Electronics Prototyping
Grounding and Power Supply
Grounding

- “Ground”, +0V and resistance
- Single-point (Star) grounding and common power supply returns

Ground Loops
- Voltage induced in wire loop due to changing magnetic field

\[ V = kNA \frac{dB}{dt} \]  
(Faraday’s law of induction)

where \( B \) = Flux density (Gauss), \( N \) = number of turns, \( A \) = cross section of loop (\( m^2 \))
Ground Loops

• Solving ground loop problems
  • Star point
  • Find the current – make it flow where you want it
    • Low resistance metal cable ducts
    • Close to metal chassis
  • Break the path
    • Transformer coupling
    • Opto isolator
  • Filter
  • Modulate carrier transmission
Protective Earth

- Connection between the equipment chassis or frame and the ground at zero potential
- Purpose
  - Avoid a potentially lethal potential on the equipment in case of a fault
  - Trigger protection systems placed upstream to isolate the equipment
Power Supply Filtering

- Big capacitor 10–47uF and 1–2uF in parallel at entry point (large capacitor has low self-resonance frequency)
- Electrolytic or Tantalum
IC Decoupling

- “Ground bounce” and power supply bypass (decoupling) caps

\[ i = C_n \frac{dV}{dt} \]

- where \( C_n \) is ‘node’ capacitance, \( \approx 50\text{pF} \)
- \( dV/dt \approx 1\text{V/ns} \) for 74ALSxxx
- \( i \approx 50\text{mA} \) per gate (400mA for 8 gates!)

- One 10-100pF (0.01-0.1μF) ceramic or tantalum per 2 logic ICs
- Close to power pins (15 mm)
- Minimum lead inductance
Rules for Wiring Up

- You must have a circuit diagram!
- Connect power supply and grounds *first*
- Check them
- Check them again

- On first power-up:
  - Set power supply current limit low
  - Monitor current
  - Any hot chips?
Wires
Wires

- Wire = single conductor, insulated or not
- Cable = multiple conductors
  (group of insulated wires in a sheath)

- Single strand for breadboard only
  - e.g. 1/0.6 rated at 3.0A @ 25°C, 64Ω/km
- Multistrand (e.g. 7/0.2) for crimp connectors
  - e.g. 7/0.2 rated at 2.0A @ 25°C, 88Ω/km

- Colour code
  - Strictly: Black = +0V; Red = +5.0V
  - Other colours to help tracing
  - Put colours (and pin numbers) on circuit diagrams
  - Keep schematics up to date
Resistance of Cables

- Resistance is proportional to the length of the conductor, $l \ (m)$ and inversely proportional to the cross section of the copper, $A \ (m^2)$
- Resistivity $\rho_{cu} = 1.72 \times 10^{-8} \ \Omega m$ is the constant of proportionality

$$R = \rho_{cu} \frac{l}{A}$$
Cross-Talk and Shielding

- Cross-talk introduced by mutual inductance and/or capacitance
- How to minimise induced noise
  - Keep conductors bundled
  - Twisted pairs reduce magnetic and capacitive interference
  - Shield signal lines
  - Maintain low impedance terminations
  - Filter connectors
  - Ferrite beads
- Grounding shields – which end?
- Faraday cage
Analog and Digital Separation

- Physically separate analog and digital circuits
- Connect analog & digital grounds at one point only
Analog Interference

- Control analog tracks – minimise loop area to minimise induced voltage

\[ V = kNA \frac{dB}{dt} \]

- Use shielded twisted pairs (STPs) where possible on analog wiring
  - Orientation changes to minimise differential pickup
  - Minimises loop area to reduce magnetically induced noise
  - Shields from electrically induced noise
Analog and Digital Transmission Lines

- Keep lengths of individual bus conductors the same to reduce “skew”
- \( \lambda \approx 300 \text{m} @ 1\text{MHz} \) (\( c = f.\lambda, c \approx 300 \times 10^6 \text{ m/s} \))
  - Actually, \( v \approx 0.8c \) in real media
  - Consider transmission line effects ("wave behaviour") if shortest rise time < 3 x propagation time along conductor
Unreliable Components

Anything with mechanical bits

1. Connectors
2. Switches
3. Potentiometers

Trim Pots

- Only allow user to trim about ±10%
- A trim pot is a 2-terminal device! (falling off the end)
- Set pots to mid-range before powering-up…
Crimps for 0.1” Header Strips

before crimping  well crimped  over-crimped

in housing

David Rye :: MTRX3700  Prototyping :: Slide 17 of 21
Static Protection

- Cumulative! Expensive to repair in field
- Static sensitive when
  - Not in a circuit
  - Unpowered

- In lab
  - Store in anti-static foam and/or bag before use
  - Don’t touch circuit conductors or chip pins
  - Earth your hand to discharge static before handling

- In production
  - Also use anti-static mat and wrist strap
Logic Gates
• There is no such thing as digital electronics!

• Bypass power pins generously

• Unused gate inputs
  • TTL – 4k7 pull up to +5V  \( (I_{\text{min}}, \text{overvoltage protection}) \)
  • CMOS – tie to +5V or +0V
Recommended References