# SELECTING CURRENT TRANSFORMERS FOR ACCURACY AND CAPABILITY

*1) Basic Equivalent Circuit*

The diagram shown in Figure 1 gives a basic model for a real Current Transformer of torroid design.

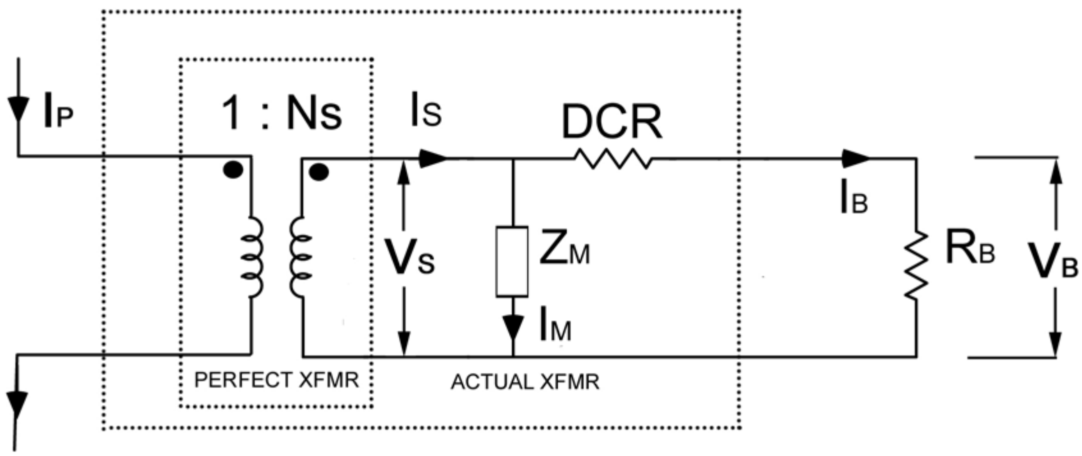


***FIGURE 1***

Assuming a single turn on the primary with a secondary turns count of Ns, the perfect secondary current Is is equal to the primary current $I_P$ divided by the number of secondary turns.

To model real world conditions, a complex impedance $Z_M$ is placed across the output, and an associated magnetizing/excitation current of $I_M$ is realized.

Additionally, a series dc resistance called the DCR is also placed into the model which is typically the dc resistance of the secondary winding.

The output current $I_B$ is then applied to a user specified burden resistance $R_B$ to generate the desired voltage for signal processing and measurement.

*2) Mathematical Analysis*

From the schematic of Figure 1, $I_S$ equals the sum of $I_M$ and $I_B$. It is important to remember that the values in the model are vector values meaning they have an amplitude and phase. $I_M$ is a vector quantity with a magnetizing component that is 90 degrees out of phase with $I_S$, and a heating component that will be in phase with $I_S$. Figure 2 shows the diagram that represents the vector addition of $I_M + I_B = I_S$.

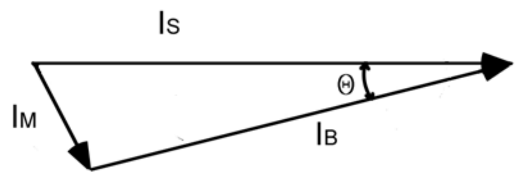


***FIGURE 2***

The resulting output current $I_B$ is then less than the perfect ideal current $I_S$, and is out of phase with the perfect current $I_S$ by the phase angle Θ (theta).

*3) Engineering Specifications*

Figure 3 shows a typical engineering specification from CR Magnetics.

| Part Number | $I_r$ | Vmax RMS | Te (typ.) | DCR Ω |
|---|---|---|---|---|
| CR8348-2500-N | 40 | 7.5 | 2510 | 134 |

***FIGURE 3***

**Ir** – This is the primary current rating of the part. This number is determined by the gauge of the secondary, the capability and size of the core, and the limits of linearity.

**Vmax** – This is the saturation point of the CT. Derived from core materials, size of core, and number of secondary turns, this is the maximum $V_S$ that the part can develop due to maximum magnetizing of the core.

**Te** – This represents the effective turns ratio of the part. As shown in Figure 2, the output amplitude of the current transformer ($I_B$) will be a bit less than the perfect output according to the turns ratio. The Te will be higher than the actual turns wound on the part.

**DCR** – Represents the DC series resistance of the secondary winding. This can vary as much as 10%.

*4) Choosing a Part*

CR Magnetics offers various sizes and construction materials in its current transformer offerings. Each type has specific characteristics that make it particularly suited for typical applications that engineers are challenged with. Typically, the following steps are needed to select the best solution.

**Primary Current Rating** – This is the first selection. A CT physical size is first matched with the needed full scale measuring amount. Higher currents mean larger gauge wire, so the window size is critical here.

**Output Voltage** – In most cases, there will be circuitry connected to the CT sensor that processes the signal. This engineer designed circuitry will have a voltage level input requirement. The CT chosen should have a Vout capability that is at least 20% below saturation for linearity. An easy formula is given on our CT spec sheets to help guide the designer in choosing this value. Please note the lower the voltage required from a CT, the more accurate it will be.

**Accuracy** – This is a combination of amplitude and phase angle accuracy. Core material, number of turns, and degree of saturation of the magnetics will determine the amplitude and phase angle accuracy.

Figure 4 shows a quick guide to selecting CR Magnetics current transformers based upon materials and their relative accuracies. This provides a good starting point for the selection process.

The guide in Figure 4 gives typical accuracy numbers for common applications. A known input current and a known burden is required to estimate application accuracies. CR Magnetics engineers are ready to assist you in determining the accuracies available for your particular design.

CR Magnetics has been providing targeted solutions to our customers for 30 years. Our support will insure that you will receive the best solution for accuracy, performance, and cost for your specific application. Please contact us today!

| CT Line | Core Material | Saturation Voltage | Amplitude Accuracy | Phase Accuracy | Frequency | Losses | Temperature Variance | Cost | Typical Applications |
|---|---|---|---|---|---|---|---|---|---|
| General Purpose | Silicon Steel | High | 1% | < 1 Degree | 1000 | highest | high | $ | Low Cost, non-revenue sensing applications. Use for high voltage output designs which need to drive LEDs, switches, and relays. Low accuracy sensing such as motor controls and indication of current. |
| Revenue Grade | Nickel-Steel | Low | 0.20% | < 20 minutes | 1000 | lowest | very low | $$$ | Power metering applications. Temperature independent sensing. High accuracy applications such as energy mangement and load sensing. Low current sensing applications such as ground fault and leakage detectors. |
| High Frequency | Ferrite | Medium | 1% | < 1 degree | up to 200K (1) | highest | high | $ | SMPS power supply current sensing. Low cost high frequency indicators. High frequency power systems and motor drives. |
| DC Immune | Special | Medium | 0.50% | < 1 Degree | 1000 | medium | medium | $$$ | Special applications which have DC component on power signal. Specifically, special CT used to prevent theft of power from grid utilizing half-wave illegal connections. |
| Amorphous/Nano | Special | High | 0.50% | < 100 minutes | up to 200K (1) | small | low | $$ | Modern material with combination of advantages of other materials. High frequency, good saturation voltage, and high initial permeability makes for good replacement for ferrites and silicon steel. Drop in replacement to increase accuracy over all materials except nickel. |

(1) Contact Factory for applications above 20 Khz

***FIGURE 4***