HOW DOES IT WORK?
CURRENT SENSE MAGNETICS

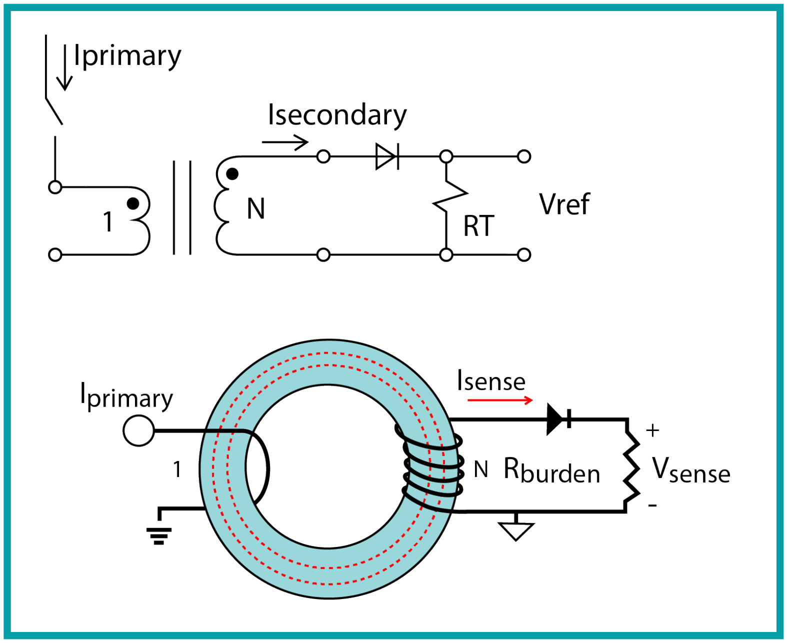
Introduction

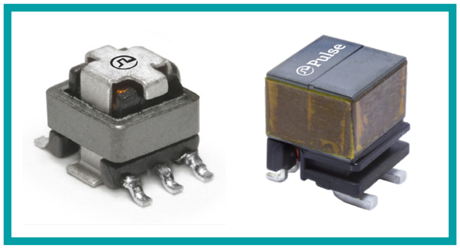
In many power supplies and circuits it is advantageous and even necessary to monitor the currents flowing in, out, or through a power supply circuit. For example, monitoring for transient overcurrent conditions in the output a DC-DC converter to trigger protection circuitry or to monitor the resonant tank current for control of a Resonant LLC circuit.

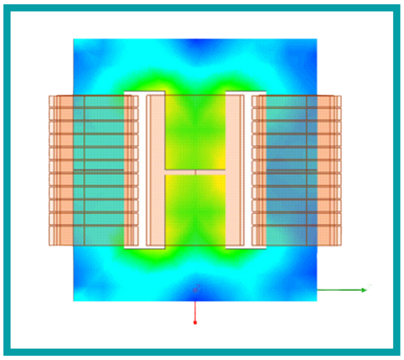
While many AC current sense solutions exist on the open market, the current sense transformer can be an appealing solution in many applications. A combination of low primary DCR, low core losses (due to typically low core flux densities), and small secondary currents give rise to a simple, effective, and low-cost method of sensing AC current.

Current Sense Magnetics - Explained

The operation of a current sense transformer is relatively straight-forward but often misunderstood. A current sense transformer typically has two windings each of which passes through a ferromagnetic core. The primary winding (typically one turn) is designed with low resistance and is in series with the current that is being measured. The secondary winding (typically ranging from twenty to two hundred turns) has higher DCR and carries the much lower current which will be sensed via a burden resistor (Vsense= Rburden*Isense) that is in series with the secondary winding. The sensed voltage (Vsense) can then be fed to a comparator or other IC to take the appropriate action. A typical application circuit can be seen below, although it is possible for the rectifying diode to be omitted depending on the sensing requirements:







Due to Faraday's law as the primary current passes through the winding it creates a magnetic field proportional to the current multiplied by the number of primary turns. The magnetic field then passes through the secondary winding creating a current in the secondary which is proportional to the magnetic field divided by the number of secondary turns. In general, a simplified mathematical analysis of the current sense circuit can be used to get a first pass at selecting the required turns ratio and Sense Voltage.

- Assume an H field (magnetic field),Hpri, is generated and proportional to Iprimary*Nprimary
- The AC magnetic field generated by the primary, Hpri, will create an H field of equal magnitude in the secondary winding, otherwise said Hpri = Hsec
- The current, Isense generated in the secondary winding is proportional to Hsec/Nsec
- It then follows that Iprimary*Nprimary = Isense*Nsec or more commonly recognized as Nprimary/Nsec = Isense/Iprimary
- Therefore Isense = Nprimary/Nsec*Iprimary
- By Ohm's Law, then Vsense = Isense*Rburden and a proper terminating resistor can be selected to ensure the proper sense voltage range.

As noted, the secondary current (Isense) is passed through a sense resistor (Rburden)to create the voltage (Vsense). Although, Pulse Electronics offers multiple turns ratios for any given platform, it is clear that to produce a desired Vsense one can either change the turns ratio or change the sense resistor. In principle using a larger turns ratio, for a given Vsense, will allow for lower frequency operation as the flux in the core is reduced. In reality, for any high frequency (>20kHz) application the ratio is not critical as the flux in the core is typically very low.

Current Sense Magnetics - Saturation

Many customers worry about 'saturating' (ie: putting too much flux through the core) due to the high primary side currents. This misunderstanding possibly originates by looking at the current sense in the same way as one looks at an inductor. In an inductor application the flux in the core is proportional to the inductance times the peak current because all of the energy is stored in the core.   However, in a transformer application the flux generated by the Lpri*Ipri is immediately balance by the energy removed from the core (Lsec*Isec) and therefore there is no saturation or energy storage that is strictly related to the primary current. A more accurate view of the flux generated in the current sense is to look at the voltage across the secondary winding. In general, this sense voltage is low (<1v, typically <200mV) and the secondary turns are relatively high (>20T). As the flux in the core is proportional to the Voltage / (Turns*Freq) it is clear that unless the frequency gets very low (<kHz) the flux will be very low (typically <20G) and therefore there is often no need to be concerned about saturation when using a current sense transformer. It is critical to note that although a DC current in the primary will produce a proportional DC magnetic field in the core this DC magnetic field will not induce, again per Faraday's law, any DC current in the secondary winding. As a result, a current sense transformer cannot be used for DC sensing.

Conclusion

Current Sense Magnetics are an efficient and easy solution for measuring AC current in a variety of switch mode power supply applications. The operation, as reviewed, is fairly straight-forward.   Pulse Electronics has a wide-variety of catalog solutions for measuring currents from 4A to 50A in both through-hole and surface mount terminations and are available in functional, basic and reinforced insulation systems. For more information please see our Current Sense Magnetics Overview

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