System interconnection issues:

- How to manage electrical connections?
- What to ground? Where?
- How to solve electrical noise problems?
- How to accurately transduce sensor signals and actuator commands?
Connections between subsystems:

Two principal approaches:

a) Tie commons and chassis grounds together extensively; try to keep systems at equal potentials.

b) Keep subsystems electrically separate; use differential as instrumentation amplifiers for analog connections, opto-isolators for digital connections.

Key is to think about where currents will flow and how disturbances are coupled.

$$E$$

Electric field

Coupling via strong capacitance

$$B$$

Magnetic field

Coupling via strong mutual inductance
E-coupling: coupling capacitance $C_{stray}$

If disturbed system has a low impedance to ground, a current is injected.

If disturbed system has a high impedance, no current is injected but the voltage is driven away from ground.
B-coupling:

\[ i = M_{12} I_d \]

\[ \nu = 0 \]

source

disturbed system

If disturbed system has a low impedance, a disturbance current will flow.

\[ \nu = M_{12} \frac{dI_d}{dt} \]

If disturbed system has a high impedance, a disturbance voltage will be generated.
System layout: Current control loop for motor drive

Note that ±15 and ±40 supply currents will return on respective commons, and do not cross-return!
• Target board must have a good ground plane.

• In any of these arrangements
  be sure to maintain connection
to earth ground for safety
reasons

• We assume that the supply common
  can be "floated" with respect to
  chassis ground and the power hot (H)
  and neutral (N). This is not always
  the case; may need to use an
  isolation transformer.

• Key advantage here is that supply
  commons often meet at one point
  on the target board. This is also the
  point where the board common is
  tied to ground. The commons are not
  connected back at the supplies.
  Result: Each supply current returns
  only on its associated common, and
  not on other commons or the ground
  wire.

• Pet peeve: open-frame supplies
Connections between subsystems

Due to magnetic and electric field coupling, separate subsystems exhibit a common-mode voltage difference.

If you try to connect the commons a ground loop current will flow, and will generate error voltages.

If you don't connect the commons, you have to manage the common mode voltage $V_{CM}$. 
- Ways to absorb common-mode voltage, i.e. allow it to be there but not allow it to disturb the communication of signals.

- Opto-isolator

- Common-mode choke

- Differential amplifier:

\[ V_{CM} = \frac{V_1 + V_2}{2} \]

\[ V = A(V_1 - V_2) \]
BUT, to eliminate E-field pickup, we need to shield the connections. Shield cannot be connected on both ends.
- not differential amplifier

Shield generally connected back to source, not connected to receiver
Switching amplifiers are particularly nasty, but can be tamed if you think carefully about how commons are tied, managing E-field-coupled noise and B-field-coupled noise.

Motor feedthrough and stray capacitances are particularly problematic.

Low signal switching amplifiers need to be inductive to prevent high-amplitude current spikes at each switching instant.