APPLICATION NOTES

Contents

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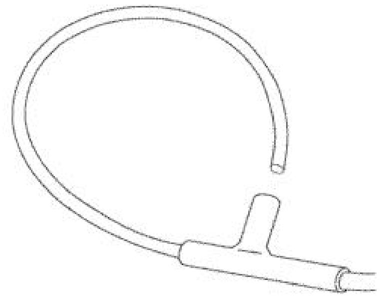
1. The Basics

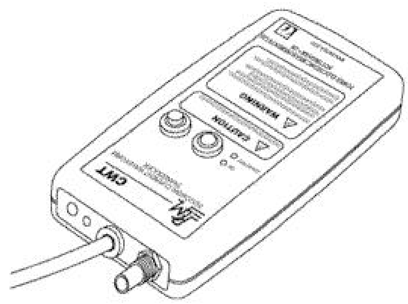
All measuring instruments are subject to limitations. The purpose of these application notes is to explain some of those limitations and to help the engineer maximise the many advantages of PEM's Rogowski current transducers.

1.1 What is a Rogowski current transducer?

A Rogowski current transducer is used for measuring an electric current. It provides an output voltage which is proportional to current (e.g. 1mV/A). It tracks the current as it changes with time and therefore can reproduce the current waveform on an oscilloscope or any type of data recorder.



Alternatively the output can be connected to a digital voltmeter (DVM) to give a reading of rms current.
PEM produces a range of Rogowski transducers for measuring currents from a few hundred mA's to hundreds of kilo-amps. Each transducer comprises a Rogowski coil connected to an electronic integrator by a co-axial cable as shown.

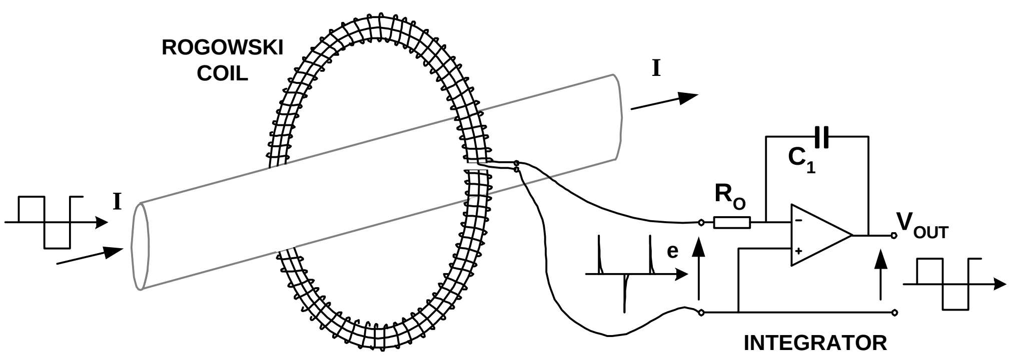


The coil is closely wound on a thin plastic tube of circular cross section and surrounded by insulation. It is looped around the conductor or device carrying the current to be measured. One end of the coil is permanently attached to the connecting cable. The other end is free and is normally inserted into a socket adjacent to the cable connection. However the free end can be unplugged to enable the coil to be looped around the conductor. The free-end must be fully inserted into the ferrule to achieve full accuracy.

The coil is flexible and therefore can be inserted between closely mounted conductors or devices where access is restricted. The loop does not need to be circular and the current does not need to be centrally situated or evenly distributed within the loop.

1.2 How does a Rogowski current transducer work ?

The voltage induced in a Rogowski coil is proportional to the **rate of change** of current enclosed by the coil-loop. It is therefore necessary to **integrate** the coil voltage in order to produce a voltage proportional to the current.



The coil is uniformly wound with ***N*** turns/m on a non-magnetic former of constant cross section area ***A*** m^2. If formed into a closed loop then the voltage **e** induced in the coil is given by the equation

$$e = \mu_o NA\ di/dt = H\ di/dt$$

where ***H*** (Vs/A) is the coil sensitivity and ***I*** is the current to be measured passing through the loop.

The loop does not need to be circular and ***e*** is independent of the current position in the loop. To reproduce the current waveform as a measurement signal which can be displayed on an oscilloscope or quantified using a DVM, all that is required is means for accurately integrating the coil voltage, such that

$$V_{out} = 1/T_i \int e.dt = R_{SH}.I$$

where $T_i = R_o C_1$ and $R_{sh} = H/T_i$ is the transducer sensitivity in (mV/A).

1.3 What are the advantages of Rogowski current transducers ?

PEM's Rogowski current transducers

- **Can measure large currents without saturating.** The size of the Rogowski coil required remains the same despite the size of current. This is unlike other current transducers which become bulkier as the current magnitude increases. For currents of several kA's or more there is really no better alternative than the Rogowski transducer!
- **Are easy to use** - the coil is thin and flexible and easy to insert around a current carrying device.
- **Are non-intrusive**. They draw no power from the main circuit carrying the current to be measured. The impedance injected into the main circuit due to the presence of the transducer is only a few pico-Henries!
- **Have a very wide bandwidth extending from typically 0.1Hz up to 17MHz**. This enables the transducer to measure or reproduce the waveform of very rapidly changing currents - e.g. several thousand A/µs. With the exception of co-axial shunts, which are very inconvenient to use, most other current transducers have bandwidths limited to about 100kHz.
- **Provide an isolated measurement at ground potential** similar to other current transducers (except co-axial shunts) i.e. there is no direct electrical connection to the main circuit.
- **Can measure AC signals superimposed on large DC**. The transducer does not measure direct currents - as a result it can measure small AC currents in the presence of a large DC component
- **Can measure changes of current as fast as 40,000A/µs.**

1.4 How does a Rogowski transducer compare to a Current Transformer ?

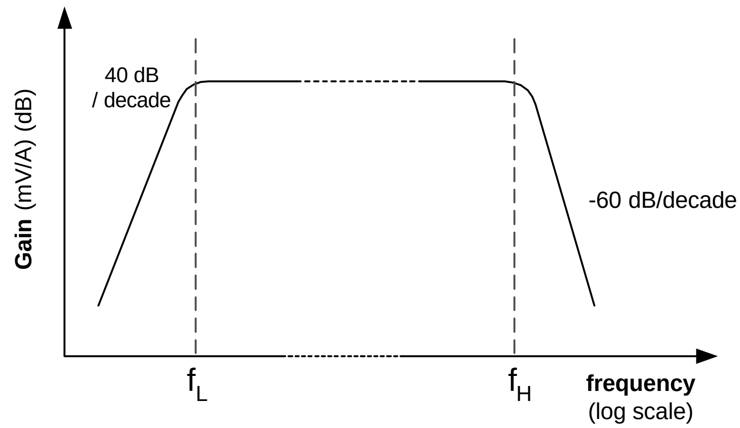
The main feature in common with a current transformer is that a Rogowski transducer does not measure the direct current component, it only measures the alternating components. However unlike current transformers PEM's Rogowski current transducers.....

- do not suffer from magnetic saturation
- can take large current overloads without damage (provided the dI/dt ratings are not exceeded – see Sections 4.2 to 4.5)
- can measure very large currents without increase in transducer size
- have a very wide bandwidth (although this is also true for certain specialised CTs)
- .... and of course are flexible, thin, clip-around and easy to use

2. Frequency Response – measuring sinusoids, quasi sinusoids and pulses

2.1 What is the typical frequency response of a Rogowski current transducer?

For sinusoidal currents the measurement will be within 3dB of the specified sensitivity over a range of frequencies from f_L to f_H which is referred to as the bandwidth, this is shown below.



To ensure that the widest possible range of currents can be measured PEM produce several types of Rogowski current transducer enabling sinusoidal, quasi-sinusoidal and pulsed currents containing frequency components from 0.1Hz to several MHz to be monitored.

2.2 What determines high frequency (-3dB) bandwidth of Rogowski current transducers?

The transducer behaviour at frequencies approaching and exceeding its specified (-3dB) bandwidth is very complicated. It is related to the distributed inductance and capacitance of both the coil and the co-axial cable (which have different characteristic impedances) and their terminations, and to the gain-frequency characteristic for the op-amp IC used for the integrator. It also varies depending on the position of the current within the loop although up to the (-3dB) bandwidth the variation is small.

PEM has produced several publications regarding the high frequency behaviour of Rogowski transducers and these can be downloaded in http://www.pemuk.com/publications.

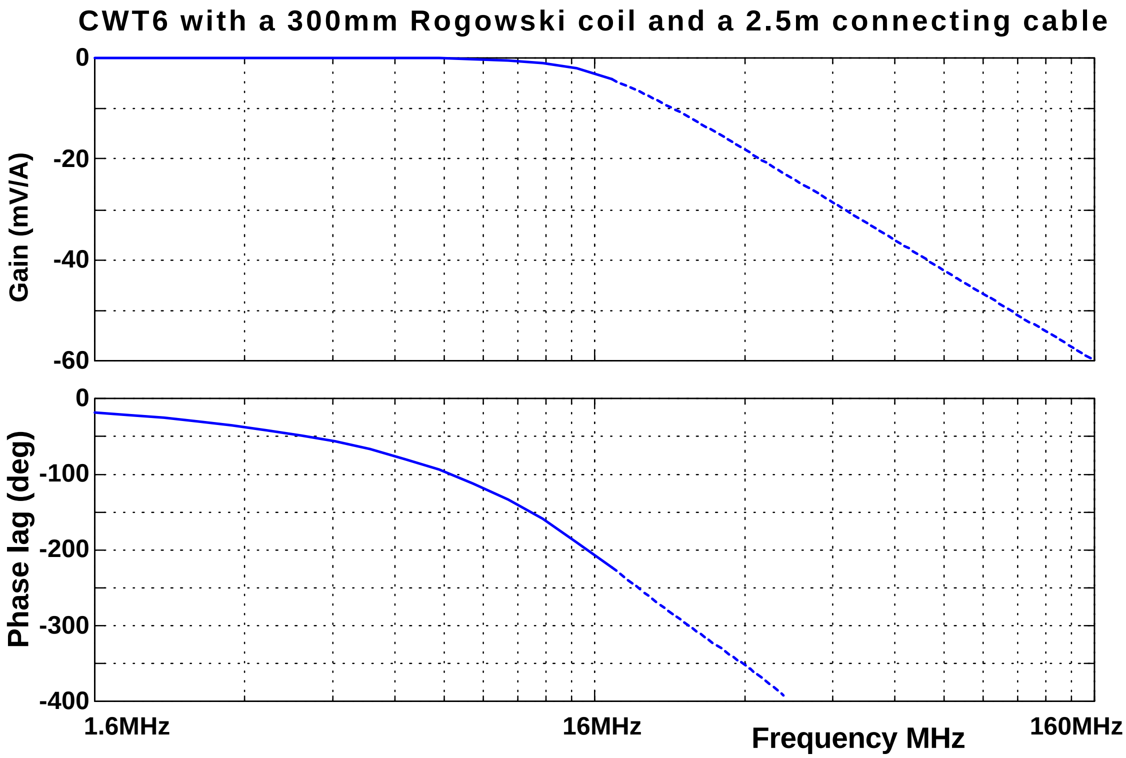
The typical (-3dB) high frequency bandwidth for each type of Rogowski transducer manufactured by PEM is listed on the relevant specification sheet. These can be downloaded in http://www.pemuk.com/products. The values given assume the current is centrally distributed within a circular coil loop.

2.2.1 Phase shift and attenuation of sinusoidal currents from kHz to MHz

For sinusoidal current at frequencies approaching the specified bandwidth the measurement gain (mV/A) reduces and there is an increasing phase delay.

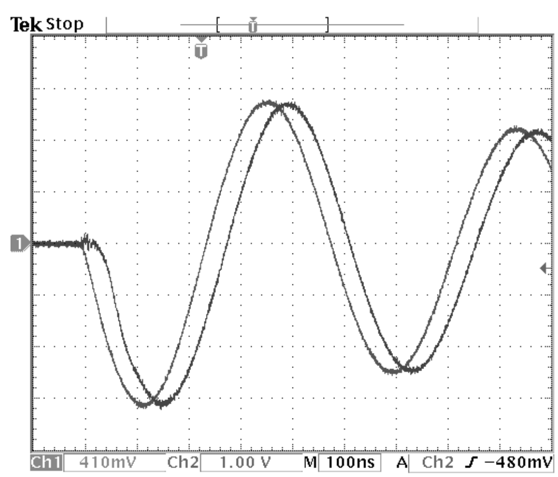
PEM Ltd has a detailed computer simulation of the coil-cable-integrator system and can predict the measurement performance for any type of pulse or waveform e.g. phase shift at a given frequency. If you have questions regarding the high frequency behaviour of a particular transducer please contact us.

The figure below is a simulation of the high frequency performance of a new addition to PEM's CWT range, the CWT6, with a 300mm coil and a 2.5m cable.

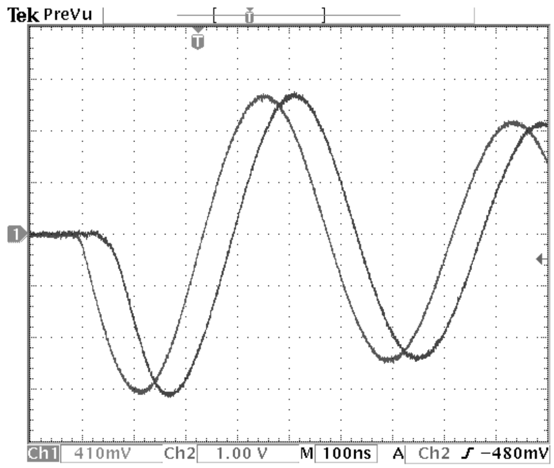


The dashed line shows the ideal response above the –3dB limit and is only typical since the performance becomes more dependant on current position as the frequency increases. The 2.5m cable provides a significant proportion of the phase delay (4.5 deg per MHz).

As an example the picture below and the picture on the next page show a comparison between - a CWT6 with $f_{H(-3dB)}$ = 16MHz, a CWT6LF with $f_{H(-3dB)}$ = 6.5MHz and a 50 MHz coaxial shunt. The CWT6LF has a lower high frequency bandwidth and shows some slight distortion and increased delay over the CWT6.



Measurement of a 2MHz damped sinusoid timebase = 100ns /div – CWT6 with a 300mm coil and 2.5m connecting cable versus a coaxial shunt

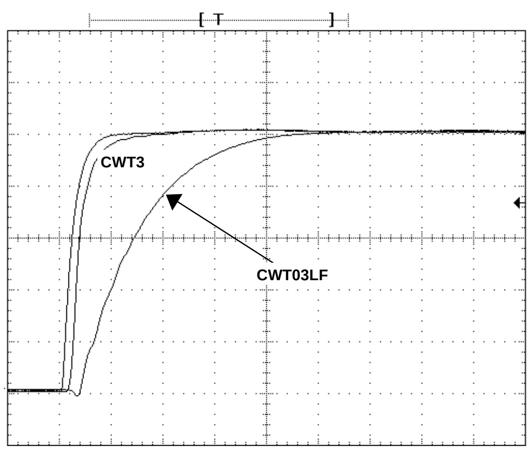


Measurement of a 2MHz damped sinusoid timebase = 100ns/div – CWT6LF with a 300mm coil and 2.5m connecting cable versus a coaxial shunt

Where very high frequency bandwidths are required and low frequency performance can be sacrificed PEM can produce custom designed Rogowski current transducers featuring passive integration - see http://www.pemuk.com/products/custom.htm.

2.2.2 Measuring fast switching transients (sub µs)

In practice, transducer users are unlikely to be measuring sinusoidal currents at several MHz but they can be measuring current pulses, or current waveforms with fast switching edges, which contain harmonic components extending into the MHz range. Such pulses or switching transients may suffer some distortion of shape and will have a measurement delay in the region of 20 to 200ns depending on the transducer bandwidth and the length of connecting cable.

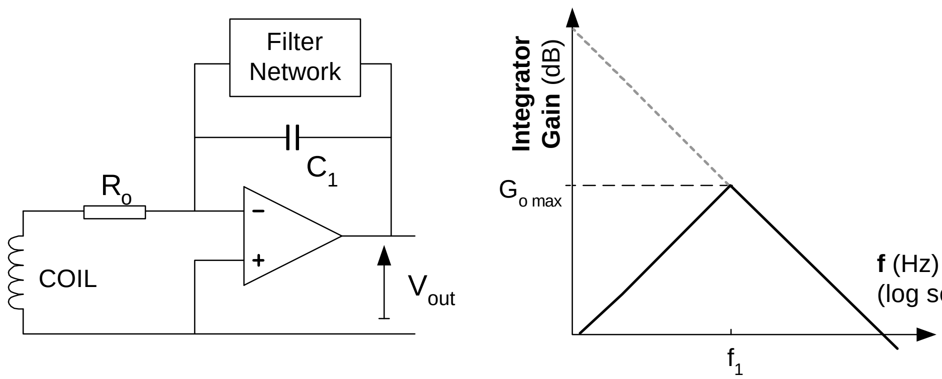


Measurement of a fast switching edge - timebase = 250ns/div - 10A/div (100A/div in case of CWT3)

CWT03LF with a 200mm Miniature coil and 4m connecting cable
CWT3 with a 500mm coil and a 2.5m connecting coil
High performance Current Transformer – 70MHz – 0.1V/A

2.3 What determines the low frequency (-3dB) bandwidth of Rogowski current transducers?

The integrator gain increases as frequency is reduced and in theory becomes infinite as the frequency approaches zero. The bandwidth of the integrator must be limited otherwise the gain at very low frequencies and the dc drift will be excessive. The limitation is achieved by placing a low pass filter in parallel with the integrating capacitor. The diagram below shows a simplified version of the integrator circuit which is sufficient to explain the performance limitations.



The overall transducer gain-frequency relationship is as shown in section 2.1. The (-3dB) bandwidth f_L is usually approx. 20% greater than the filter break frequency f_1.

Setting the low frequency (-3dB) bandwidth is a compromise between

- the capability of the transducer to measure small currents at low frequency
- minimising the phase shift and droop
- … maintaining a good high frequency bandwidth.

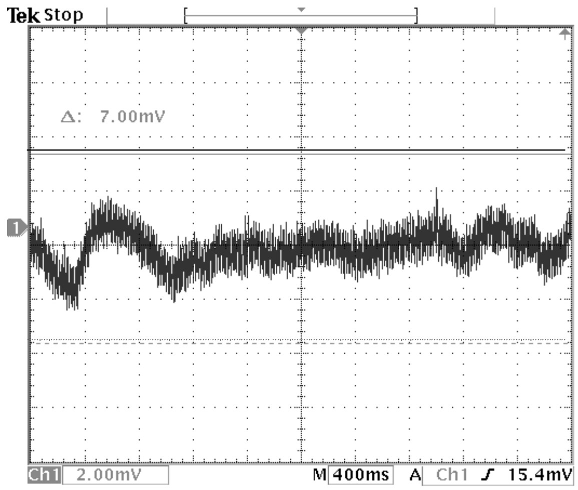
2.3.1 Phase shift, small currents and low frequency noise

Rogowski transducers can readily measure large currents at low frequencies or small currents at high frequencies but they are not as suitable for measuring low currents (e.g. 10mA) at low frequencies (e.g. 50Hz). This section explains why.

The integrator op-amp generates low frequency random noise (1/f noise) which is distributed around the low frequency bandwidth where the integrator gain is at a maximum. The magnitude of this noise is proportional to $1/f_1H$ where H is the coil sensitivity. The value of 'Noise max' for each transducer is listed on the specification sheet as a peak to peak voltage. An example of low frequency noise for a CWT15 is shown on the next page where the magnitude of the predicted noise (7mVp-p) is shown by the cursor bars on the oscilloscope trace.

To minimise the noise, the low frequency bandwidth can be reduced, (i.e. f_L increased), but this results in increased phase distortion at low frequencies. Alternatively coils with a higher value of H can be used but, because this increases the coil inductance, this also reduces the high frequency bandwidth of the transducer.

For the majority of PEM's transducers a compromise between the values of noise max and low frequency bandwidth is reached such that the transducer has a small phase lead at 50Hz (typically 1 to 2^o).



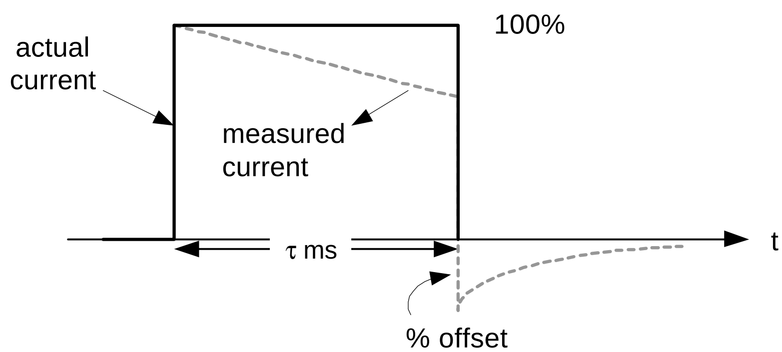
Measured low frequency noise from a CWT15 transducer timebase = 400ms – 2mV/div

For high sensitivity ranges of CWT (200mV/A to 20mV/A) the integrator gain is relatively high and the low frequency bandwidth has to be reduced to keep the noise down to acceptable levels. For example the CWT015 with a sensitivity of 200mV/A and peak current of 30A has a f_L bandwidth of 150Hz.

Conversely the CWTLF range has an extended low frequency bandwidth so that it is suitable for measuring small currents at low frequency. For example the CWT15LF has an f_L = 0.11Hz compared to the CWT15 where f_L=0.8Hz. To achieve this a coil with a high H value is used and the penalty is a reduced high frequency bandwidth.

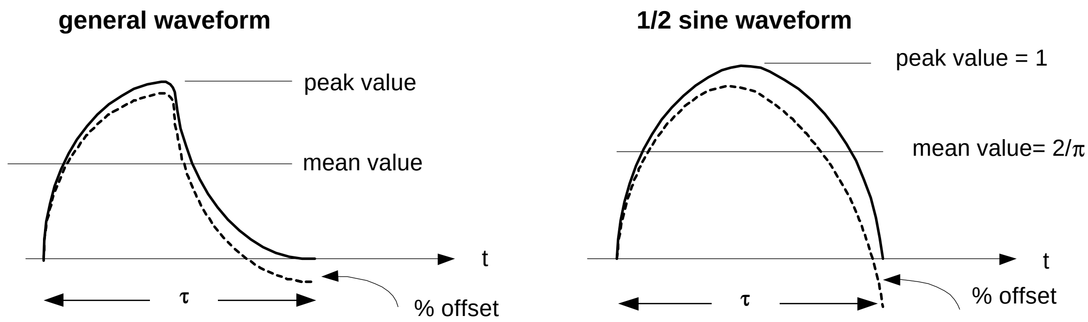
2.3.2 Measuring long (ms to 100's ms) pulses of current and the droop effect

For non-sinusoidal current waveforms (such as a chopped or rectified current) the effect of the phase displacement at low frequencies will cause some distortion of the waveform. This also applies for current pulses of relatively long duration. This distortion is termed droop and the effect is shown below.



The output eventually decays exponentially to zero with a time constant T determined by the low frequency bandwidth of the unit. PEM define a value of droop for a rectangular pulse in %/ms for each transducer. The droop value for a particular unit is listed on the relevant specification sheet.

The diagram below shows how the '% offset' for a given pulse of time duration τ (where τ<<T) can be calculated given the droop value for a rectangular pulse



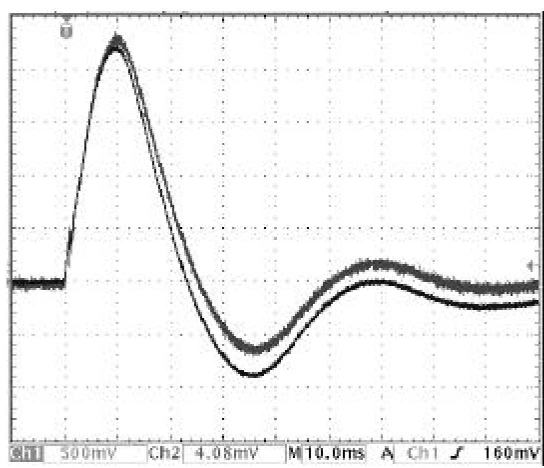
So for the general waveform

$$\% \text{ offset} = \tau \text{ x (mean value / peak value) x (droop in \%/ms)}$$

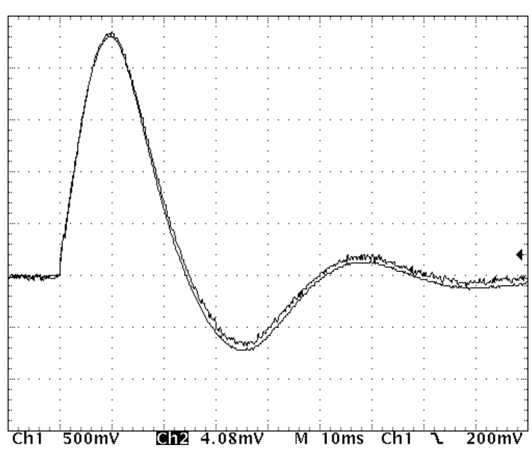
e.g. for the ½sine waveform

$$\% \text{ offset} = \tau \text{ x } (2 / \pi) \text{ x (droop in \%/ms)}$$

The two oscilloscope traces below show a practical comparison between measurements by - a CWT6, CWT6LF and a coaxial shunt. The shunt has no droop. The CWT6LF has a much improved droop performance due to its lower f_L=0.27Hz compared to f_L= 1.0Hz for the CWT6.



Measurement of a capacitor discharge time=10ms/div – 100A/div – CWT6 versus a coaxial shunt



Measurement of a capacitor discharge time=10ms/div – 100A/div - CWT6LF versus a coaxial shunt

3 Accuracy and Calibration

3.1 How do PEM calibrate their transducers (and to which standards)?

Where the sensitivity ≤ 10mV/A

The transducers are calibrated with a 50Hz test current approximately central in the loop and perpendicular to the plane of the coil. RMS currents of 400A, 1000A, 2000A, or 4000A at 50Hz are used depending on the transducer rating. An ac current controller has been developed which keeps the test current constant to better than 0.2%. A UKAS calibrated 4000:1 current transformer and burden resistor are used for comparison with the transducer reading. The transducer integrator gain is trimmed to give a reading within 0.2% of the specified output for the transducer.

Since the integrator gain is set by high stability resistors and capacitors little change if any of the transducer sensitivity with time is expected. Transducers that have been returned for calibration after several years of use have needed less than 1% adjustment.

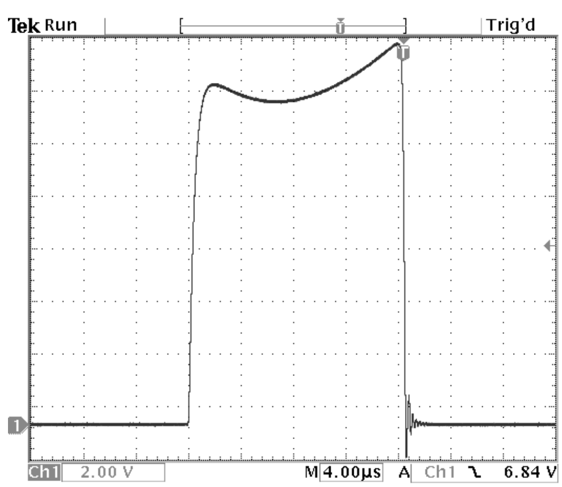
The ac current controller was the subject of a conference paper at the 1999 European Conference on Power Electronics and can be downloaded from http://www.pemuk.com/publications.

Where the sensitivity ≥ 20mV/A

The transducers are calibrated with a 2kHz test current distributed around the coil circumference (in such a way as to approximate to a current central in the loop). RMS currents in the region of 10A to 100A are used depending on the transducer rating. A precision signal generator and wide-bandwidth amplifier generate the test current. A UKAS calibrated wide-bandwidth CT is used for comparison purposes. The transducer integrator gain is trimmed to give a reading within 0.2% of the specified output voltage for the transducer.

High Frequency performance

The high frequency performance is checked using a 17µsec pulse of approx. amplitude 150A, 300A or 1500A depending on the coil sensitivity. The pulse has fast rising and falling edges as shown below (with dI/dt up to 7000A/µs). The pulse is measured by the Rogowski transducer and by a 20MHz Pearson CT for comparison.



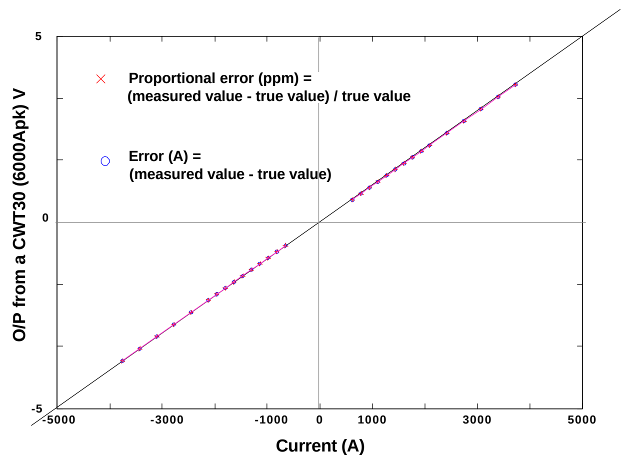
Timebase = 4.0 ms

3.2 Linearity

Linearity error is the difference ΔI between the true current value, I ,and the measured value V_{out}/ R_{SH} (where R_{SH} is the transducer sensitivity). For a fixed frequency and fixed current position the linearity error will vary with the current magnitude over the rated range of the transducer.

Because Rogowski current transducers contain no magnetic materials they are expected to be very linear since there are no saturation or non-linear effects associated with the magnitude of the current.

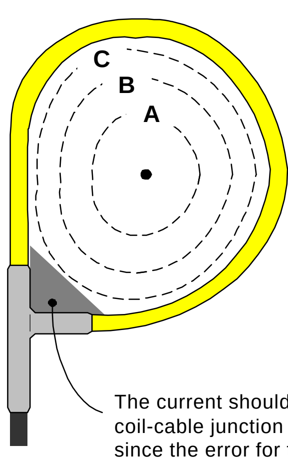
For example a test was made using a CWT30 (R_{SH} = 1.000 mV/A and a rated peak current of 6kA). A 50Hz current was kept in a fixed position, central to the coil-loop, and increased in steps of 200A from zero to its rated value. It was found that the maximum difference was 1.7A (with 3600A current) and the maximum proportional difference was 930ppm (1.3A difference with 1400A current). The linearity was therefore found to be better than 0.05% of full scale or 0.1% of actual reading. The linearity may in fact be better than this since the accuracy of measuring the current was of the same order as the differences.



3.3 Positional Accuracy

Due to small variations in the winding density and coil cross-sectional area the transducer output varies slightly depending on the position of the current within the coil loop. For standard coils the error associated with moving the conductor under test around the current loop is typically ±1% of the calibrated value, for miniature coils typically ±2% of the calibrated value.

The diagram below shows the variation of accuracy throughout the coil. The variation is greatest when the current is positioned near the junction of the connecting cable and the coil, where there is some discontinuity, and the error here can be typically 4%. Since in most applications the current is distributed throughout a significant part of the area contained by the coil loop the reading will be very close to the calibration value.



POSITIONAL ACCURACY OF A STANDARD ROGOWKSI COIL - % error with a point source of current

Type	A	B	C
Miniature Coil	±0.5%	±1%	±3%
Standard Coil	±0.5%	±1%	±2%

The current should not be positioned close to the coil-cable junction (shown by the shaded area) since the error for this region is greater.

3.4 The effect of external currents and voltages external to the Rogowski loop

Error can also arise due to the presence of currents close to but outside the Rogowski coil loop which ideally should not provide any reading. However an external current of magnitude 100A close to the side of the coil will give a reading of up to ±2A. This error will significantly decrease as the external current becomes more distant from the coil.

If the external current (outside the coil loop) is much greater than the current being measured (inside the coil loop) then the error may be significant. This is particularly relevant if the external current is flowing in a nearby multi-turn coil.

Similarly if there is a surface with a high voltage very close to the coil, and the voltage is subject to high rates of change (e.g. several 100 V/µs) or high frequency oscillations in the MHz range, then interference can arise due to capacitive coupling with the coil.

As a check for the effect of external currents or voltages the user should place the Rogowski coil in approximately the same position as used for measuring the desired current, but not looped around the desired current. Ideally there should be no measured signal. If there is interference then the same interference will be superimposed on the current waveform when it is measured and this can be taken into account when interpreting the measurement.

3.5 Temperature

The overall sensitivity of Rogowski transducers varies with temperature because over the rated temperature range

- the coil sensitivity reduces with increasing temperature mainly due to expansion of the plastic former of the coil.
- the passive component values which set the integrator time constant, drift slightly with temperature.

These sources of error are minimised by using a plastic former with a very low expansion coefficient and using high stability capacitors and resistors.

A summary of the effect of temperature for each product type is included in the table below:

Product Type	Rogowski coil		Integrator	
	Temperature range (^{o}C)	Thermal coefficient (ppm/^{o}C)	Temperature range (^{o}C)	Thermal coefficient (ppm/^{o}C)
CWT	-20 to 100	-150	0 to 40	±100
CWT Mini	-20 to 100	no data	0 to 40	±100
RGF	-20 to 70	-200	0 to 50	±120
IRF	-20 to 70	-200	-10 to 55	±120

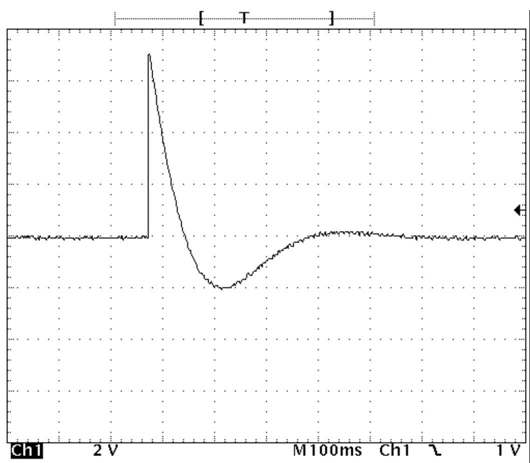
4 What happens the current rating of the transducer is exceeded?

4.1 Peak Current

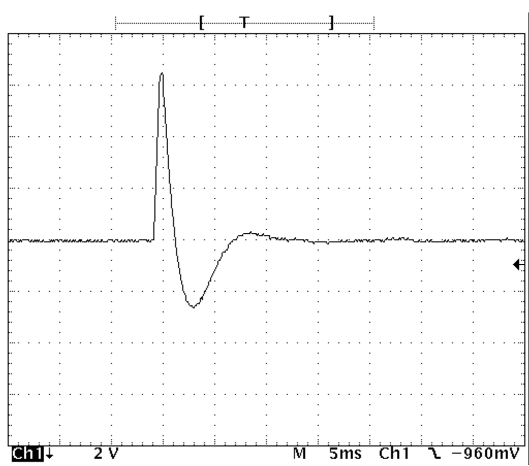
The transducers are designed to have an output of 6V for the rated peak current. If the peak current exceeds its rating the integrator will saturate and the measured waveform will be completely corrupted (unlike an amplifier for which the output waveform is merely clipped).

Exceeding the peak current rating will not damage the transducer provided the dI/dt ratings are not exceeded. It will return to normal operation after the current surge has passed.

The time it takes for the transducer to return to normal operation once the surge has passed is dependent on the low frequency bandwidth of the unit. For example the following oscilloscope traces show the recovery of a CWT03 and a CWT03LF from saturation. Both transducers are subjected to a step of dc current of 100A which is sufficient to cause saturation (the peak current rating is 60A corresponding to an output voltage of 6V). The CWT03LF has an extended low frequency bandwidth f_L= 2.2Hz and it takes the transducer approximately 350ms to recover from saturation. The CWT03 on the other hand has an f_L = 105Hz and has recovered from saturation in approximately 13ms.



CWT03LF - f_L = 2.2Hz - Timebase 100ms



CWT03 - f_L = 105Hz - Timebase 5ms

4.2 RMS current

There is no limit on rms current.

4.3 Peak di/dt

This is the maximum di/dt above which the transducer will fail to correctly measure the current. Values are given on the specification sheet.

4.4 Absolute maximum di/dt (peak)

The transducer can be damaged by excessive dI/dt due to the voltage generated in the coil. The specification sheet gives an absolute maximum rating for dI/dt for each transducer that must not be exceeded.

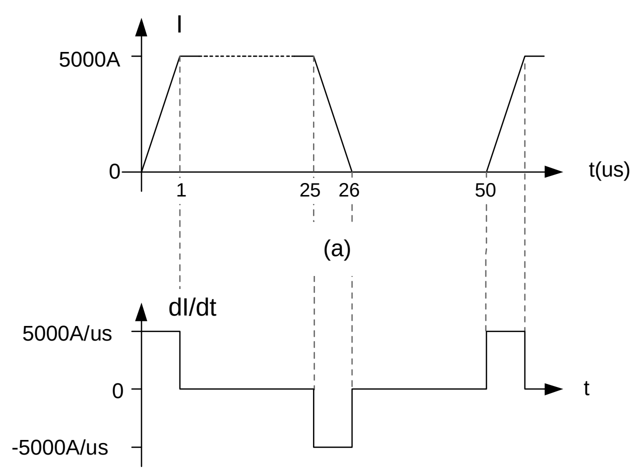
4.5 Absolute maximum di/dt (rms)

The transducer can also be damaged by sufficiently high repetitive dI/dt even though the peak dI/dt rating is not exceeded. A damping resistor is used to provide correct termination of the Rogowski coil and cable to prevent reflections (seen as high frequency damped oscillations) appearing on the measured waveform. A high repetitive di/dt will cause excessive power to be dissipated in this resistor.

For **sinusoidal waveforms** the calculation of rms di/dt is straight-forward,

di/dt rms = $2\pi f I_{rms}$ (where f is the measured frequency and I_{rms} the rms value of the measured current)

For **pulsed waveforms** an example of how to calculate the di/dt rms is shown below,



Consider the current waveform shown in Figure (a) with a repetition frequency of 20kHz. Figure (b) shows the corresponding dI/dt waveform.

The rms dI/dt is given by 5000 A/µs x $(1\mu s/25\mu s)^{0.5}$ = 1 kA/µs rms.

Where very high di/dt ratings are required and low frequency performance can be sacrificed PEM can produce custom designed Rogowski current transducers with passive integration (see Products).

5 Output loading and cabling

With the exception of the IRF range of Rogowski transducers the minimum input impedance for any measuring device (oscilloscope, DVM, power recorder etc.) connected to the transducer must be 100kΩ or greater for rated accuracy.

The IRF requires an input impedance of at least 10kΩ for rated accuracy. The IRF is designed for permanent installation into equipment and the lower input impedance allows it to interface with a wide range of data acquisition equipment.

The output impedance of all PEM's Rogowski current transducers is approximately 50Ω. Any cables used to connect the output of the transducer to the data acquisition device, longer than the 0.5m co-axial cable supplied with the unit, should be 50Ω singly screened coaxial cable. Although at present cables longer than 0.5m have not been included in the immunity tests and may decrease RF noise immunity, PEM does not consider the use of extension cables to be problematic from the noise viewpoint. PEM has conducted tests using a 25m extension and no discernible attenuation of measured current signal has occurred although, as is to be expected, there is an increased measurement delay of 5ns/m.

PEM's Rogowski current transducers cannot be terminated into a 50Ω impedance. The integrator op-amp has insufficient output current capacity to drive a 50Ω load.

6 How do PEM rate the voltage insulation of their Rogowski coils?

The CWT and RGF ranges of Rogowski current transducers are intended for instrumentation use and not for permanent installation on equipment. The peak voltage insulation ratings for these transducers reflect the fact the transducers are not to be used continuously at high voltages.

Every Rogowski coil supplied by PEM is given a peak voltage insulation rating. The rating is derived from the following test:

The coil is exposed to an ac ***test voltage (kV) = (2 x Peak voltage rating + 1) / √2 (kV)****, for 60 seconds at 50Hz. So for example a 5kV peak insulated coil will be flash tested at 8kVrms (11kV peak), 50Hz, for 1 minute.*

The user should visually inspect the Rogowski coil and cable for insulation damage each time the transducer is used. Every Rogowski coil has at least two layers of insulation covering the winding. These are always different colours making visual inspection of the integrity of the insulation easier.

It is imperative that the user grounds the BNC connector from a safety viewpoint so that in the event of an insulation breakdown at the coil (due to exceeding the voltage rating or due to mechanical damage), a fault current path exists via the co-axial cables to the grounded BNC connector.

The practice of “floating the oscilloscope” which results in the BNC connections being isolated from ground is strongly deprecated.

6.1 What advice do PEM have for customers using Rogowksi coils continuously at high voltage?

As for the majority of plastics the material used for insulating PEM’s Rogowski coils can be damaged by exposure to corona over a reasonably long period of time.

The Rogowski coils for CWT’s and RGF’s have been designed for intermittent use at voltages no greater than the peak voltage to ground specified by PEM. For these conditions the effects of corona are small and the degradation of coil insulation is negligible. Furthermore the coil can and should be inspected for damage to the insulation each time it is used.

The IRF has been designed for permanent installation and hence continuous exposure to nearby voltages. For voltages to ground of less than 3kV peak (i.e. 2kVrms for a sinusoidal voltage), corona effects will be negligible, and continuous operation is permitted.

For voltages to ground of more than 3kV peak the coil must be sufficiently distanced from the high voltage conductor or device, using air and / or insulating materials such that corona does not occur in the vicinity of the coil. Sharp corners should be avoided on the high voltage structures near the Rogowski coil as sharp corners lower the voltage at which corona begins. PEM has no control on how its customers install Rogowski coils, and hence the responsibility for long continuous life when operating in a HV environment lies with the customer.

PEM’s 1 minute flash test, applied to all coils during manufacture, establishes the integrity of coil insulation when despatched and is not intended to apply to continuous exposure to voltages in excess of 3kV peak when the high voltage conductor / device can be very close to or touching the coil.

7 Datasheets – Glossary of terms

Datasheets are available for

- CWT standard range
- CWT miniature range
- CWT LF range
- RGF range
- IRF range

The datasheets specify various performance parameters for each transducer in the range. These are briefly summarised below. More detailed explanation is given in the application notes.

Sensitivity (mV/A) – the instantaneous relationship between the output voltage and the current being measured for the specified frequency range. The sensitivity reduces as the bandwidth limits are approached. See section 2.1.

LF (3dB) bandwidth, f_L (Hz) – the lower frequency limit at which the sensitivity reduces to 70.7% of its specified value. See section 2.3.

HF (3dB) bandwidth, f_H (Hz) - the higher frequency limit at which the sensitivity reduces to 70.7% of its specified value. f_H reduces with increasing coil length. See section 2.2

Peak current (kA) – the maximum instantaneous value of the ac current that can be measured. (AC current is the variation in current with respect to its mean (dc) value). See section 4.1.

Peak di/dt (kA/µs) – the maximum rate of change current that can be measured. See section 4.3.

Absolute maximum values of di/dt (kA/µs) – the values of peak di/dt and rms di/dt which, if exceeded, may damage the transducer. See sections 4.4 and 4.5.

Droop (%/ms) – the rate at which the measurement of a current pulse of constant amplitude will reduce with time. See section 2.3.2.

Noise max. (mV p-p) – the maximum peak to peak variation of random low frequency noise appearing at the transducer output. The noise is mainly distributed at frequencies around the LF bandwidth. See section 2.3.1.

Phase lead at 50Hz (deg) – the phase relationship for the output measurement of a 50Hz sinusoidal current. If the lead at 50Hz is greater than 2 degrees the phase lead is given for a higher frequency for which the lead is approx. 2 degrees.

Provided the phase lead is small, phase lead at other values of low frequency f (Hz) can be obtained from the relationship

$$\text{Phase lead at } f = \text{phase lead at 50Hz} \times (50 / f)$$

Linearity – the variation in sensitivity with current magnitude variation for a current in a fixed position in relation to the coil. See section 3.2.

Accuracy – the variation in sensitivity with variation in current position in relation to the coil. See section 3.3.

Peak Coil Voltage Isolation – the maximum safe voltage at or adjacent to the coil surface for intermittent use. For permanent installation it must be ensured that corona does not damage the coil over a period of time. This may require additional insulation and / or clearance between the coil and high voltage conductors, or operation at lower safer voltages. See section 6.