

Fig. 7 - Trip voltage E_s for a Supermalloy ring core, area $.144\text{cm}^2$, $\ell_m = 3.5\text{cm}$, $n_s = 600$ and 1000 turns at 5mA fault current. Parameters: Load resistance $R_s = 5000, 1500, 500\Omega$.

We have therefore developed a series of supermalloy cores made of $.33\text{mm}$ thick ring laminations with an inner diameter as small as 7.4mm and as large as 12mm , and outer diameters smaller than 14.5mm , which exhibit all the required properties. The minimum permeability in the remanent state, over the temperature range from -35°C to $+70^\circ\text{C}$ is greater than $40,000$ (typical greater than $50,000$). The change of permeability is small, so that a properly terminated current transformer wound with secondary turns of $n_s = 600$ to $1,500$ turns will provide a very constant output voltage at 5mA to 30mA . In an ideal current transformer, the primary to secondary current ratio is inversely proportional to the turns ratio. In practice, there is an error proportional to the load resistance R_s and inversely proportional to $2\pi fL_s$ in which f is the frequency, L_s the secondary inductance, which is proportional to the core permeability μ . Fig. 7 shows the relationship more clearly. For a core with a cross sectional area of $.144\text{cm}^2$ and a mean path length, $\ell_m = 3.5\text{cm}$, the voltage sensed by the IC on the load resistance R_s varies strongly with a change in permeability when the core is terminated with 5000Ω . At $R_s = 1500\Omega$, the output voltage becomes more stable and with $R_s = 500\Omega$ and $n_s = 1000$ turns, the output voltage is practically independent of permeability as long as it is greater than $35,000$. Fig. 8 shows this relationship even more clearly for a small core consisting of 4 ring laminations, with $A = .0236\text{cm}^2$, $\ell_m = 3.30\text{cm}$, wound with 1000 turns. At $R_s = 500$ to 1000Ω , the output voltage, and therefore the trip level is very stable and nearly independent of the core permeability as long as $\mu > 40,000$. The designer should therefore layout the current transformer with a sufficient number of turns and a low enough burden resistance to achieve the required stability of the trip level.

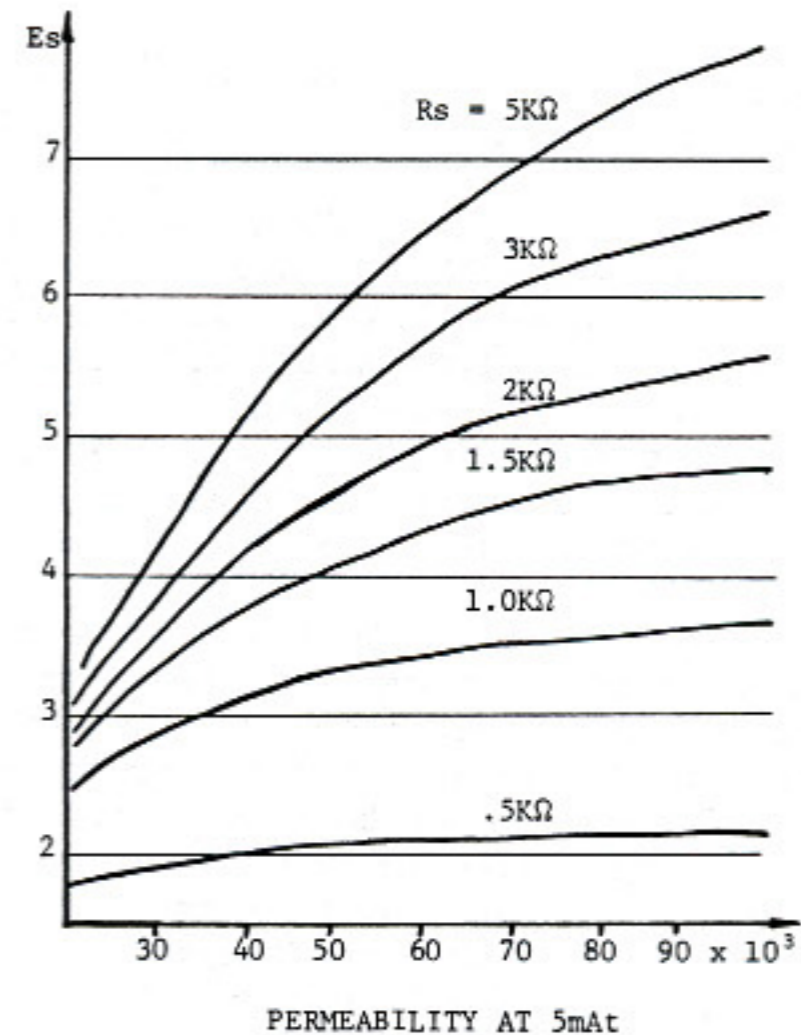


Fig. 8 Output voltage E_s over core permeability at 5mA fault current, core area = $.0236\text{cm}^2$, $\ell_m = 3.30\text{cm}$, $n_s = 1000$ turns, parameter: Load resistances from 500Ω to 5000Ω .

Fig. 9 shows a typical electronic GFCI core. Current sensing transformers using ring laminations are economical because the manufacturing can be automated, they are self shielding because of the closed magnetic paths and they are extremely stable over the temperature and with dc shock. Properly designed circuits using these current transformers will trip in less than 8ms , when a low resistance fault of 240mA would occur and will always trip in less than 200ms at 5mA fault current. Electronic GFCI's remove therefore safely an electrical shock hazard from the supply system.



Fig. 9 - Typical GFCI ring cores for electronic GFCI's