Chapter 5  Miscellaneous Aspects for Digital Systems

1. Dependability, Reliability, and Availability
   a. Dependability encompass the concept of reliability, availability, safety, performability, maintainability and testability
   b. Failure rate of a device ($\lambda$)
      i. Circuit (number of gates, number of I/O pins, technology, etc)
      ii. Environmental factors
      iii. Others: e.g., who will do this, how it is documented, with ISO 9000 or not, etc.
   c. FIT (Failure in Time Unit): Number of failures in $10^{9}$ hours.
   d. Bath Tub Curve for failure rate.

   e. Reliability: Conditional probability that the given system still works correctly at time $t_1$
given the system has been working correctly at $t_0$
P \{works at $t_1 |$ worked at $t_0$\}
Normally represented as 0.9999993 = 99.99993% = 0.9993

   f. Mean Time to Failure (MTTF)
   \[ MTTF = \frac{1}{\lambda} \]
Example: given the failure rate $\lambda$ of a digital circuit is 274 FIT, determine the MTTF for the circuit?

   g. More commonly used is MTBF: Mean Time Between Failures
   \[ MTBF = MTTF + MTTR \]
   MTTR: Mean time to repair, $MTTR = \frac{1}{\mu}$, where $\mu$ is the repair rate
h. When there is no redundancy, every component in the system is critical (must be functioning for the system to function)

\[
\text{Failure rate of the system} =
\]
\[
\text{Reliability of the system} =
\]

i. If there’s redundancy (HW, SW, Information (coding), Time)

\[
\text{Failure rate of the system} =
\]

j. For serial system, its reliability is given by

k. For parallel system, its reliability is given by

l. For high redundant system (M-of-N system), its reliability is given by

m. Read from the additional notes about the availability, maintainability and so on.
2. Transmission Line Effort

a. Statement: A transmission line has to be at least miles long (Y/N)?
   No, transmission line not necessary to be a wire miles long!

b. Then, what is a transmission line?
   If the propagation delay of a segment of wire is greater than the transmission time of a
   pulse to be sent, it can be considered to be a transmission line

c. Results from transmission line effects include
   Ringing, Overshooting, Undershooting, Producing Erroneous Signals

d. Equivalent circuit of a segment of the transmission line

\[
L: \text{ inductance in Henry per unit length of wire} \\
C: \text{ Capacitance in Farads per unit length of wire} \\
\text{Wire width, thickness, and spacing of conductors and dielectric constant of} \\
\text{insulation materials decide the capacitance.}
\]

Time delay per unit length =

Characteristic impedance \( Z_0 = \)

Reflected voltage \( V_r = \)

e. Transmission Line Effect
   Electricity travels roughly half of the speed of light
   \( 1 \text{ s light travels } 3 \times 10^8 \text{ m} \)
   \( 1 \text{ ns electricity travels 0.15 m} \)
Assume characteristic impedance $Z_0$, then we will have

$$I = \, , \quad V = \, .$$

Analysis:

Case 1: Matching Impedance

Case 2: Short Circuit (when $Z_0$ equals internal resistance of the power source)

Case 3: Short Circuit ($Z_0$ dose not match internal resistance of the power source)
Case 4: Open Circuit

Case 5: More General Case

3. Noise in Digital Systems

Questions:
* Source of Noises and Types of Noises?
* Effect of Noise on different parts of the system?
* How to design and implement system to control noise?

a. External or Radiation Noise
   i. Electrostatic: Lighting (High Voltage Noise)
      Remedy ➔ Use Aluminum (AL) chassis
   
   ii. Electromagnetic: High current sources in the vicinity
       Examples: welding machine, current from large motors
       Remedy ➔ Chassis made of high-µ ferromagnetic material

   iii. Shielding
iv. Grounding depends on the frequency of signal

If low frequency signals (< 1 GHz)
   Ground only one end of shielded wire.

If high frequency digital system with no amplifier
   Ground both ends of shielded wire.

Ribbon caller: use alternative lines as ground in high noise environment

b. Internal Noise
   Mainly from the power supply.

   FFs, one-shots, high-gain Op amps, Schmidt trigger input, and other regenerative
   modules are more prone to noise
   Transducer producing low strength signals are vulnerable

   To get rid of internal noise:
   1) Decoupling: use decoupling capacitors
      Across power supply inlet on a PCB
      250 – 2000 µF electrolytic or tantalium and a 0.1 µF disc capacitor in
      parallel.

      If this is not enough ➔
      Directly across the power supply pins of each critical chips connect to a
      0.1 µF disc cap.

   2) Grounding
      Very important if unit consist of analog and electromechanical parts

      -- Each subsystem: should have its own (or isolated) power supply. At
      least have separate voltage regulators chips or DC/DC converters.

      -- Two grounding systems: chassis ground and AC power ground

      -- Use opto-couplers for electromechanical systems (Usually it’s a must).

      -- Avoid ground loops, use center point configuration for ground and
      power lines.