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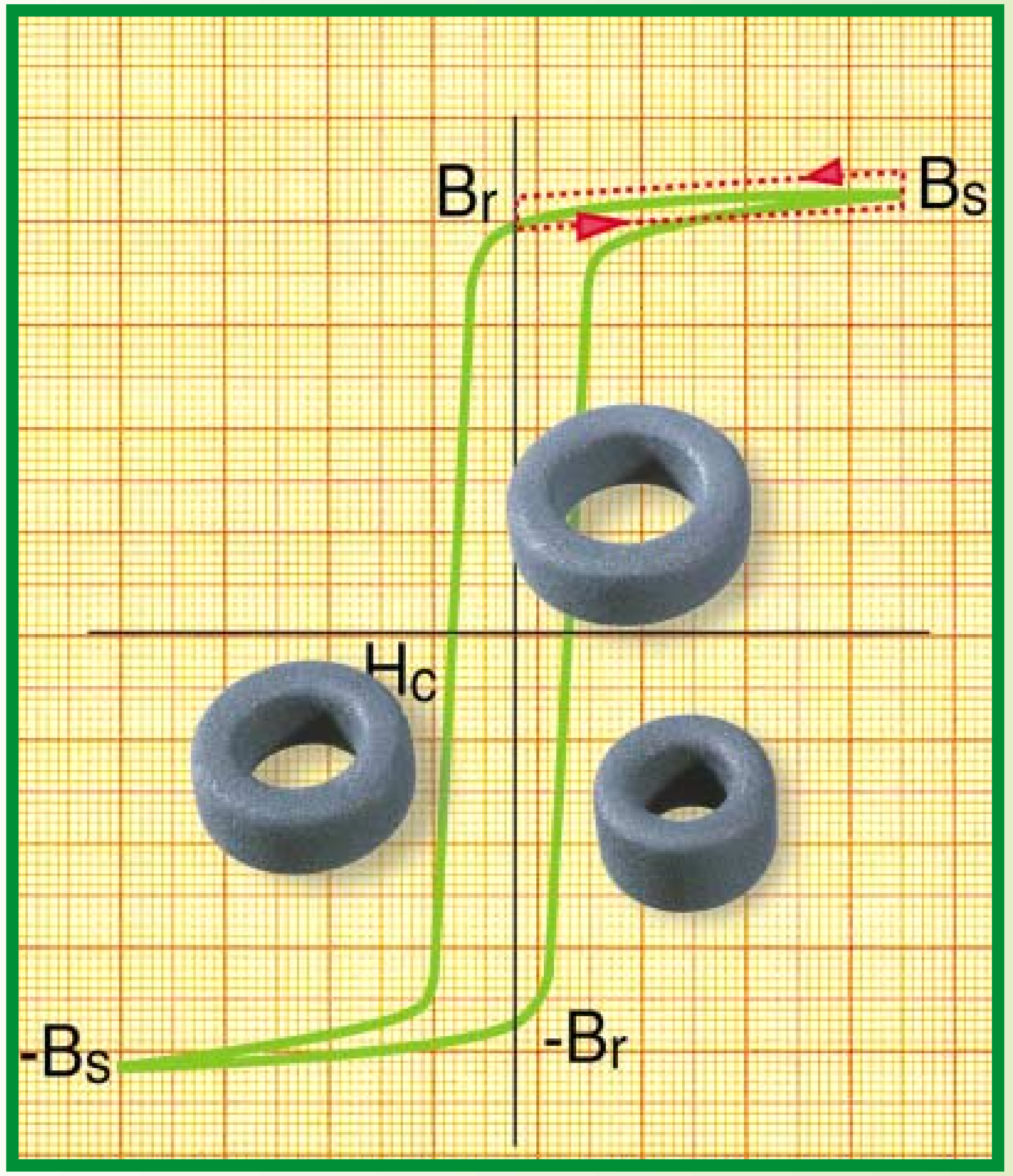
PHILIPS

Let's make things better.

Square Loop Ferrite Toroids for Magnetic Amplifiers



Philips Components
Ferrite Ceramics

PHILIPS

Let's make things better.

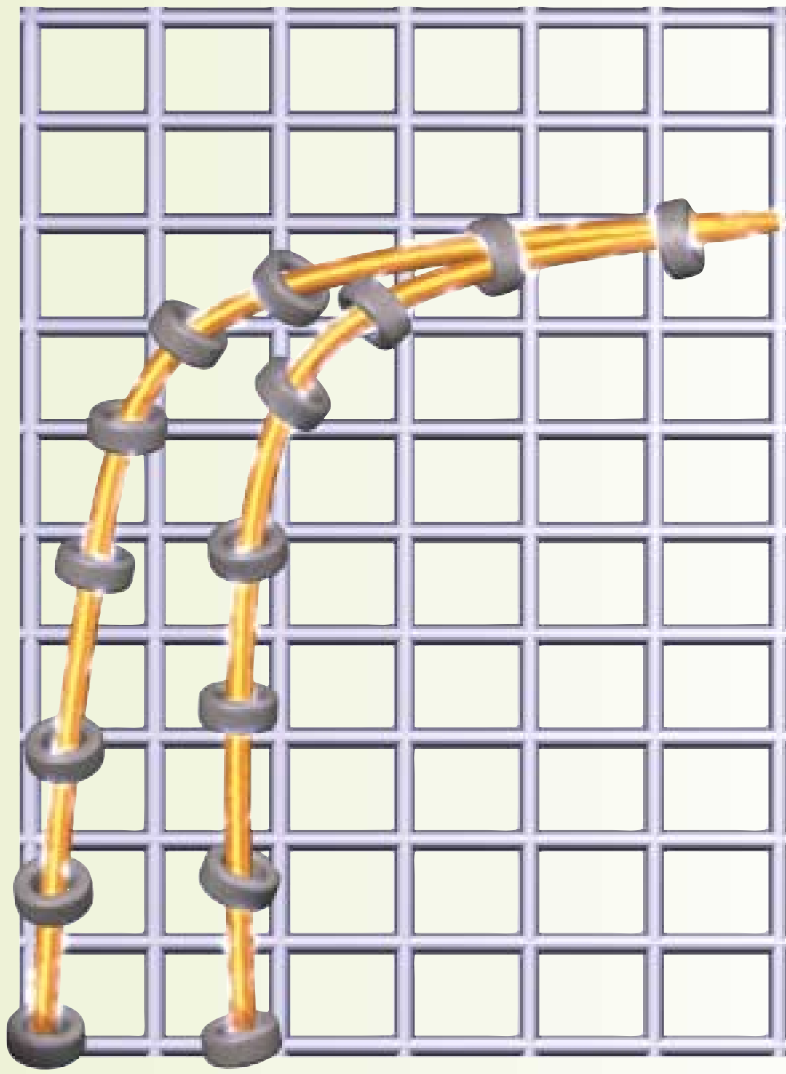
Square Loop Ferrite Toroids for Magnetic Amplifiers

In recent years, square loop ferrite toroids have continuously gained market share and more and more designers have learnt to appreciate them as an economic replacement for amorphous metal cores in magnetic amplifiers.

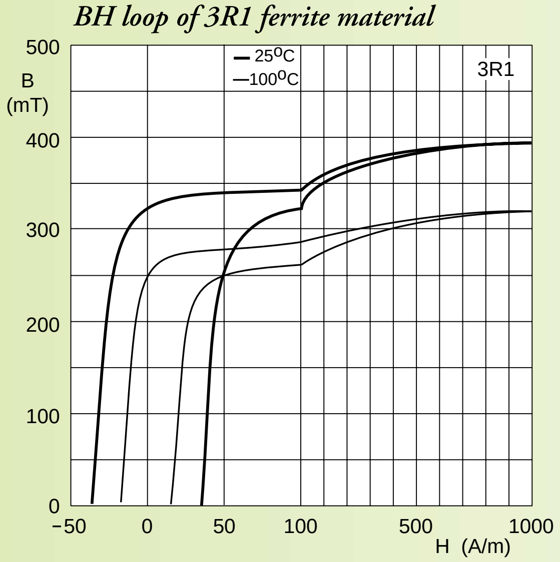
Continuous research, the use of improved raw materials and well controlled process conditions have led to a robust and stable ferrite material, 3R1.

These developments have resulted in a range of 3R1 toroids, featuring a very good squareness ratio, a low Hc and an excellent performance under high loading current conditions.

As an alternative to the normal toroids, the Integrated Inductive Component (IIC) is offered for SMD only designs.



BH loop of 3R1 ferrite material



Features

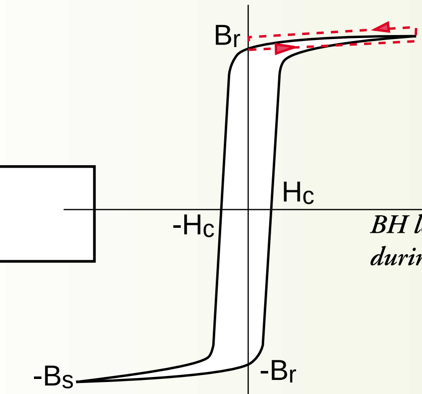
- *Squareness ratio of 85 to 90% at 100 kHz, 100 °C depending on applied field strength*
- *Excellent load handling*
- *Low H_c*

Current product range

TN9/6/3-3R1
TN10/6/6-3R1
TN13/7.5/5-3R1
TN14/9/5-3R1
TN17/11/11-3R1
TN23/14/7-3R1
TN36/23/15-3R1

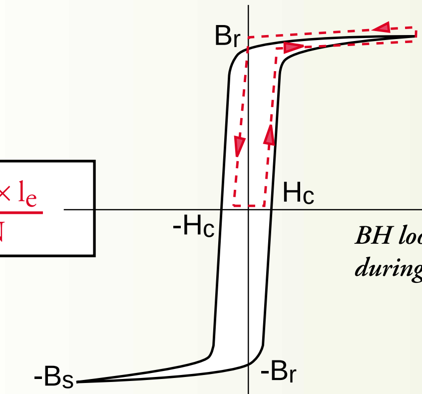
IIC10-14/4-3R1

$I_{reset} = 0$



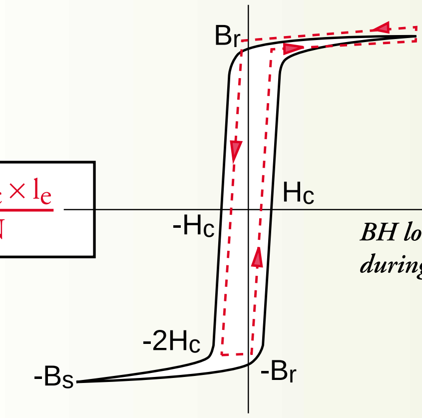
BH loop excursion during no blocking

$I_{reset} = \frac{H_c \times l_e}{N}$

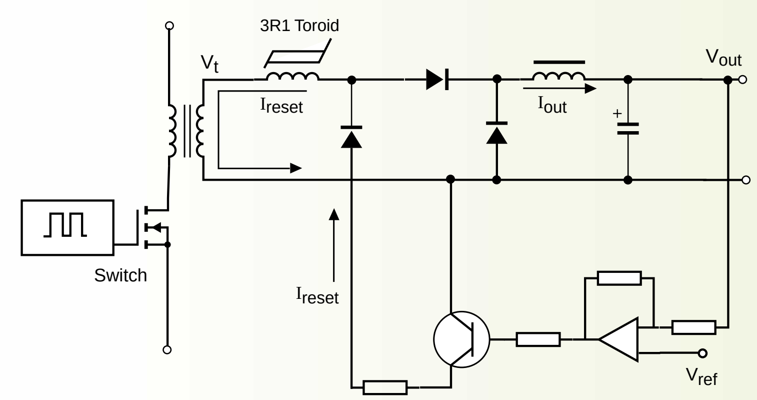


BH loop excursion during partial blocking

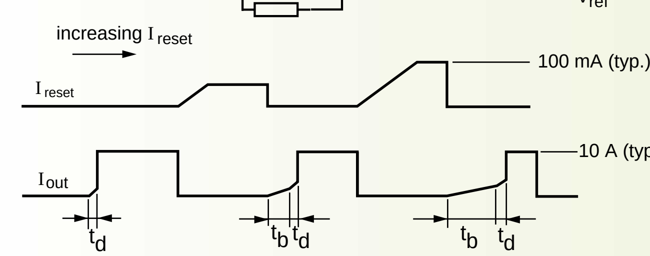
$I_{reset} = \frac{2H_c \times l_e}{N}$



BH loop excursion during full blocking



$I_{reset} = \frac{H_c \times l_e}{B_r \times N} \times \Delta B$



Basic circuit

3R1 Toroids in Magnetic Regulators

Saturable inductors can be used to regulate several independent outputs of an SMPS by blocking varying amounts of energy from the secondary of the transformer.
The rectangular BH loop of our 3R1 ferrite toroids makes them ideal for magnetic regulators with reset control.
The circuits required are both simple and economic and can be easily integrated.

Operating principles

When the main switch is ON (t_{on}) the current (I_{out}) flows through the winding of the saturable inductor to the output inductor and from there to the load.
During OFF time this current falls to zero and so does the magnetic field H. Because the saturable inductor has a rectangular B-H loop, the flux remains at the high level Br even when the driving field H has fallen to zero.

When no reset current is applied, the flux in the toroid remains at the level of Br until the next ON time starts after a complete cycle time T (=1/f). There is only a short delay (t_d) because the flux rises from B_r to B_s. After that, the current sharply rises to its maximum value, limited only by the load impedance. The output voltage has its maximum value, given by:

$$V_{out} = V_t \times (t_{on} - t_d)/\ T$$

When V_{out} is higher than V_{ref} a reset current flows during OFF time, regulated by the transistor. This current can only flow through the winding of the saturable inductor. Because this current induces a magnetic field in reverse direction it will move the ferrite away from saturation. Resetting to -Hc, for instance, causes some extra delay (t_b) because of the larger flux swing. Full reset causes a flux swing of almost $2 \times B_s$, resulting in a maximum delay ($t_d + t_b$) and the blocking of a major part of the energy flowing from the transformer to the load.
The output voltage is regulated to the required level and is given by:

$$V_{out} = V_t \times (t_{on} - t_d - t_b)/\ T$$

In this way a reset current in the order of 100 mA can regulate load currents of 10 A or more, depending on the layout of the saturable inductor. For this reason the described circuit is called a magnetic regulator or magnetic amplifier.

The performance of the material 3R1 is comparable to that of amorphous metal, making it an excellent choice for use in magnetic regulators. However, since the value of H_c is higher for the ferrite than for most amorphous metal compositions, a simple replacement will often fail to deliver the expected results. A dedicated design or a slight redesign of the regulating circuit is then required, for which we will be glad to give you advice.