

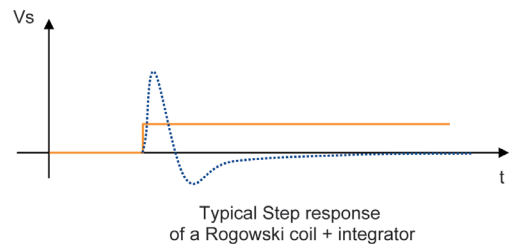
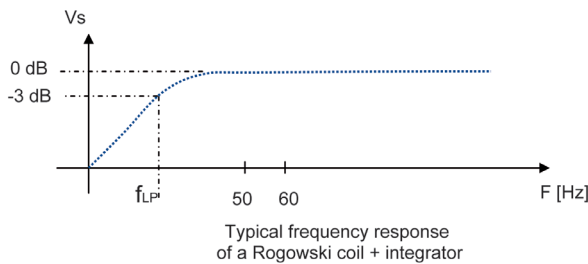


Design of an integrator for the Rogowski coil

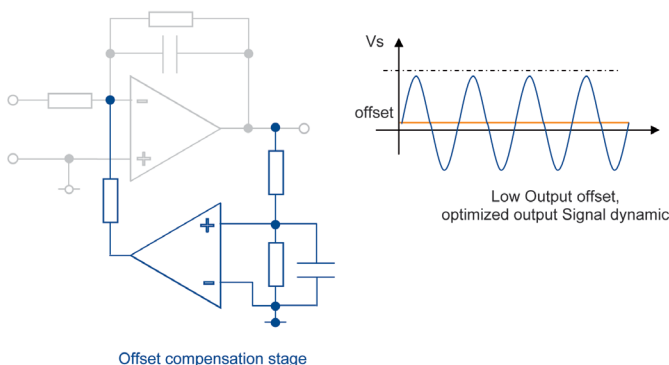
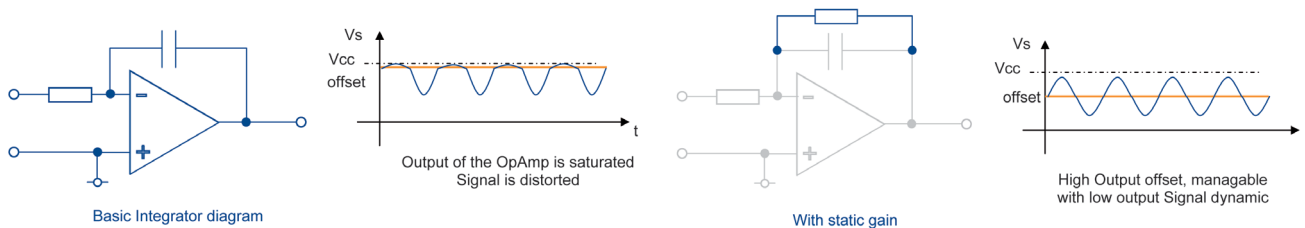
The Rogowski coil supplies a voltage in proportion to the derivative of the primary current at its terminals. An electrical integrator circuit is therefore necessary to convert this signal into a signal that is proportional to the value of the primary current.

The integrator is an essential component in current measurement with the Rogowski coil, and the way this amplification stage is implemented will have a major impact on the sensor's electrical performance (linearity, phase-shift and frequency bandwidth). A list of the various critical aspects of such an integrator, with some possible solutions, is given below:

- Very low signal level** (for example 20 mV / kA for sensors in LEM's RT range)
 The use of very low noise OpAmps is recommended to optimize the signal/noise ratio
 It is necessary to try to minimize the surface of the PCB or possibly to shield the amplification stage to reduce sensitivity to external fields.
- Low cut-off frequency**
 When an integrator is connected to a Rogowski coil the two form a high-pass filter. Since it will reject very low frequencies it is necessary to define the cut-off frequency in order to optimize performance at the nominal operating frequencies, while still obtaining the best possible response time.



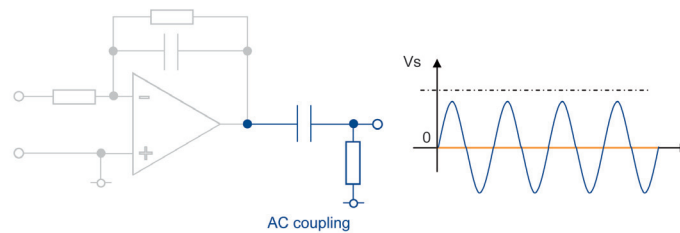
- Rejection of offset**
 The main problem of a pure integrator lies in the fact that it will integrate the slightest parasitic offset (e.g. due to the AmpOp), with the effect that the output will always be unstable and will drift sooner or later to saturate at the upper or lower level. Consequently it is essential to limit this drift, using a static gain or an active compensation stage:



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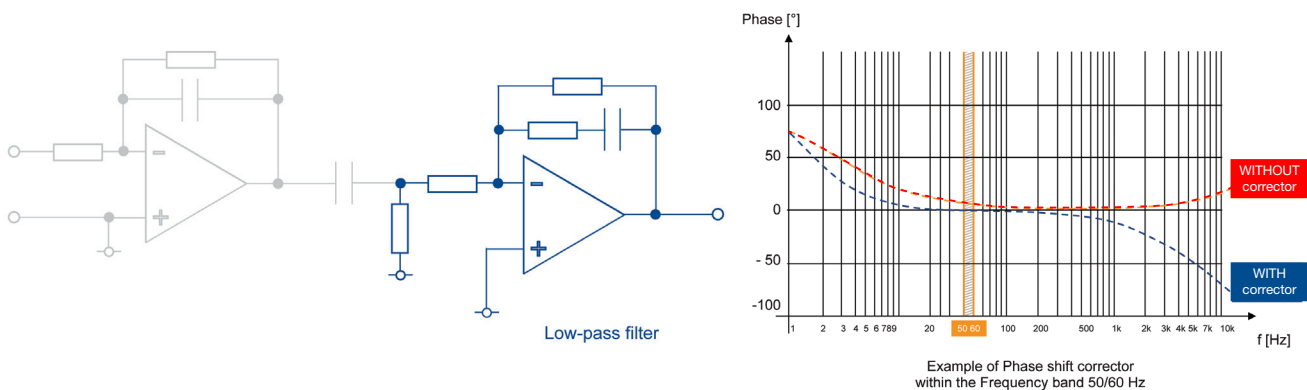
- **Total offset rejection**

It is possible to completely eliminate the residual offset by adding a capacitive coupling device between the integrator and the measuring stage:



- **Phase-shift**

The offset rejection circuits described above will generate several degrees of phase error which poses a major problem for the measurement of power. In this type of application, it is therefore necessary to add a phase-shift compensation stage, which generally consists of a low-pass filter. Unfortunately, the correction will not be constant, but will depend on the frequency, meaning it will be necessary to optimize the design to minimize the phase difference at the fundamental frequency, typically 16 2/3, 50, 60 or 400 Hz.



- **Calibration: active adjustment of gain**

A Rogowski coil requires calibration against a reference signal in order to fine-tune its gain which is never exact by construction, due to inevitable imperfections in the manufacturing process. In general engineers use the integrator stage to which an analogue device, such as a potentiometer, is attached. The most recent digital calibration solutions are more likely to use a microcontroller or the combination of a microcontroller and a PGA (programmable gain amplifier). In all cases calibration is specific to each individual Rogowski coil which must always use the same circuit with which it has been calibrated.

- **Calibration: passive adjustment of gain**

Historically, the Rogowski coil was used simply for measurement of the current effective value (rms) without phase constraint. Many loops offered factory calibration based on a purely resistive or a resistive/capacitive circuit (RC circuit). While this method continues to be straightforward and economical, unfortunately it does not lend itself to power measurements due to the strong phase error that it generates, and its possible dependence on the frequency (if an RC circuit is used).

When developing the new Rogowski coils, LEM decided to offer a simple and generic product, keeping in mind that the integrator technology leads to the best performances and is a well known method. Therefore the transducers of the RT family are not calibrated in the factory, do not use any additional electronic components or housings and do not require power supply. Using an integrator specific to the device connected to the Rogowski such as energy, power quality or pulse power monitor, is a cost effective and high performance solution.