

FIG 1 Explanation

According to many explanations about principle of operation of electrical transformers what could be said for sure is that:

When there is AC current in primary coil/winding (wrapped around magnetic core) variable magnetic field is “floating” within the core

When this magnetic field penetrates the secondary coil it induces EMF (voltage difference) in secondary coil.

If we connect load (R_2) to the both ends of the secondary coil, there will be a current whose magnetic field direction will be opposite to the direction of magnetic field of the current in primary coil (Lenz law).

My assumptions are that in this case (transformer under load conditions) the magnetic fields from primary and secondary coils/windings will “travel their paths” from North pole to the South pole of the windings/coils as it shown on figure 1.

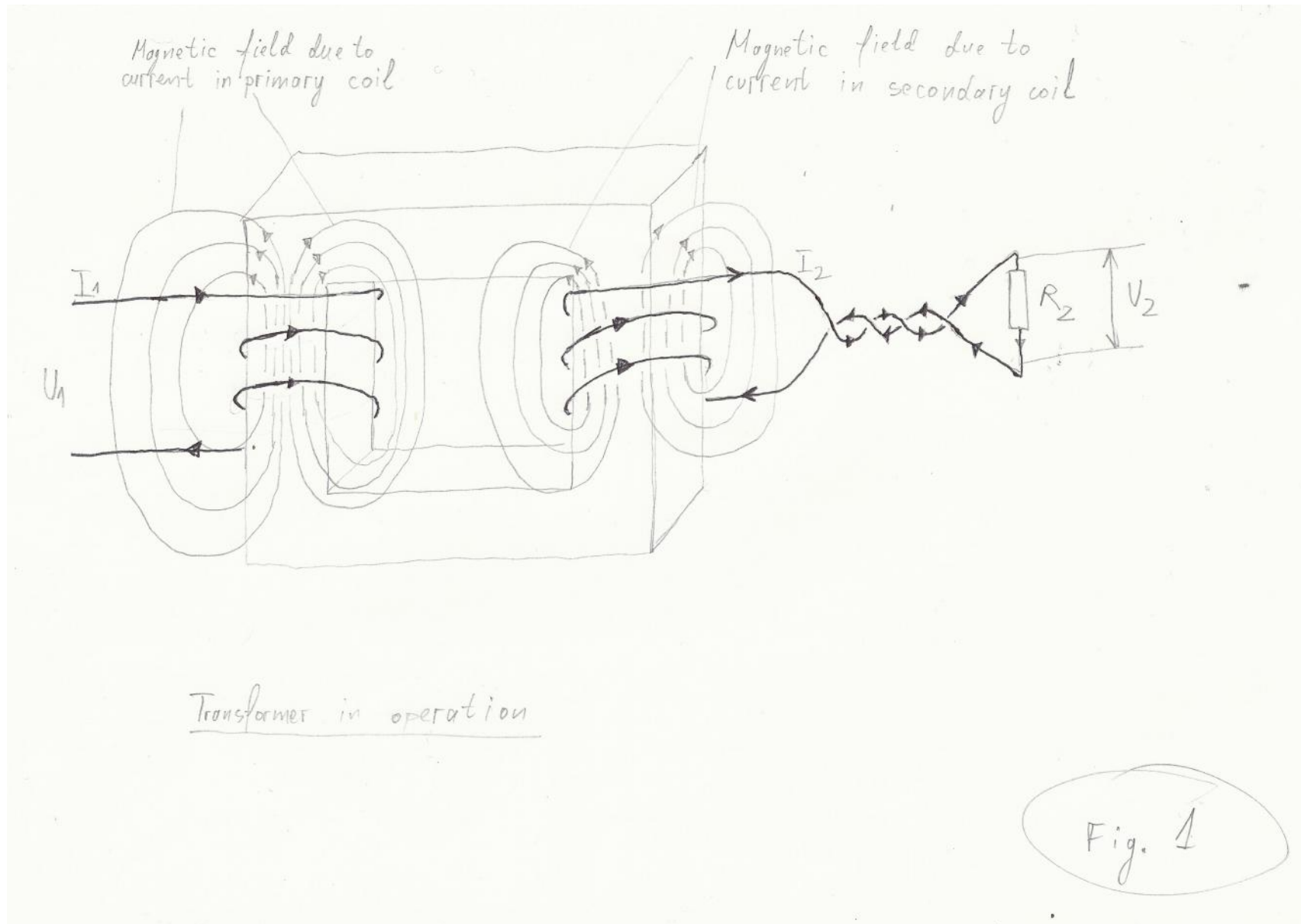


FIG 2 Explanation

If we add some magnetic field shunt , then according to one of the properties of the magnetic fields (It goes from north to south through the path/zone with the least total permeability) then the magnetic fields from primary and secondary coils/windings will go/travel from north to south through/via magnetic shunt.

Initially (in case with the magnetic shunt) almost all the magnetic field from primary winding goes **ONLY** through the secondary coil/winding

(The shunt initially is shielded and almost no, or small fraction of the magnetic field from primary coil passes through the shunt)

where it induces voltage difference and then after counteracting with the magnetic field from the secondary coil winding , **together with the magnetic field from secondary coil winding** it passes through the shunt on its way to the south pole.

The magnetic field within the shunt is greater than the magnetic field from primary winding and the magnetic field from secondary winding

$MF(\text{shunt}) > MF(\text{primary winding})$,

$MF(\text{shunt}) > MF(\text{secondary winding})$ MF stands for magnetic field

So basically the magnetic field from primary coil induces emf(voltage difference) in the secondary coil and then (together with the magnetic field from the current in the secondary coil) passes through the magnetic shunt on its way to the south pole.

If we wrap a third coil/winding around the shunt, we could further utilize the energy of the magnetic field (after it has been utilized once in the secondary coil/winding).

In other words, after the magnetic field from primary coil induces emf and current in secondary winding, then goes through the shunt , where it could induce emf and current again (it could be utilized second time/again/further).

*It gets even better. The amount/strength of magnetic field through the shunt is greater than **the strength of magnetic field from primary coil or the strength of magnetic field from secondary coil**. All that magnetic field in the shunt could be used to induce emf and current in coil wrapped around the shunt (third winding) again.*

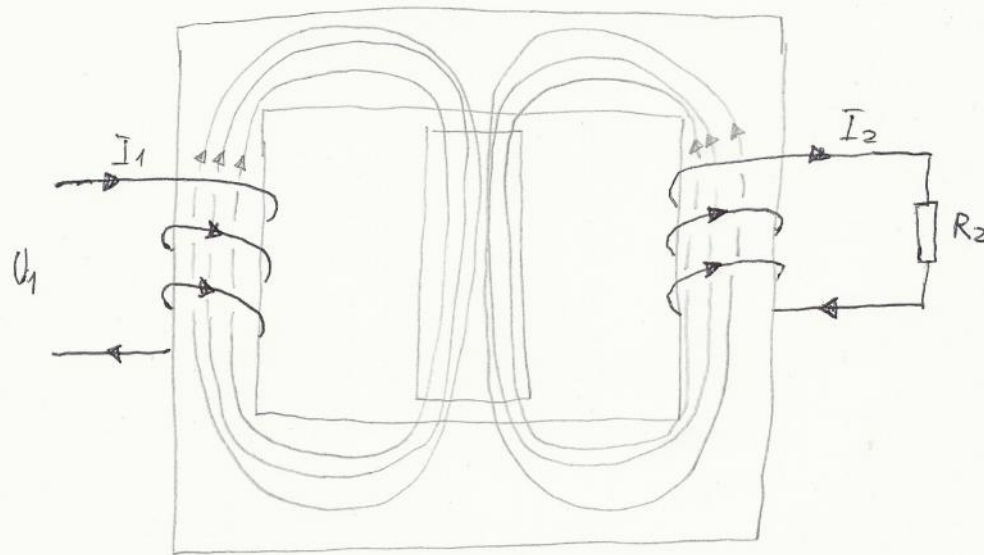


Fig 2

FIG 3 Explanation

Rms stands for root mean square value of the voltage and the current.

Let's assume that $R_2 = R_3$.

As a result it should be something like $P_{\text{primary}} < P_{\text{secondary}} + P_{\text{third}}$, where

P_{primary} Power input in the system and

$P_{\text{secondary}} + P_{\text{third}}$ Power output of the system.

Or more generally said the Power consumed in the primary winding (the power that is put in the system) should be less than the sum of the Power ,coming out from secondarycoil/winding and the Power ,coming out from third coil/winding.

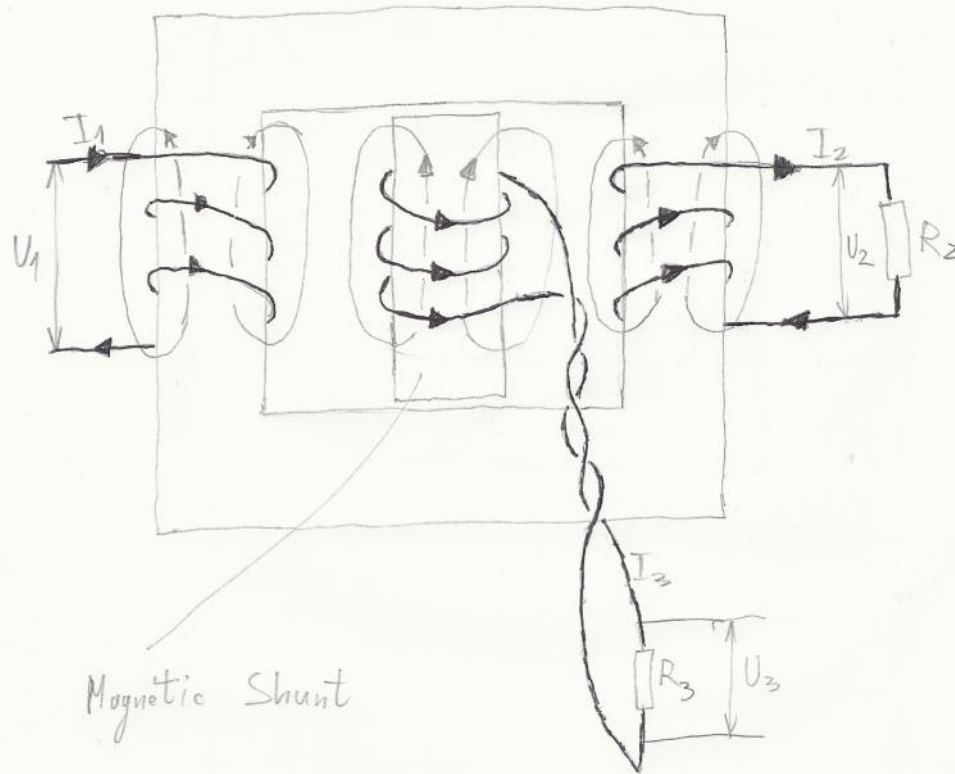
In case of simple resistors as load the $P_{\text{primary}} < P_{\text{secondary}} + P_{\text{third}}$ could became something like:

$$U_{1\text{rms}} \cdot I_{1\text{rms}} < U_{2\text{rms}} \cdot I_{2\text{rms}} + U_{3\text{rms}} \cdot I_{3\text{rms}},$$

where **U1** is input voltage,

U2 is the voltage drop on secondary resistor (R2),

U3 is voltage drop on third resistor (R3).



$$R_2 = R_3$$

Fig 3

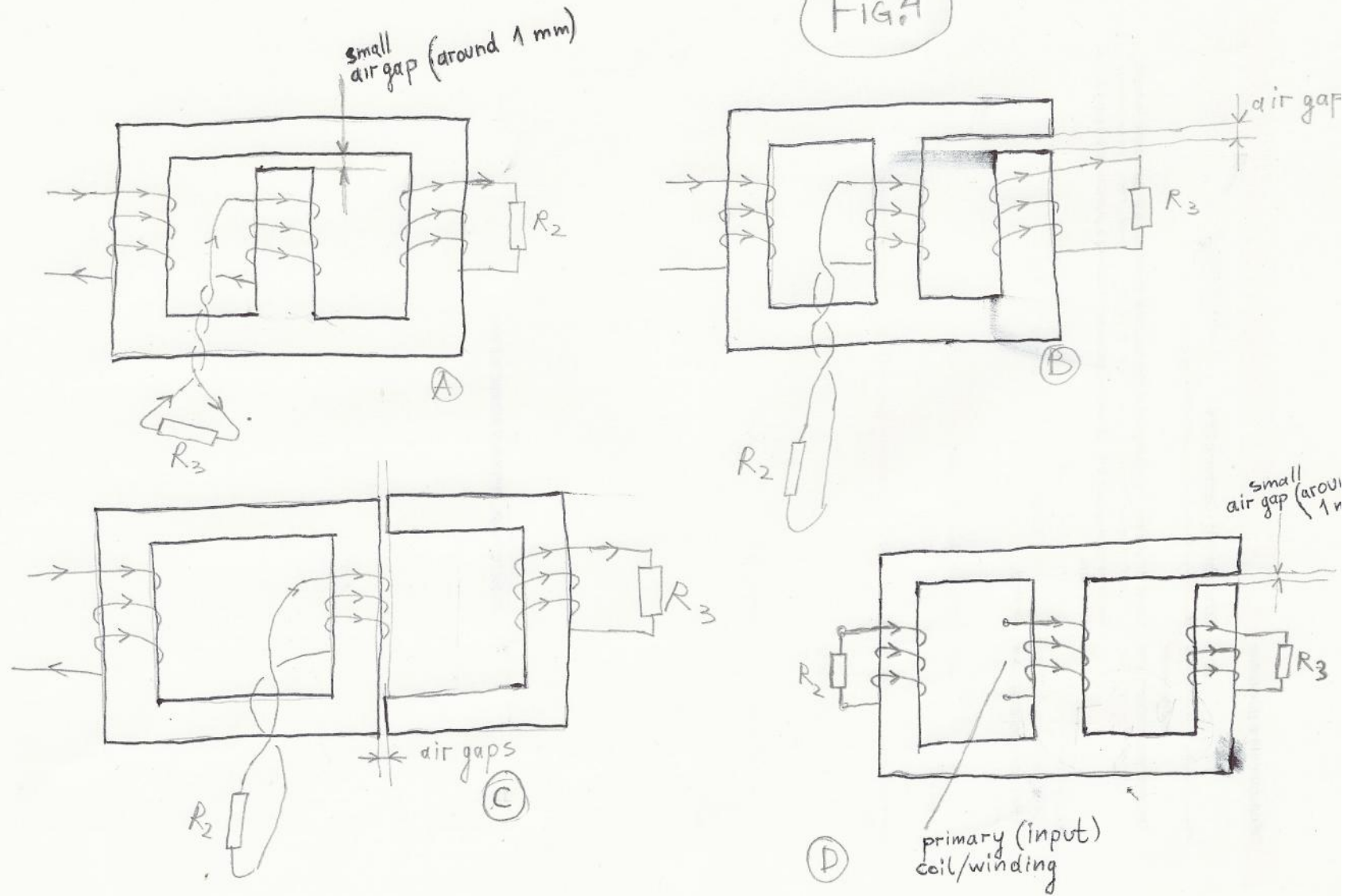
$$\frac{U_2 I_2}{\text{RMS RMS}} + \frac{U_3 I_3}{\text{RMS RMS}} > U_1 I_1$$

FIG. 4 Other suitable configurations for magnetic core with shunt are shown **on fig. 4**, where the coil/winding with current I_3 , voltage U_3 and load/resistor R_3 is around the shunt. The shunt coil/winding is the one, whose both ends are connected to resistor/load R_3 .

Simple explanation on FIG.4 is as follows:

The devices like those on FIG 4A, FIG 4B and FIG 4D could be obtained from simple three phase transformer , when removing the secondary/output winding/coil on each phase and make a proper cut for the air-gap.

FIG. 4



Lets take a look at FIG. 4B.

Almost entire magnetic flux/field from primary coil/winding goes only through the secondary coil/winding. Very small part of the magnetic field goes through the third coil/winding , so in case of equal number of turns for secondary and third coil/winding the induced voltage in secondary coil/winding is significantly greater than the induced voltage in third coil/winding.

$U_2 \gg U_3$, where in case of ideal transformer (no flux leakage losses, no core losses, no other losses) $U_1 = U_2 + U_3$, Because the magnetic field from primary coil/winding is equal to the sum of magnetic fields passing through secondary and third coil/winding.

Or for short : $MF_1 = MF_2 + MF_3$

In case of (equal)/(same by value) resistors R_2 and R_3 , the currents through the secondary and third coils/windings will be different , where the current in secondary coil/winding will be significantly greater compared to the current in third coil/winding ,

$I_2 \gg I_3$ because the induced voltage in secondary coil/winding is significantly greater than third induced voltage

$U_2 \gg U_3$.

Or for short :

Magnetic field from primary coil/winding (MF)

$MF(\text{primary coil/winding}) = MF(\text{secondary coil/winding}) + MF(\text{third coil/winding})$ or for short $MF_1 = MF_2 + MF_3$, $MF_2 \gg MF_3$ hence $MF_1 \approx MF_2$

Voltages

$U_1 = U_2 + U_3$, but $U_2 \gg U_3$ and hence $U_1 \approx U_2$.

Currents

$U_2 \gg U_3$; $R_2 = R_3 \Rightarrow I_2 \gg I_3$ (because $I_2 = U_2/R_2$ and $I_3 = U_3/R_3$).

As a result of induced currents in secondary and third coils/windings there will be induced magnetic fields from secondary and third coils/windings (M_{Induced2} and M_{Induced3}) which oppose the M_F2 and M_F3 (M_F2 is opposite to M_{Induced2} and M_F3 is opposite to M_{Induced3}) where since $M_F2 \gg M_F3$ therefore $M_{\text{Induced2}} \gg M_{\text{Induced3}}$.

To visualize the mentioned about FIG 4B so far please see the FIG 5 (Vizimag software simulation).

So UP to this moment

we have defined :

- the ratio of voltages ($U_1 = U_2 + U_3$, $U_2 \gg U_3$), currents ($I_2 \gg I_3$), inducing magnetic fields ($M_{\text{Inducing2}} \gg M_{\text{Inducing3}}$, $M_{\text{Inducing1}} \approx M_{\text{Inducing2}}$) and induced magnetic fields ($M_{\text{Induced2}} \gg M_{\text{Induced3}}$) for secondary and third coils/windings

- The M_{Induced2} is counteracting/opposing/against $M_{\text{Inducing2}}$

and the M_{Induced3} is opposing/counteracting/against $M_{\text{Inducing3}}$

The question is what will happen further/next.

