V_{in}(t) dt$$

## Analog Front End IC

There are several Analog Front End IC's, from several manufacturers that can perform the signal integration in the firmware of an IC. The following IC's are an example of Analog Front End (AFE) IC's

- Analog Devices ADE7753 family
- Cirrus Logic CS548x & CS5490 family
- ST Micro STPM3x family

The Sidewinder is connected directly to the IC input channel, and an RC filter can be added between the Sidewinder and the IC as required. The IC integration function must be enabled in the IC, and then the IC will digitize the original waveform, integrate the waveform, and do other internal math calculations like RMS values, peak values, phase shift and more. The IC can then communicate these data values to a CPU via the I2C bus or SPI serial bus.

These IC's were developed for metering applications, such as a 1S smart meter for single phase, residential applications. Below is a typical loadline accuracy curve of a 1S meter, using the Pulse Sidewinder PA3202NL and the Cirrus CS5484 analog front end.

The entry level IC such as the CS5490 is a recommended solution for basic current measurement and power measurement with the Pulse Sidewinder for non-metering applications as well. This combination will provide a circuit solution that is easy to set up, low cost, and very accuracy.

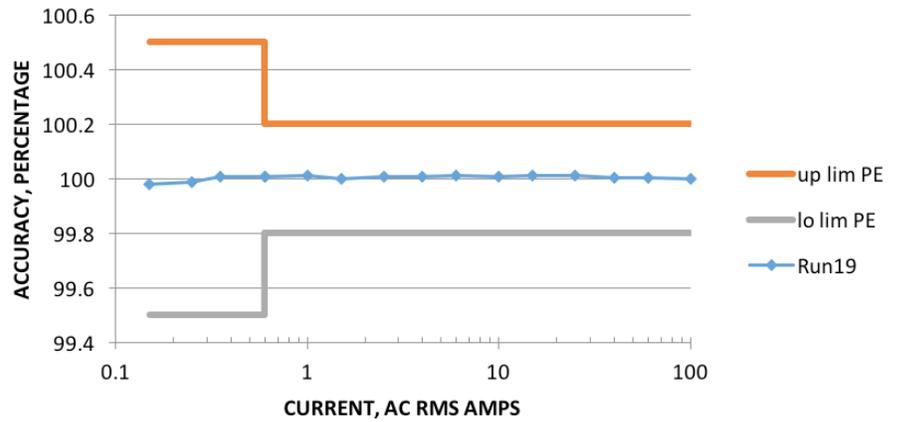
The reader is also referred to the [Cirrus Logic AN356 Application Note](#) for further information on the AFE solutions as well as independently tested data on the PA3202NL Sidewinder. Also see the [CS5490 Eval board application note](#) for further support on configuring the CS5490 for current measurement.

The reader is referred to the [Pulse Sidewinder Rogowski coil overview](#) for a more complete summary of the Pulse product line and its advantages compared to other current sensing technologies.

## Summary

The Pulse Sidewinder Rogowski coil is a recommend alternative to other current sensing technologies, with significant added benefits, including wide dynamic range, and immunity to the effects of saturation. An easy to implement solution based around the low cost Analog Front End IC's has been presented with offers 0.2% current measurement accuracy or better over a 4000:1 dynamic range.

## 1S Meter PA3202NL with Cirrus CS5484 Demo Board with Power offset



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