# CPE 186 Computer Hardware Design

## EMC – Cabling and Shielding

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# Capacitive Coupling Between Two Conductors

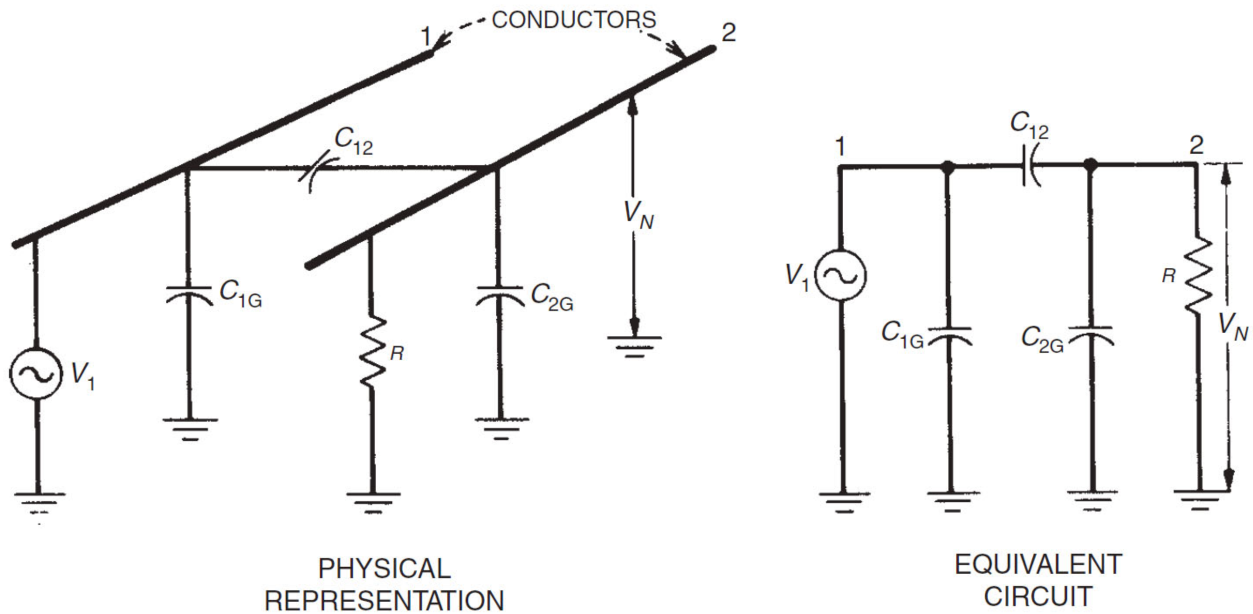


**FIGURE.** Capacitive coupling between two conductors.

# An Ideal Shielded Conductor

$$V_S = \left(\frac{C_{1S}}{C_{1S} + C_{SG}}\right) V_1.$$

$$V_N = V_S.$$

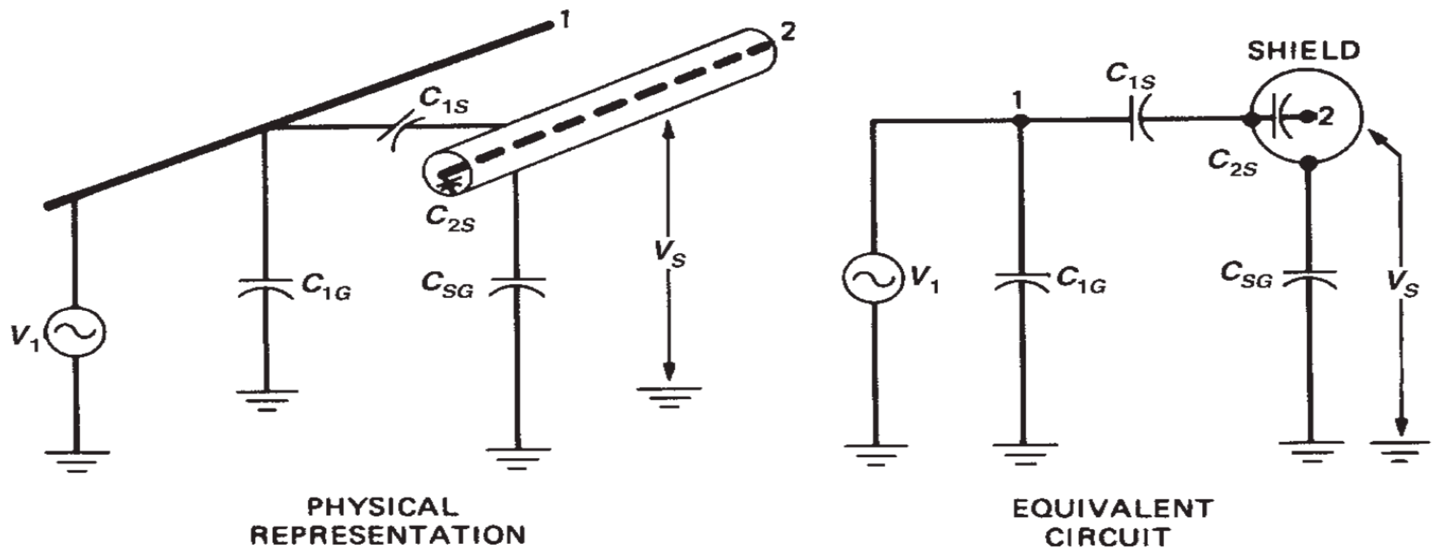


**FIGURE.** Capacitive coupling with shield placed around receptor conductor.

If, however, the shield is grounded, the voltage VS = 0, so VN = VS =0.

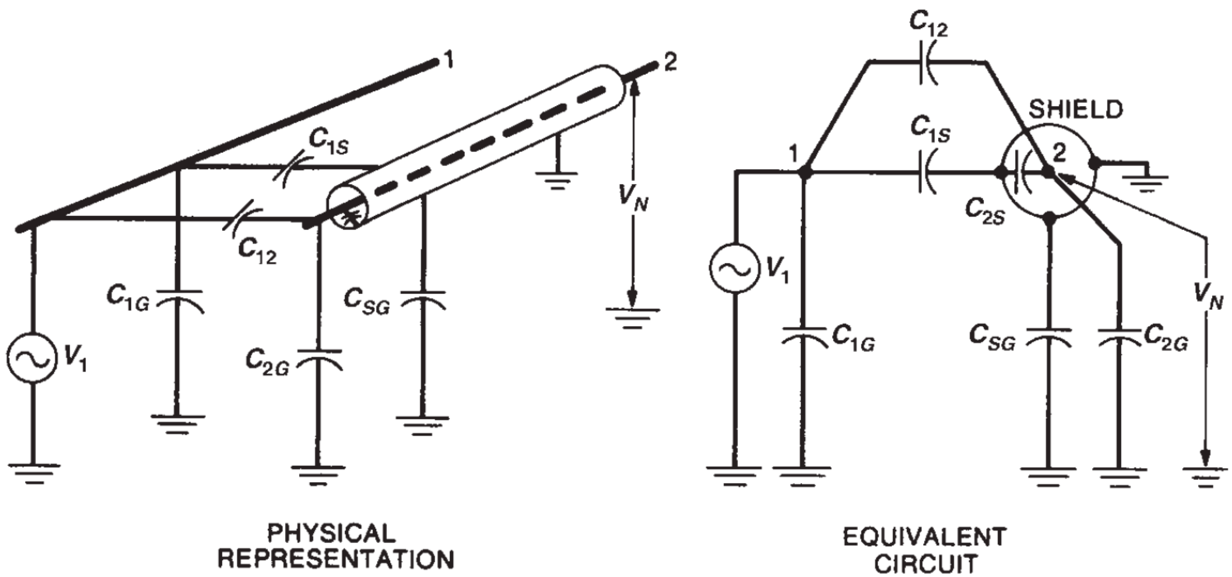


**FIGURE .** Capacitive coupling when center conductor extends beyond shield; shield grounded at one point.

Even if the shield is grounded, there is now a noise voltage coupled to conductor 2. Its magnitude is expressed as follows:

$$V_N = \frac{C_{12}}{C_{12} + C_{2G} + C_{2S}} V_1.$$

# Good Electric Field Shielding

(1) Minimize the length of the center conductor that extends beyond the shield;

(2) Provide a good ground on the shield;

(3) A single ground connection makes a good shield ground, provided the cable is not longer than one twentieth of a wavelength;

(4) On longer cables, multiple grounds may be necessary.

# REDUCING CAPACITANCE-COUPLED NOISE

- **Reduce Level of High dV/dt Noise Sources**
- **Use Proper Grounding Schemes for Cable Shields**
- **Reduce Stray Capacitance**
  - **Equalize Input Lead Lengths**
  - **Keep Traces Short**
  - **Use Signal-Ground Signal-Routing Schemes**
- **Use Grounded Conductive Faraday Shields to Protect Against Electric Fields**

# Magnetic Coupling Between Two Circuits

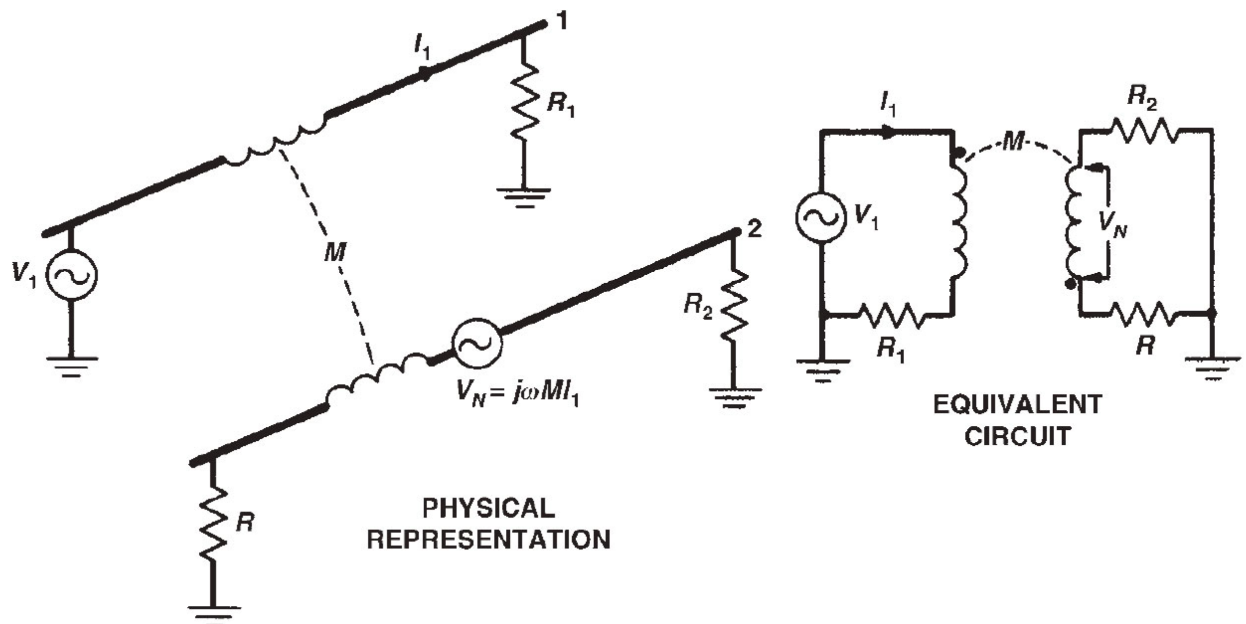


**FIGURE.** Magnetic coupling between two circuits.

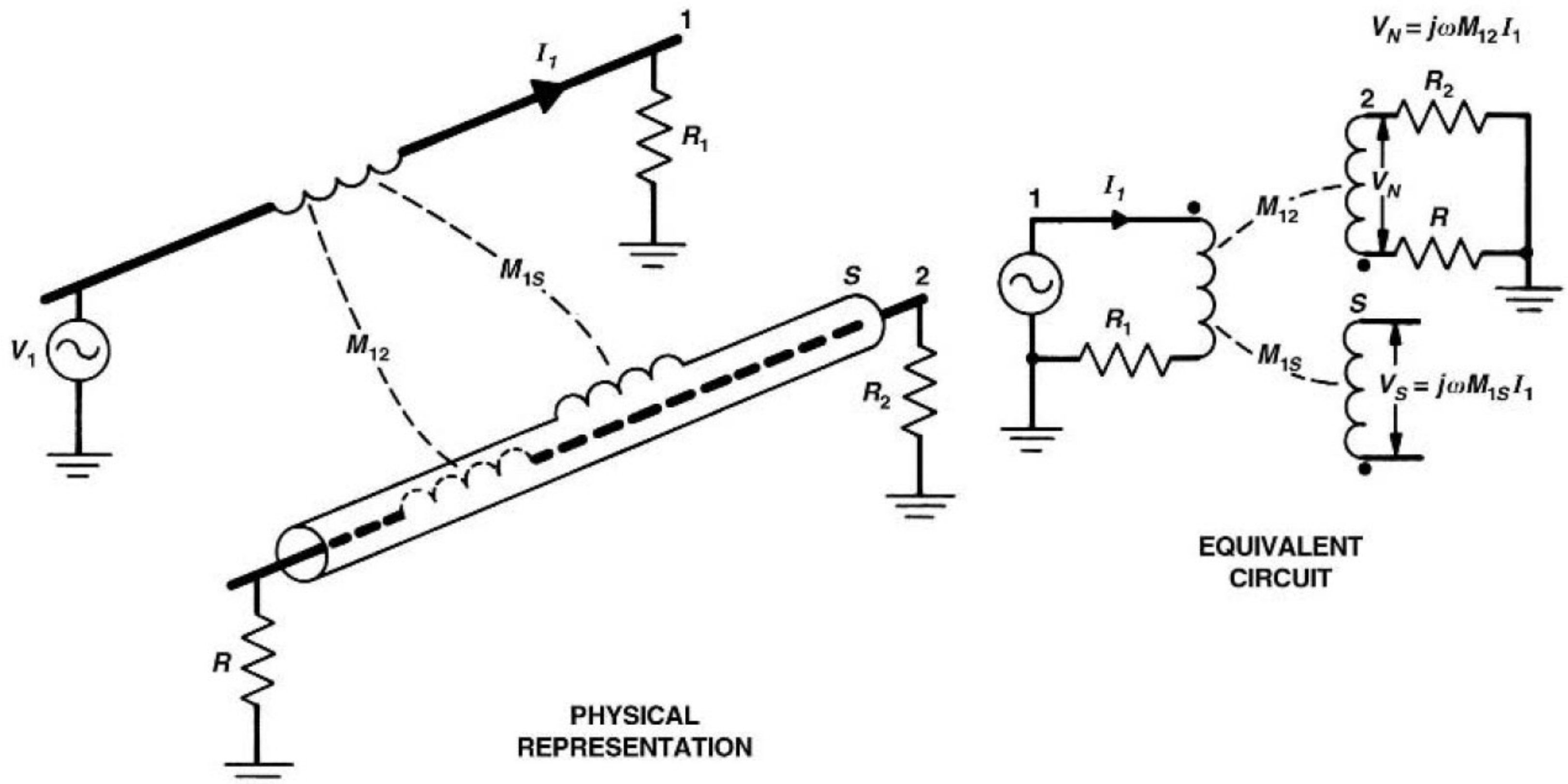


**FIGURE .** Magnetic coupling when a shield is placed around the receptor conductor.

# Equivalent Circuit of Shielded Conductor

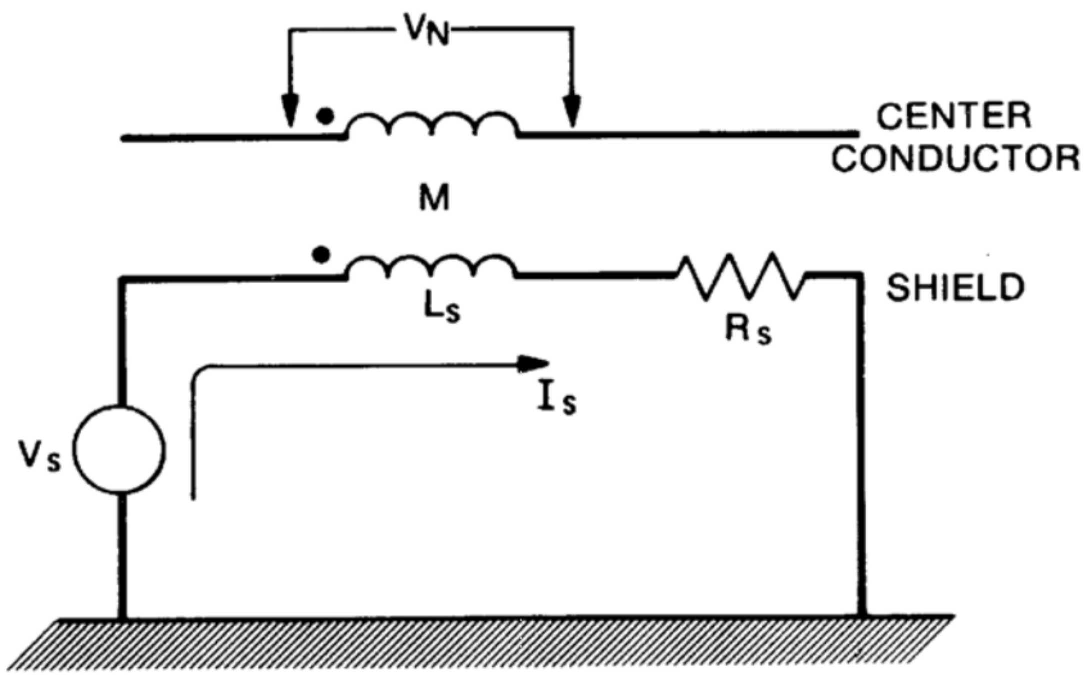


**Figure .** *Equivalent circuit of shielded conductor.*

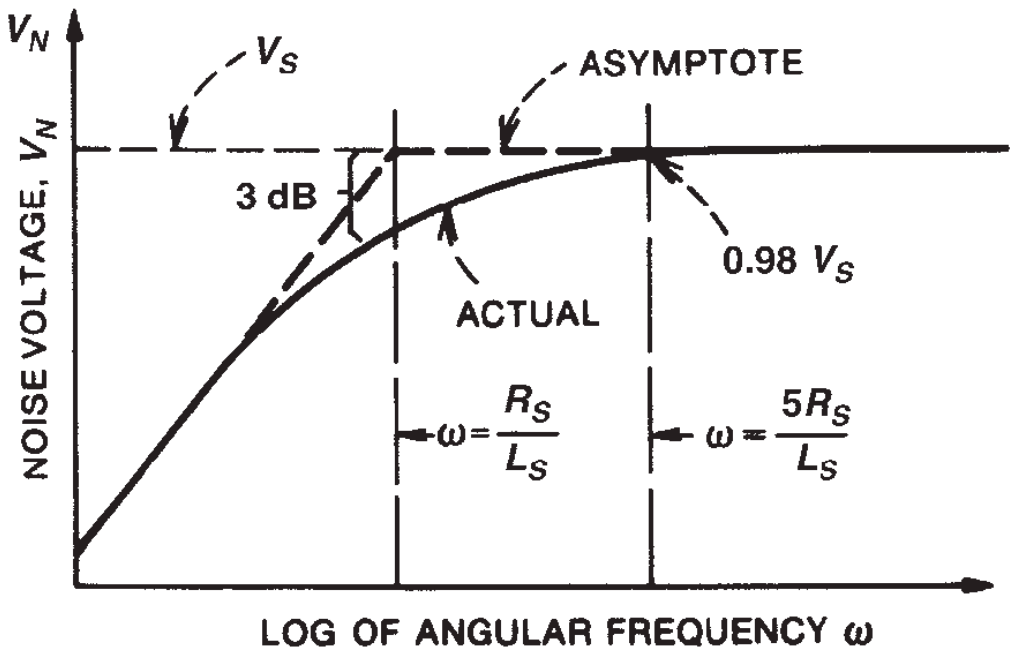


**FIGURE**. Noise voltage in center conductor of coaxial cable because of shield current.

$$V_N = \left( \frac{j\omega}{j\omega + R_S / L_S} \right) V_S$$

Cut-off frequency:

$$\omega_c = \frac{R_S}{L_S} \qquad f_c = \frac{R_S}{2\pi L_S}$$

# Measured Values of Shield Cutoff Frequency

**TABLE.** Measured Values of Sheild Cutoff Frequency $f_c$.

| Cable | Impedance (Ω) | Cutoff Frequency (kHz) | Five Times Cutoff Frequency (kHz) | Remarks |
|---|---|---|---|---|
| Coaxial cable | | | | |
| RG-6A | 75 | 0.6 | 3.0 | Double shielded |
| RG-213 | 50 | 0.7 | 3.5 | |
| RG-214 | 50 | 0.7 | 3.5 | Double shielded |
| RG-62A | 93 | 1.5 | 7.5 | |
| RG-59C | 75 | 1.6 | 8.0 | |
| RG-58C | 50 | 2.0 | 10.0 | |
| Shielded twisted pair | | | | |
| 754E | 125 | 0.8 | 4.0 | Double shielded |
| 24 Ga. | – | 2.2 | 11.0 | |
| 22 Ga.[a] | – | 7.0 | 35.0 | Aluminum-foil shield |
| Shielded single | | | | |
| 24 Ga. | – | 4.0 | 20.0 | |

# Magnetic Flux

When a current $I$ flows through a conductor, it produces a magnetic flux $\Phi$, which is proportional to the current. The constant of proportionality is the inductance $L$; hence, we can write

$$\phi_T = LI,$$

where $\Phi_T$ is the total magnetic flux and $I$ is the current producing the flux. *self-inductance* of a conductor :

$$L = \frac{\phi_T}{I}.$$

The inductance depends on the geometry of the circuit and the magnetic properties of the media containing the field.

# Mutual Inductance

When current flow in one circuit produces a flux in a second circuit, there is a *mutual inductance* $M_{12}$ between circuits 1 and 2 defined as

$$M_{12} = \frac{\phi_{12}}{I_1}.$$

The symbol $\phi_{12}$ represents the flux in circuit 2 because of the current $I_1$ in circuit 1.

# The magnetic Flux Density B

the magnetic flux density $B$ at a distance $r$ from a long current-carrying conductor as

$$B = \frac{\mu I}{2\pi r},$$

$\mu$ the permeability of the medium (material)

Calculate the mutual inductance between the two nested coplaner loops:

The magnetic flux produced by the current in conductor 1 crossing the loop between conductors 3 and 4 is

$$\phi_{12} = \int_a^b \frac{\mu I_1}{2\pi r}\,dr = \frac{\mu I_1}{2\pi}\ln\left(\frac{b}{a}\right).$$

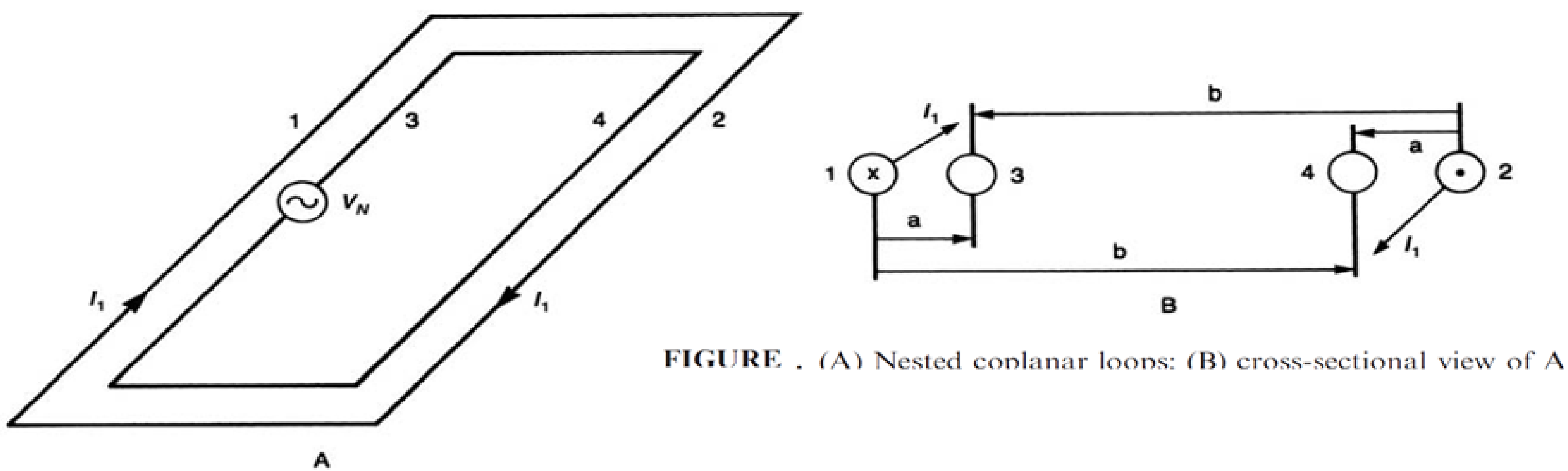


FIGURE . (A) Nested coplanar loops: (B) cross-sectional view of A.

# Mutual Inductance

Dividing $\phi_{12}$ by $I_1$ and substituting $4\pi \times 10^{-7}$ H/m for $\mu$, we obtain as the mutual inductance in H/m

$$M = 4 \times 10^{-7} \ln\left(\frac{b}{a}\right)$$

Example:

$f = 10\text{MHz}$ $\quad$ $I_1 = 100\mu\text{A}$

$a = 10\mu\text{m}$ $\quad$ $b = 3000\mu\text{m}$

$V_N = 14\text{mV}$

# REDUCING MAGNETICALLY-COUPLED NOISE

- **Careful Routing of Wiring**
- **Use Conductive Screens for HF Magnetic Shields**
- **Use High Permeability Shields for LF Magnetic Fields (mu-Metal)**
- **Reduce Loop Area of Receiver**
  - **Twisted Pair Wiring**
  - **Physical Wire Placement**
  - **Orientation of Circuit to Interference**
- **Reduce Noise Sources**
  - **Twisted Pair Wiring**
  - **Driven Shields**