MORE ON CABLES & CONNECTORS

The interaction or coupling of extraneous signals into wiring cables has been a problem since devices such as sensitive radio receivers and sensitive microphones have been employed. The many uses of electronic subsystems have developed complex and often-occurring problems of interference on wiring.

CONCEPTS OF CABLE COUPLING PHENOMENA

The physical model for analyzing the coupling between cables is that two or more cables run parallel. The coupling may be expressed in terms of the transfer impedance which can be defined as the ratio of the voltage appearing between the conductors of the second cable to the current applied at the first. At low frequencies, i.e., those frequencies for which the total length of one is short compared to the wavelength (these are defined as those cables shorter than one-sixteenth wavelength), the current and voltage along the cable may be considered to be constant; therefore, it does not matter at which end of the cable the current or voltage is measured. At higher frequencies, standing waves on the cables must be taken into account if the cables are not terminated in their characteristic impedances.

TRANSFER IMPEDANCE

The transfer impedance is clearly dependent upon the impedances terminating between the source and the susceptible cable. It will depend upon both magnetic and capacitive coupling effects. At low frequencies capacitive coupling is easily prevented by placing one or both of the cables in metallic shields. If the concern is with individual sensors in a cable, this shielding will not be possible, and both magnetic and capacitive coupling will be significant.

CONSIDERATIONS

The decision as to types and lengths of cables connecting equipment of separate subsystems should be made by the cognizant system engineers in coordination with each of the respective subsystem engineers. Likewise, shield terminations, lead twisting, and cable routing should be coordinated. Thus, the integrity of the grounding philosophy and shielding may be maintained. Coupling problems, cross talk, and ground loops will be minimized while compatible integration will be greatly enhanced.

Routing of the wires and cables within a modern aircraft and missile is no longer the simple matter of getting a circuit from one point to another by the shortest, least complicated way. Wires and cables are actually part of the individual electronic subsystems. The term "routing" includes separation, segregation, and sorting into bundles and cable placement.

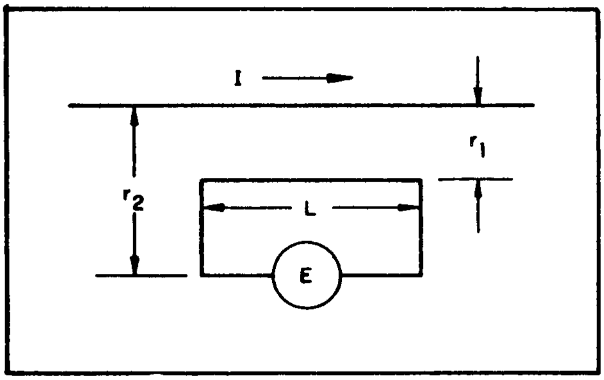
Vibrating electrical and electronic wiring and cables can generate a small voltage that degrade susceptible circuits. Vibration can also cause chafing of insulation on sharp metal edges which can cause short circuits and electrical fires. Ensure that cables and wires do not come in contact with sharp metal edges by shielding these edges and using bushings when cables are fed through the frame.

The information contained in Table 1 should be used for guidance.

TABLE 1. GUIDANCE FOR CABLING

1. Analyze for both inductive and capacitive coupling.
2. Separate power wires from signal wires and input lines from output lines (do not install in same wire bundle or connector).
3. Route susceptible wires away from power supplies, transformers, and other high power devices.
4. Use twisted pairs instead of shielding power cables.
5. Use *DN 5B5* for determining wiring methods and classifications.
6. Terminate wires and cables as suggested in *DN 5B5* and *DN 5C4*.
7. Select and mate coaxial cables with RF connectors according to *MIL-HDBK-216*.
8. Ensure that cables (wires) interface with the other EMC disciplines (shielding, filtering, and bonding).

FIGURE 1. Voltage Induced in a Loop



COUPLING AT LOW FREQUENCIES

Low frequency coupling is considered to be one-sixteenth of a wavelength or lower. Magnetic coupling will be most noticeable as a contributor to interference when the circuitry attached to the cable operates into low impedances at each end. Interference voltages are induced into a wire by flux linkage to the source of interference. The source of interference will be a generator magnetic flux which may be a transformer, a solenoid, or another current-carrying wire. The voltage induced in a loop by an adjacent wire of infinite length carrying current as represented in Figure 1 will be

$$E = (3.19 \times 10^{-8})\, fLI \ln \frac{r_2}{r_1} \qquad \text{(Eq 1)}$$

where

- f = frequency, Hz
- L = length, inches
- I = current, amperes
- E = induced voltage, volts
- r_1 and r_2 = loop distance, inches

If the susceptible loop is at an angle to the interference source, Equation 2 holds true. Figure 2 illustrates a source loop coupled to a sensitive wire loop.

$$E = (1.595 \times 10^{-8})\, fLI \left[\ln\left(\frac{R_1^2 + W^2 + 2R_1 W \cos\theta}{R_1^2 + W^2 - 2R_1 W \cos\theta} \right) - \ln\left(\frac{R_2^2 + W^2 + 2R_2 \cos\phi}{R_2^2 + W^2 - 2R_2 \cos\phi} \right) \right] \qquad \text{(Eq 2)}$$

The induced voltage rises with frequency, source current, and length of closed loop. The induced voltage also increases with effective area enclosed by the pick-up loop. The induced voltage will act in circuits by driving current through the impedances in the pick-up loop and its loads. For low frequencies, the impedance of the pick-up loop will consist primarily of wire resistance, and maximum power will be delivered to a load of low reisistance. It is assumed that the source circuit is a low impedance circuit since the most significant interference will result from a high current source. The voltage delivered to the circuits attached to the pick-up loops will rise to half the induced voltage as the load impedance in the pick-up loop rises to match the driving impedance due to the coupling. As the load impedance rises from this point, the voltage at the circuit loads will rise to the full induced voltage as a maximum.

FIGURE 2 Susceptible Loop at an Angle