Electromagnetic Compatibility & CAN Bus

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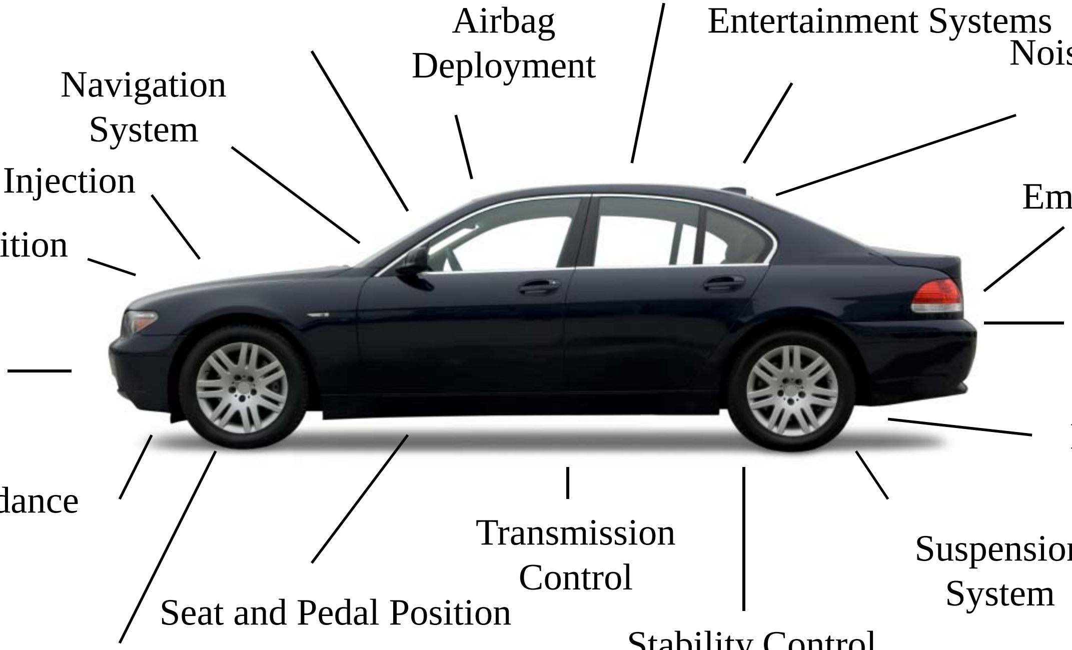
Automobiles are Complex Electronic Systems



Cabin Environment Controls

Communication System

Airbag Deployment

Entertainment Systems

Noise Cancellation

Navigation System

Fuel Injection

Emissions Controls

Engine Ignition

Security System

Lighting

Braking Control

Collision Avoidance System

Transmission Control

Suspension System

Seat and Pedal Position

Stability Control

Tire Pressure Monitoring

Automotive Networks

- **LIN** (Local Interconnect Network)
- **MOST** (Media Oriented Systems Transport)
- **CAN** (Controller Area Network)
- **FlexRay**
- **Others:** Byteflight, DSI bus, D2B, IEbus, Intellibus, MI, MML Bus, SMARTwireX

Automotive Networks

LIN (Local Interconnect Network)

A primary advantage of this bus is that it can be implemented with a single wire (using the vehicle chassis as a current return path). A small and relatively slow in-vehicle communication and networking serial bus system, LIN bus is used to integrate intelligent sensors and actuators. LIN can also communicate over a vehicle's power distribution system with a DC-LIN transceiver.

Maximum Data Rates: 19.2Kbaud at 40m

Physical Layer: Single-Wire Implementation

Transmission Format: SCI (UART) Data Format

Operating Voltage: 12v over a Single Wire

Network Topology: Single Master / Multiple Slave (Up to 16 slaves)

Standards: Enhanced ISO 9141

Automotive Networks

MOST (Media Oriented Systems Transport)

MOST was originally designed by Oasis Silicon Systems AG (now SMSC) in cooperation with BMW, Becker Radio, and DaimlerChrysler for multimedia applications in the automotive environment. It was intended to be implemented on an optical fiber, so the bit rates of this bus system are much higher than previous automotive bus technologies. MOST buses provide an optical solution for automotive peripherals like car radios, CD and DVD players, and GPS navigation systems.

Maximum Data Rates: 23 Mbaud

Layers: All Seven Layers of the ISO/OSI Reference Model for Data Communication

Network Topology: Point to Point via a Ring Topology but Star Configurations

Other Feature: Plug and Play; 60 Channels, 15 MPEG1 Channels for user configuration

Standards: ISO 7498-1 (OSI Model)

Automotive Networks

CAN (Controller Area Network)

A serial bus originally developed by Robert Bosch GmbH in 1986 for in-vehicle networks in cars. CAN buses employing twisted wire pairs were specifically designed to be robust in electromagnetically noisy environments. The applications of CAN bus in automobiles include window and seat operation (low speed), engine management (high speed), brake control (high speed) and many other systems.

Maximum Data Rates: 1Mbps at 40m, 125Kbps at 500m, 50kbps at 1000m

Circuit Type: Differential

Physical Layer: Twisted Wire Pair, 9 pin D-Sub

Transmission Format: Asynchronous

Drive Voltage: High: 2.75v ~ 4.5v; Low: 0.5v ~ 2.25v; Differential: 1.5v ~ 3.0v

Network Topology: Point to Point

Standards: ISO 11898/11519

Automotive Networks

FlexRay

FlexRay is a high-speed serial communication bus for in-vehicle networks. It is an extended protocol version of byteflight. The extended FlexRay has the performance features required for active safety, such as redundant transmission channels and a fault-tolerant synchronization mechanism. Applications for FlexRay include steer-by-wire and brake-by-wire systems.

Maximum Data Rates: 500 kbps ~ 10 Mbps

Communication Modes: Time-triggered, Event-triggered

Network Topology: Single-channel topologies, Dual-channel topologies

OBDII

OBDII (On-Board Diagnostics II)

Since on-board vehicle computers were introduced in the early 1980's, OBD systems have made it possible to give the vehicle owner or a technician access to information on the state of vehicle subsystems. OBD II defines a communications protocol to provide a standardized series of diagnostic trouble codes (DTCs) via a standardized fast digital communications port. These codes allow a user to identify and remedy malfunctions within the vehicle.

There are 5 signaling protocols currently employed by the OBD II Interface

- SAE J1850 PWM (41.6 kbaud, Ford Motor Company Standard)
- SAE J1850 VPW (10.4/41.6 kbaud, General Motors Standard)
- ISO 9141-2 (10.4 kbaud, primarily used in Chrysler, European, and Asian vehicles)
- ISO 14230 KWP2000 (Keyword Protocol 2000)
- ISO 15765 CAN (250 kbps or 500 kbps).

CAN Bus

There are several CAN physical layer standards:

- ISO 11898-2: CAN high-speed
- ISO 11898-3: CAN fault-tolerant (low-speed)
- ISO 11992-1: CAN fault-tolerant for truck/trailer communication
- ISO 11783-2: 250 kbit/s, Agricultural Standard
- SAE J1939-11: 250 kbit/s, Shielded Twisted Pair (STP)
- SAE J1939-15: 250 kbit/s, UnShielded Twisted Pair (UTP) (reduced layer)
- SAE J2411: Single-wire CAN (SWC)

CAN Bus

Application layer implementations

As the CAN standard does not include tasks of application layer protocols, such as flow control, device addressing, and transportation of data blocks larger than one message, many implementations of higher layer protocols were created. Among these are:

- DeviceNet
- CANopen
- SDS
- CANaerospace,
- J1939
- NMEA 2000
- CAN Kingdom
- SafetyBUS p
- MilCAN

Electromagnetic Compatibility (EMC)

Electromagnetic Compatibility – The ability of an electronic device to operate without error in its intended electromagnetic environment.

Automobiles are Complex Electronic Systems

Functions typically controlled electronically include:

Engine ignition (spark, timing)
Fuel injection
Emissions controls
Collision avoidance systems
Heating/air conditioning
Navigation systems
Suspension systems
Transmission controls
Lights, horn, wipers, defrosters …

Entertainment systems
Braking (anti-lock brakes)
Steering (steering assist, 4-wheel steering)
Seat & pedal positions
Communication systems
Safety systems
Noise cancellation
Security systems

- Current automobile designs have nearly 100 microprocessors
- Number of processors expected to double in 5 years.
- A typical automobile contains about 5 miles of wiring.

Electromagnetic Compatibility

Types of Electromagnetic Compatibility Problems:

- Radiated Electromagnetic Interference
- Conducted Electromagnetic Interference
- Power line transient susceptibility
- Electrostatic Discharge susceptibility
- Lightning transient susceptibility

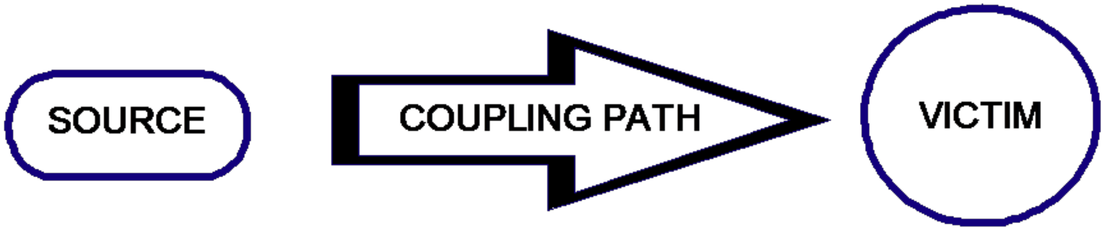
Electromagnetic Compatibility

Examples of Electromagnetic Compatibility Problems

- You can “hear” your windshield wipers in your radio
- Can’t receive your favorite FM radio station when the headlights are on.
- Engine misfires when driving under a high-voltage power line.
- Car is disabled and engine controller damaged by keying an amateur radio transmitter installed in the trunk.
- Electrostatic discharge occurs while inserting the ignition key, damaging ignition circuitry
- Nearby lightning strike causes cruise control to engage and accelerate the vehicle.

Electromagnetic Compatibility

Three Elements of an EMC Problem:



SOURCE	COUPLING PATH	VICTIM
Lightning	cables	Integrated Circuit
RF Transmitter	antennas	RF Receiver
High Speed Data Trace	common ground	High Speed Data Trace
Electric Motor	power lines	Telephone
Arc Welder	parasitic capacitance	Electronic Controls
Video Display	parasitic inductance	Video Display

EMC Design Guideline Collection

Board Level – Trace routing

- No trace unrelated to I/O should be located between an I/O connector and the device(s) sending and receiving signals using that connector.
- All power planes and traces should be routed on the same layer.
- A trace with a propagation delay more than half the transition time of the signal it carries must have a matched termination.
- Capacitively-loaded nets must have a total source impedance equal to or greater than one-quarter of the line characteristic impedance or a series resistor must be added to meet this condition.
- Nets driven at faster than 1V/ns slew rate must have a discrete series resistor at the source.
- Guard traces should be used to isolate high-speed nets from I/O nets.
- Guard traces should be connected to the ground plane with vias located less than one-quarter wavelength apart at the highest frequency of interest.
- All power and ground traces must be at least three times the nominal signal line width. This does not include guard traces.
- If a ground or power separation is required, the gap must be at least 3 mm wide.
- Additional decoupling capacitors should be placed on both sides of a power or ground plane gap.
- Critical nets should be routed in a daisy chain fashion with no stubs or branches.
- Critical nets should be routed at least 2X from the board edge, where X is the distance between the trace and its return current path.
- Signals with high-frequency content should not be routed beneath components used for board I/O.
- Differential pairs radiate much less than single-ended signals even when the traces in the pair are separated by many times their distance above a ground plane. However, imbalance in the pair can result in radiation comparable to an equivalent single-ended signal.
- The length of high-frequency nets should be minimized.
- The number of vias in high-frequency nets should be minimized.
- On a board with power and ground planes, no traces should be used to connect to power or ground. Connections should be made using a via adjacent to the power or ground pad of the component.
- Gaps or slots in the ground plane should be avoided. They should ONLY be used in situations where it is necessary to control the flow of low-frequency (i.e. less than 100 kHz) currents.

Identify Current Paths

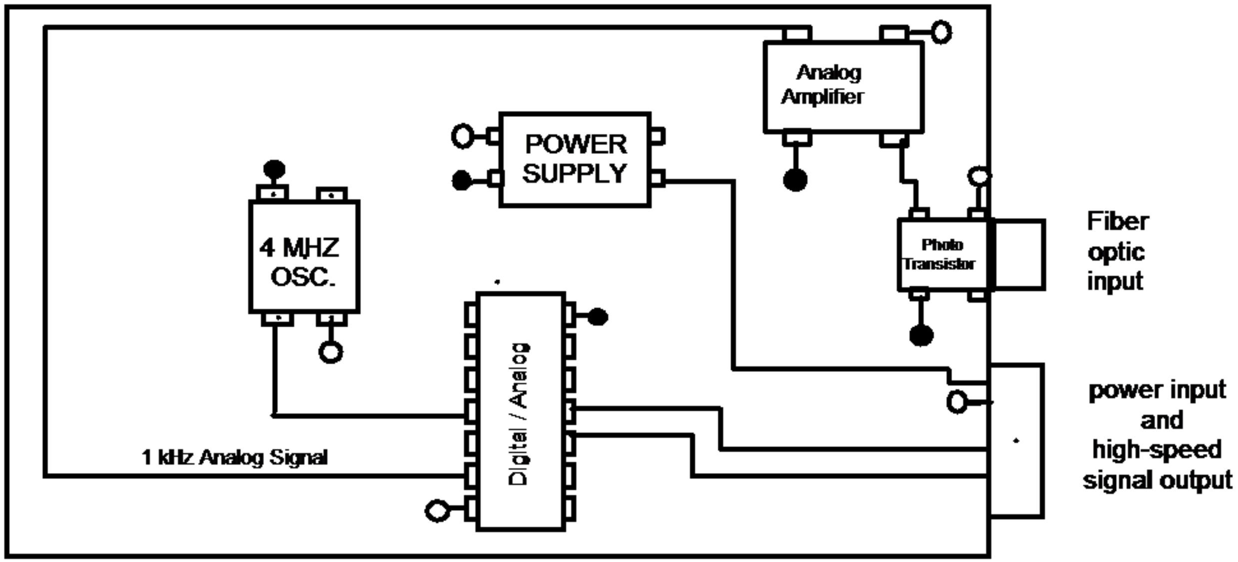
Current takes the path of least impedance!

> 100 kHz this is generally the path of least inductance

< 10 kHz this is generally the path(s) of least resistance

Identify Current Paths

Where does the 1 kHz return current flow?

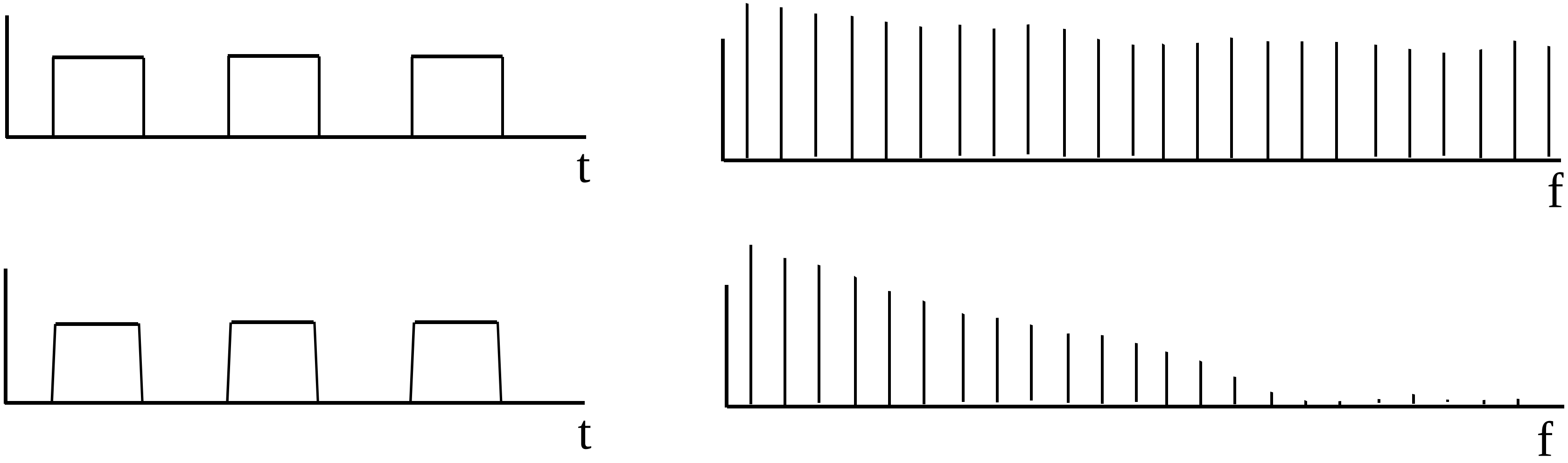


● Connection to power plane

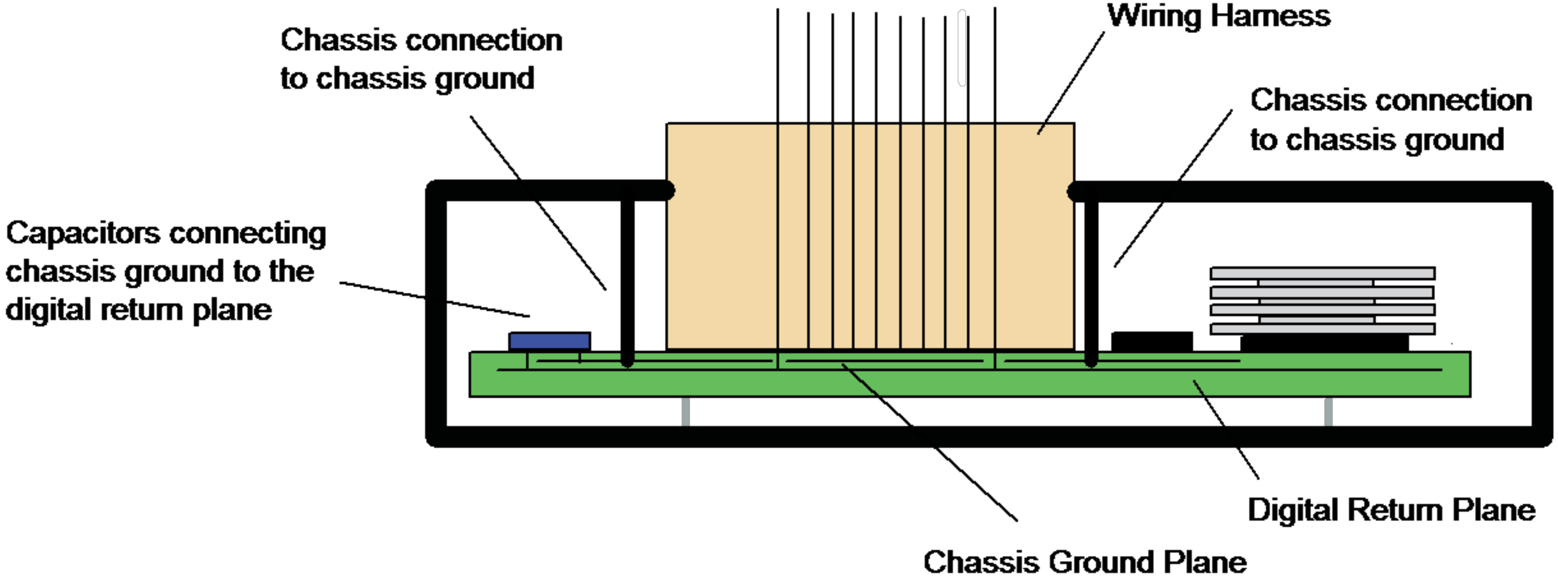
○ Connection to ground plane

Control Transition Times

Digital Signal Voltages



Chassis Ground and Digital Return



Summary

Don’t rely on design guidelines!

- Visualize signal current paths
- Control transition times and bandwidth
- One high-frequency ground
- Use common sense!