

Application

Current Transformers (CT's) are instrument transformers that are used to supply a reduced value of current to meters, protective relays, and other instruments. CT's provide isolation from the high voltage primary, permit grounding of the secondary for safety, and step-down the magnitude of the measured current to a value that can be safely handled by the instruments.

Ratio

The most common CT secondary full-load current is 5 amps which matches the standard 5 amp full-scale current rating of switchboard indicating devices, power metering equipment, and protective relays. CT's with a 1 amp full-load value and matching instruments with a 1 amp full-range value are also available. Many new protective relays are programmable for either value.

CT ratios are expressed as a ratio of the rated primary current to the rated secondary current.

For example, a 300:5 CT will produce 5 amps of secondary current when 300 amps flows through the primary. As the primary current changes the secondary current will vary accordingly. With 150 amps through the 300 amp rated primary, the secondary current will be 2.5 amps ($150 : 300 = 2.5 : 5$). When the rated primary amps is exceeded, which is usually the case when a fault occurs on the system, the amount of secondary current will increase but, depending on the magnetic saturation in the CT, the output may not be exactly proportional.

Polarity

All current transformers are *subtractive polarity*. Polarity refers to the instantaneous direction of the primary current with respect to the secondary current and is determined by the way the transformer leads are brought out of the case. On subtractive polarity transformers the H1 primary lead and the X1 secondary lead will be on the *same* side of the transformer (the left side when facing the low-side bushings). See the article *Understanding Transformer Polarity* in the Archive Catalog of the Kilowatt Classroom Web Site for more information on polarity.

Donut or Window-Type CT



White Lead is
Secondary Polarity

Primary Polarity
Mark

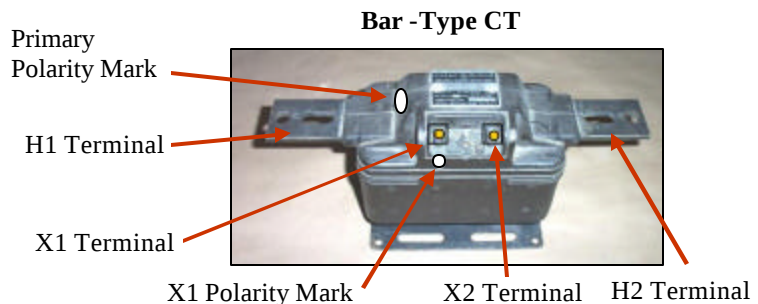
Startco Engineering Ltd Photo

On the Window or Donut-type CT's, such as pictured on the left, the conductor, bus bar, or bushing which passes through the center of the transformer constitutes one primary turn. On Window-type units with low primary current ratings, where the primary conductor size is small, the ratio of the transformer can be changed by taking multiple wraps of the primary conductor through the window. If, for example, a window CT has a ratio of 100:5, placing two primary conductor wraps (two primary turns) through the window will change the ratio to 50:5. Some types of equipment employ this method to calibrate the equipment or to permit a single ratio CT to be utilized for several different ampacities of equipment.

Bar-Type CT's have primary connections that bolt-up directly to the substation bus bars.

Outdoor-rated versions of this equipment are used in pole-mounted primary metering installations.

This type of CT often has compensating windings which improve the accuracy across the full-load range of the transformer.



Kilowatt Classroom Photo

Current Flow Analysis

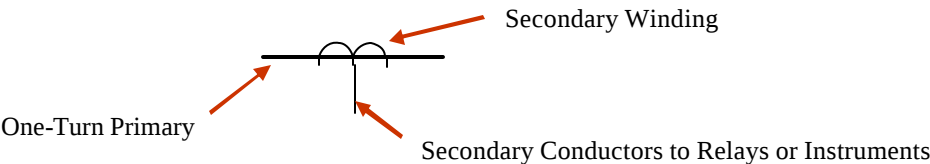
In analyzing the current flow in a system utilizing CT's the following observation can be made:

When current flows in the CT primary from the H1 lead (polarity $\pm$) to the non-polarity H2 lead, current will be forced out the secondary X1 (polarity $\pm$) lead, through the burden (load), and return to the secondary X2 non-polarity lead. The next half-cycle the current will reverse, but for the purpose of analysis and for constructing phasor diagrams, only the above indicated one-half cycle is analyzed.

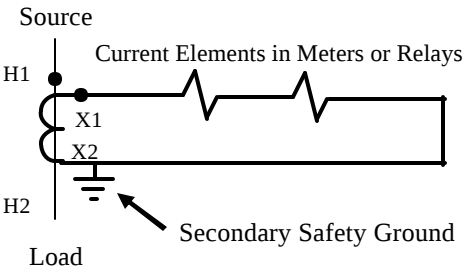
Electrical Drawing Conventions

The polarity marking on electrical drawings may be made in several different ways. The three most common schematic conventions are shown below. The drawing symbol for meters and relays installed in a draw-out case that automatically short the CT secondary is shown in the drawing at the lower right.

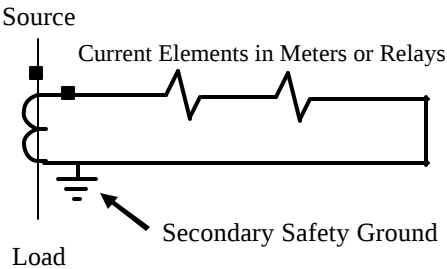
CT One-Line Diagram Symbol



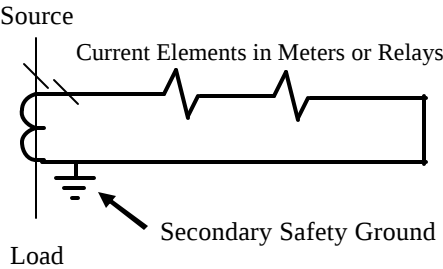
Polarity Marks Shown as Dots



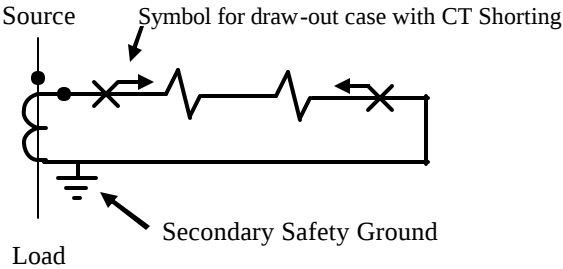
Polarity Marks Shown as Squares



Polarity Marks Shown with Slash



Draw-Out Meter or Relay Case



Caution: The secondary of a Current Transformer must always have a burden (load) connected; an open-circuited secondary can result in the development of a dangerously-high secondary voltage. Energized but unused CT's must be kept short-circuited.

Startco MPU-16
Motor Protective Relay

Retrofit installation in
draw-out case.

Startco Engineering Ltd Photo

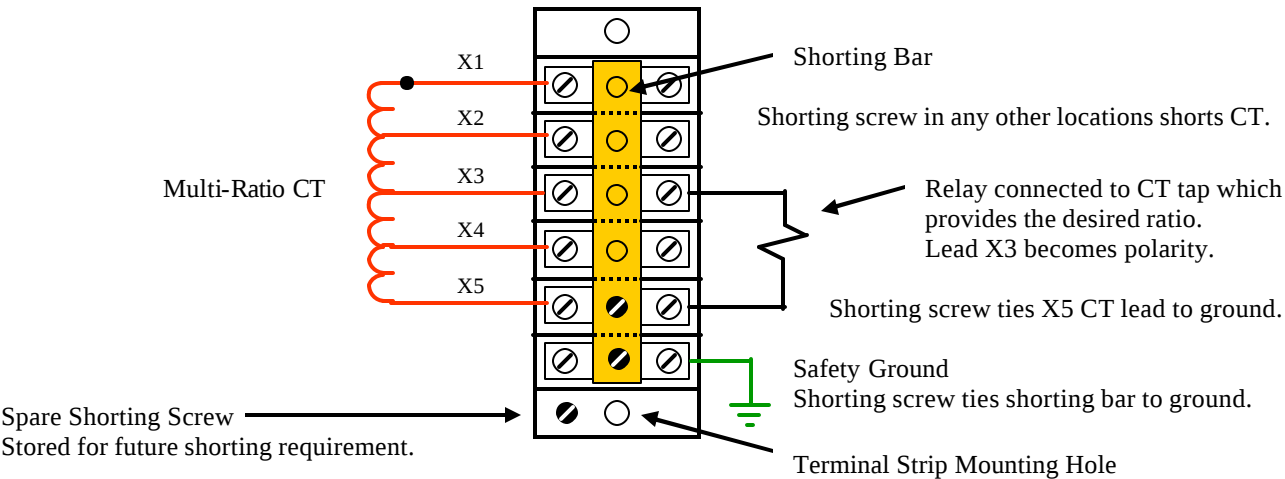


Draw-Out Instrument Cases

Meters and protective relays are available in draw-out cases that automatically short-circuit the CT when the instrument is removed for testing and calibration. Voltage and trip-circuit contacts will be opened. See symbol for draw-out case on Sheet 2.

CT Shorting Terminal Strips

The illustration below shows the termination of a multi-ratio CT on a special shorting terminal strip. Insertion of shorting screw through shorting bar ties isolated terminal strip points together. Any shorted winding effectively shorts the entire CT.



Auxiliary Current Transformers

Startco Engineering Ltd has developed a system utilizing an Auxiliary CT (pictured at left) which permits safe removal of hard-wire protective relays from the system. The current transformers are permanently wired to the input of the Auxiliary CT and the output of the Auxiliary unit is wired to the protective relay current inputs. This arrangements keeps a burden on the CT secondary circuits and permits the protective relays to be removed for repair, calibration, or replacement.

The Auxiliary CT is installed as close as possible to the current transformers. This reduces the CT burden by reducing the length of the CT secondary current conductors.



Startco Engineering Ltd Photo

ANSI Accuracy Classes

Current Transformers are defined by Accuracy Classes depending on the application.

- **Metering Accuracy CT's** are used where a high degree of accuracy is required from low-load values up to full-load of a system. An example of this application would be the current transformers utilized by utility companies for large capacity revenue billing.
- **Relaying Accuracy CT's** are used for supplying current to protective relays. In this application, the relays do not normally operate in the normal load range, but they must perform with a reasonable degree of accuracy at very high overload and fault-current levels which may reach twenty times the full-load amplitude.

Notes:
1) Instrument Transformers (PT's & CT's) are defined in ANSI C57.13-1978.
2) The load on an instrument transformer (PT or CT) is referred to as the "burden".

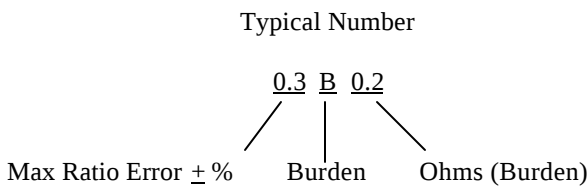
Metering Accuracy Classifications

Available in Maximum Ratio Error Classes of: $\pm 0.3\%$, $\pm 0.6\%$, $\pm 1.2\%$, $\pm 2.4\%$.

For Burdens (Loads) of: 0.1, 0.2, 0.5, 0.9, 1.8 ohms.

Which equals 2.5, 5.0, 12, 22-1/2, 45 volt-amperes (va).

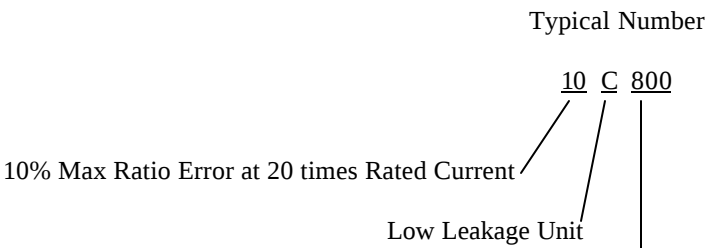
Since Power = $I^2 \times R$, use 5 amp secondary for I, and burden value for R.



Relaying Accuracy CT's

Class C (C for Calculated) is low leakage reactance type - typical of donut units - Formerly Class L (L for Low Leakage).

Class T (T for Tested) is high leakage reactance type - typical of bar-type units - Formerly Class H (H for High Leakage).

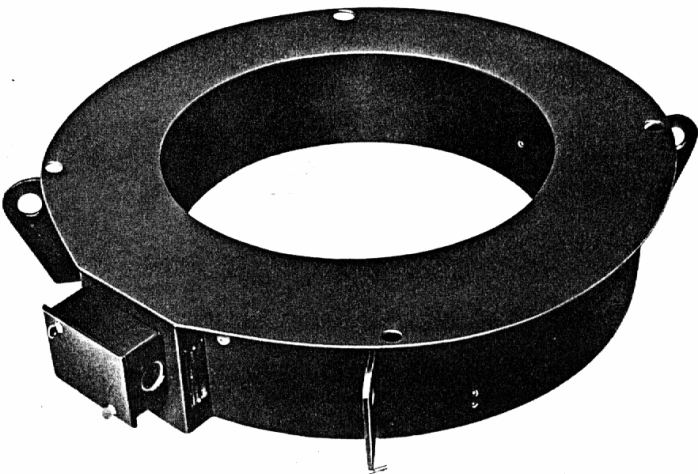


Max secondary voltage developed at 20 times rated current without exceeding the +10% ratio error.

Available secondary voltages: 10, 50, 100, 200, 400, 800.

Will support burdens of: 0.1, 0.2, 1.0, 2.0, 4.0, 8.0 ohms.

Westinghouse Multi-Ratio Bushing-Type CT
For External Installation



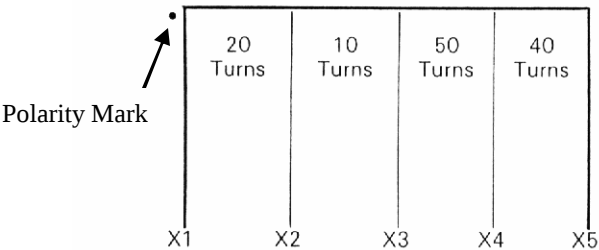
Installation Considerations

This bushing CT is designed for use on existing circuit breakers and power transformers and is installed externally (See Sheet 11). It is housed in an aluminum case which provides electrostatic shielding.

Care must be taken with the installation to insure that the mounting clamp bolts do not contact the case resulting in a one-turn primary short circuit.

Also because the case is metal and is installed externally it can decrease the bushing strike distance. The circuit breaker or transformer manufacturer should be consulted to verify acceptability of the installation.

600/5 CT



Secondary Turns Diagram

Diagram at the left shows the number of turns for each winding on a 600/5 multi-ratio CT. The full number of 120 turns, from X1 - X5, is used to obtain the 600/5 ratio. (Since there is one primary turn, 120:1= 600:5).

Another example: X1 - X2 has 20 turns, so 20:1= 100:5. Any combination of adjacent turns can be utilized. The lowest lead number of the combination will be the polarity lead. See the CT shorting strip diagram on Sheet 7 for a typical termination arrangement.

Selection Guide

Shows ANSI Accuracy Classes, Dimensions, and Mfg Style Number

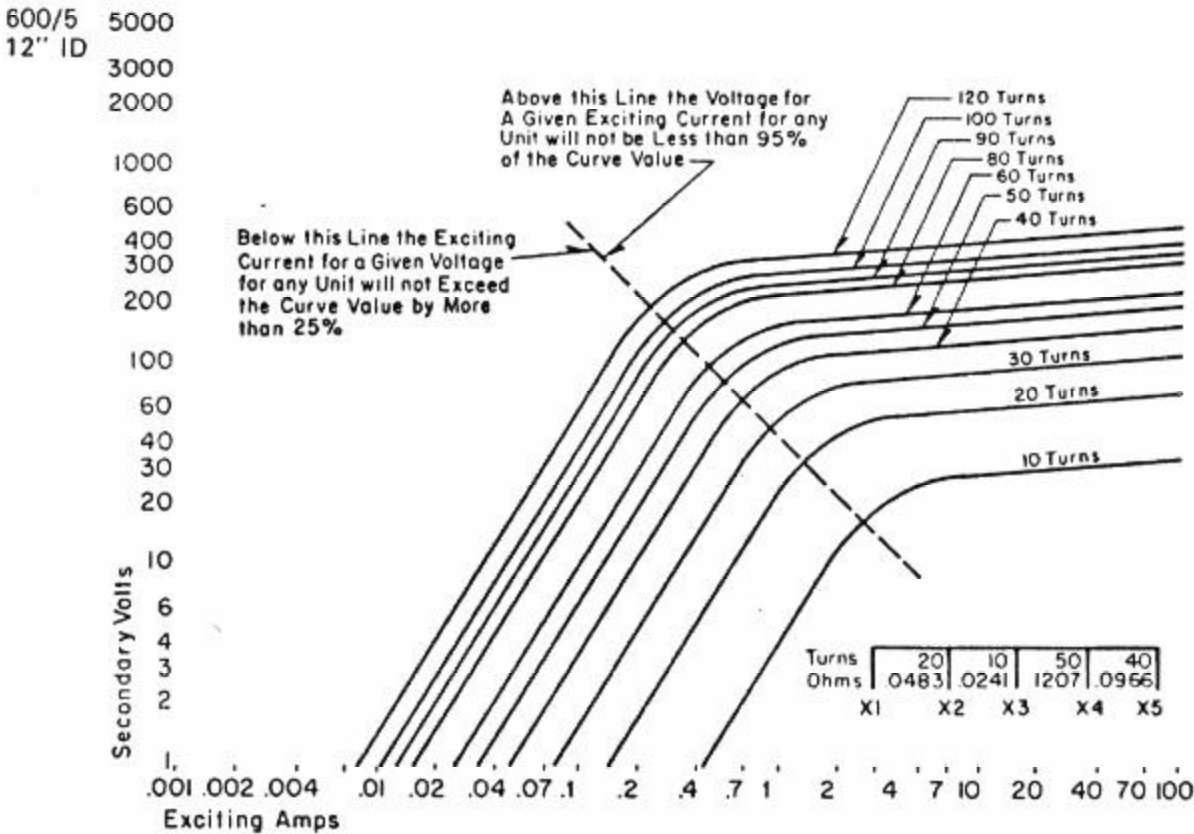
Nominal Ratio	Inside Diameter	ANSI® Relaying Accuracy	ANSI® Metering Accuracy	Style Number
600/5	12	C400	0.3 B 0.5	812A830G01
	18	C400	0.6 B 0.5	812A830G02
	22	C400	0.6 B 0.5	812A830G03
	32	C400	0.6 B 0.2	812A830G04
1200/5	12	C800	0.3 B 2.0	812A830G05
	18	C800	0.3 B 0.5	812A830G06
	22	C800	0.3 B 0.5	812A830G07
	32	C800	0.3 B 0.2	812A830G08
2000/5	12	C800	0.3 B 2.0	812A830G09
	18	C800	0.3 B 2.0	812A830G10
	22	C800	0.3 B 2.0	812A830G11
	32	C800	0.3 B 0.5	812A830G12
3000/5	12	C800	0.3 B 2.0	812A830G13
	18	C800	0.3 B 2.0	812A830G14
	22	C800	0.3 B 2.0	812A830G15
	32	C800	0.3 B 2.0	812A830G16

Excitation Curves

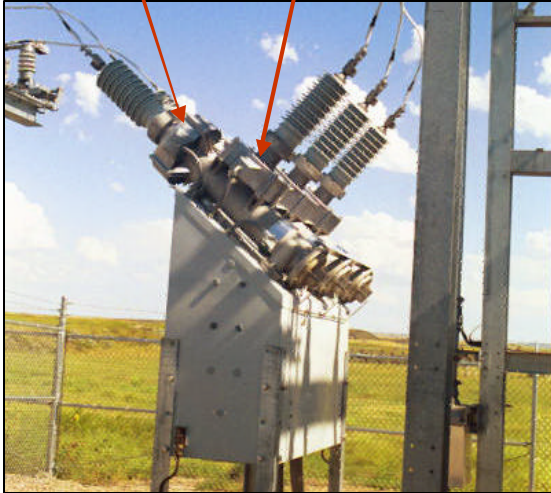
The family of curves below describe the excitation characteristics for the 600/5 multi-ratio bushing current transformer shown on the previous sheet. This is a plot of the CT secondary current against secondary voltage. These curves illustrate how high the secondary voltage will in rise in order to force the rated secondary current through the burden. The effect of magnetic saturation is also illustrated by the knee of the curve.

Next month's article will show how to perform a CT Saturation Curve Test.

Typical Excitation Characteristics



Load-Side CT's Line-Side CT's



Siemens SF6 Circuit Breaker
With externally mounted bushing CT's

Kilowatt Classroom Photo

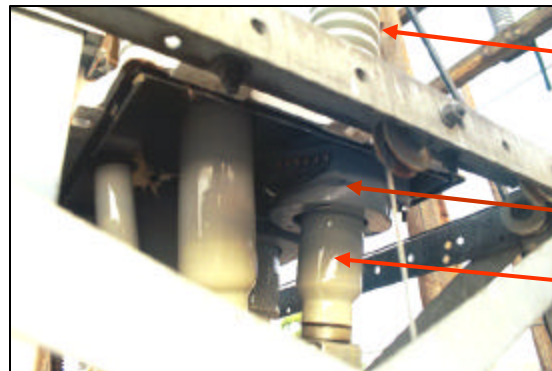
Bushing CT's

Bushing CT's may be mounted externally or internally on circuit breakers and transformers.

Multi-ratio units are often used.

Where single-ratio CT's are employed, the CT primary rating may match either the full-load ampacity of the circuit breaker or of the feeder. In the latter case, upgrading the feeder ampacity will require replacement of the CT's.

The CT secondary leads land on a *termination strip* in the breaker or transformer control cubicle.



External Portion of Bushing
Note "Petticoats" which shed moisture and increase creepage distance.

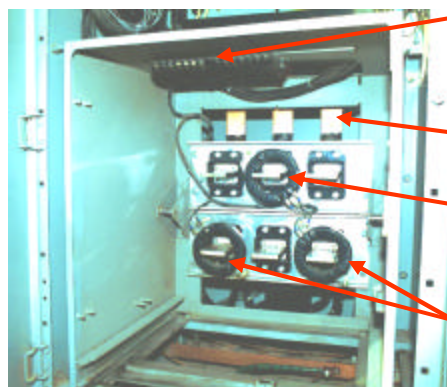
Multi-Ratio CT

Bushing Internal Porcelain
This section is submerged in oil.

Westinghouse Oil-Filled Vacuum Recloser

With tank dropped showing internally mounted CT's on line-side bushings. In this configuration the protective relays fed by the CT's are said to "look through" the breaker.

Kilowatt Classroom Photo



Control Circuit Contact Block
Mates with breaker control block.

Bus Bars

Breaker Bus-Side Stabs
With single donut CT on B-Phase

Breaker Machine-Side Stabs
With donut CT on A and C Phases

General Electric 480 Volt Metal-Clad Switchgear
Cubicle with generator breaker racked out.

Kilowatt Classroom Photo

Hall Effect CT's

Hall-Effect CT's are not current transformers in the conventional sense, rather they are electronic circuit *transducers* which can be applied in the measurement of either AC or DC circuit currents. These devices have many applications; they are commonly used in Variable Frequency Drives (VFD's) to measure the DC link current and are also employed in AC/DC instrument probes such as the TPI-A254 Current Adapter shown at the right.

Hall-Effect devices contain a null-balance type amplifier circuit. The magnetic flux (field) produced by the current flow through the primary (usually one-turn) results in an output *voltage* which is balanced by an equal and opposite output from the control or measuring circuit. Because the circuit is an amplifier, it requires external operating power which is supplied by the control circuit power supply, or in the case of a portable instrument probe, batteries are used.

As with conventional current transformers, Hall-Effect devices provide isolation from the high voltage circuit and reduce the measured current to a proportional value which can be safely measured by the control or instrument circuit.

Hall-Effect devices do not pose the same danger as conventional bus-bar or donut-type CT's with regard to an open circuited secondary. (Note: some instrument current probes are conventional CT's; these usually have a burden resistor within the probe or may be protected from an open circuit with back-to-back zener diodes.) However, good practice dictates that instrument current probes *should not* be disconnected from the meter while current is passing through the device primary.

TPI AC/DC Current Probe

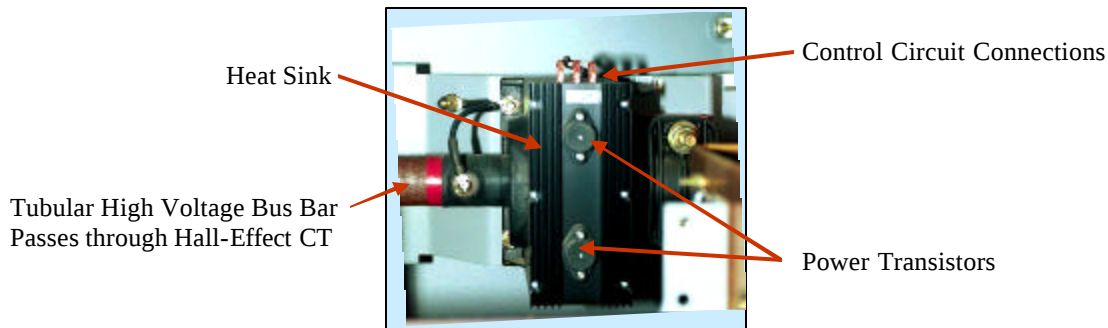


Probe employs the Hall-Effect principle and produces a millivoltage output that is applied to a TPI Digital Multimeter. The meter interprets the probe voltage as a current value. Batteries are used in the probe to power the amplifier circuitry.

Test Products International Photo

Hall-Effect CT

Used on the DC Link of a 5000 H.P. VFD.



Kilowatt Classroom Photo

Typical VFD Block Diagram Showing Hall-Effect CT (HCT) Connections

