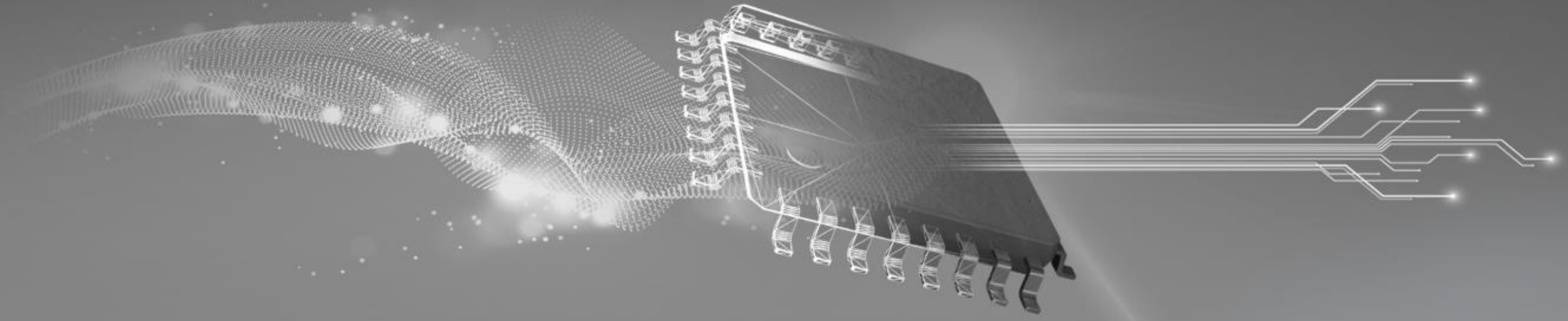
TI TECH DAYS



Designing robust in-vehicle Ethernet communication systems

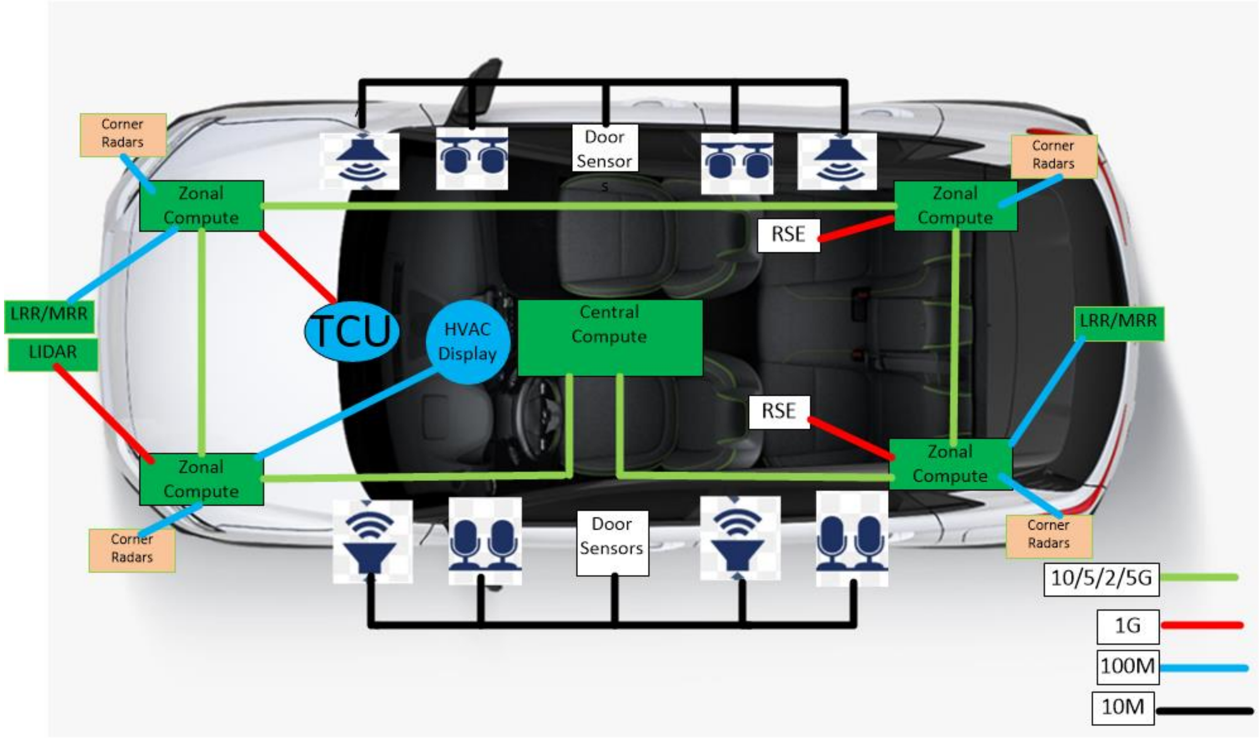
Diagnostic tool kit overview & EMC considerations

Ralf Eckhardt, Field Applications Engineer (DMTS)

Scope of presentation

- In this session you learn about the integrated diagnostic features available on TI’s Ethernet PHYs and how these diagnostic features can help increase the ‘safety level’ of your system.
- We’ll also discuss several EMC consideration while designing the Ethernet PHYs to improve the robustness of the systems.

Ethernet in automotive



In vehicle communication architecture unifying towards Ethernet

Automotive Ethernet PHYs

100BASE-T1
DP83TC811
(Mass Production)

- ***Targeted Applications:*** cluster, gateway, telematics control unit (TCU), head unit
- ***Robust:*** Excellent EMI, unshielded cable
- ***Modularity:*** Footprint compatible & upgrade to 1000Base-T1 (Gigabit Ethernet) DP83TG720 (*cost savings for 100Mbps need*)

1000BASE-T1
DP83TG720
(Sampling Now)

- ***Targeted Applications***: gateway, telematics control unit (TCU)
- ***Robust:*** Excellent EMI, no external filter, unshielded cable
- ***Modularity:*** footprint compatible with DP83TC811

DP83TC811-Q1 | Automotive Grade 100BASE-T1 Ethernet PHY
Unshielded Single Twisted Pair Ethernet PHY

Features

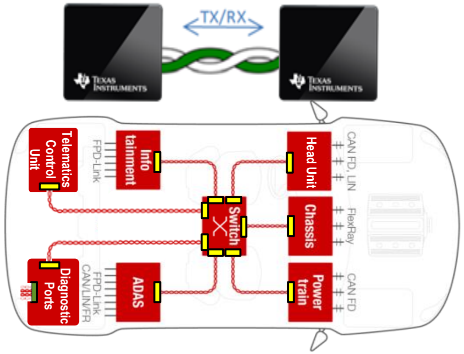
- 100Mbps over 60m USTP – **IEEE802.3bw**
  - Interoperable with other 100BASE-T1 PHYs
- Multiple MAC interfaces: **SGMII** / RGMII / RMII / MII
- ***Low latency 2x less than competition*** (<150ns)
- ***Low active power*** Up to 2x lower than competition (300mW)
- IEC 61000-4-2, +/-8kV Contact Discharge
- Diagnostic tool kit – SQI, TDR, ESD monitor, temp & voltage sensors
- Optimized for EMI and EMC performance
- 36-QFN, 6mm x 6mm (wettable flank)
- ***Pin to Pin compatible with 1000BASE-T1 (DP83TG720)***

Applications

- Backbone/Gateway – Connects all domains
- ADAS – Pre-processed object data from smart sensors
- Telematics Control Unit (TCU)
- Automotive External Amplifier
- Automotive Head Unit

Benefits

- Easy to interface with systems using other vendor PHYs.
- Provides design flexibility via multiple MAC interface support
- Low latency allows for faster response in time sensitive applications
- Ideal for battery powered applications. Low heat dissipation.
- Reliable performance in high ESD environments.
- Reduces over all system size, complexity, and cost
- Advanced feature set allows monitoring overall system status.
- Meets strict automotive EMI/EMC standards.



DP83TG720 | Low-Power, Low-Cost 1000BASE-T1 Ethernet PHY

Features

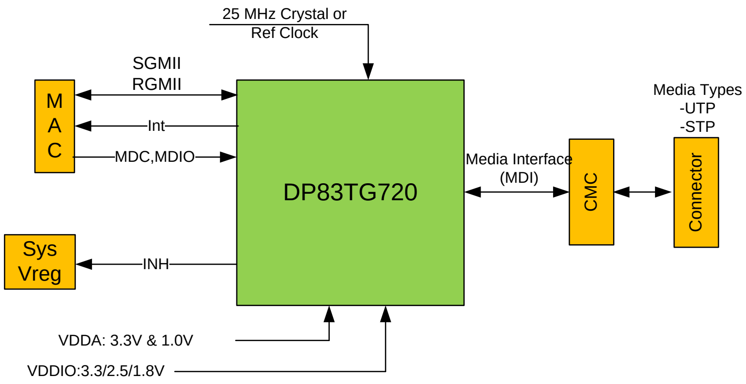
- **FTZ EMC compliant with *Unshielded Twisted Pair* with no external filter components**
- Passes major OEM EMC Test Specs ***with UTP cable***
- **Pin-to-pin compatible with** 100Base-T1 (DP83TC811)
- Active power < **500mW,** Sleep power < **2mW**
- Power saving features: Active sleep detection mode
- TC12 compliant: PHY & cable diagnostics suite
  - SQI and SNR estimation (1 dB accuracy)
- **RGMII & SGMII** w/ slew rate control
- IO Voltage : 1.8V, 2.5V, & 3.3V
- Small package QFN36, 6mm x 6mm (Wettable Flanks)
- 25 MHz Reference Output Clock (Daisy chaining)
- AEC-Q100 grade 1 qualified (-40 to 125 C)

Applications

- Telematics Boxes
- Connected Gateways, Domain Controllers
- Automotive Head unit

Benefits

- Footprint compatible w/ DP83TC811 for data rate flexibility at build time
- Qualifies EMC and FTZ test with no additional filter with UTP cable
- Passes C&S Interoperable look-ahead with competition link partners



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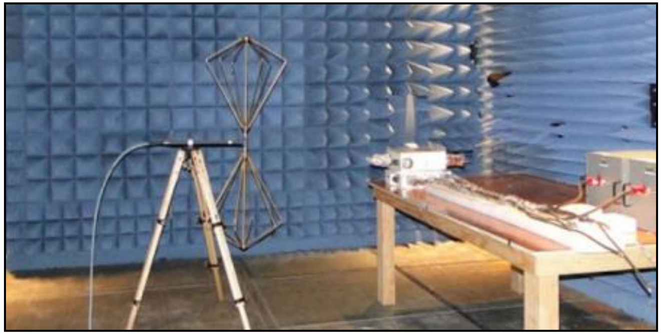
On chip diagnostic tools

Texas Instruments

On chip diagnostic tool use cases

- **Testing**
  - Component evaluation
  - During system characterization
  - System validation



- **Operation**
  - System startup, initial system check
  - Periodic system checks during operation
  - Signal monitoring
  - Long term signal monitoring (degradation)

- **Service/Maintenance/Production**
  - Get information on link quality and cable fault location

On chip diagnostic tool available in TI's PHY

- ✓ESD detector
- ✓SQI signal quality indication
- ✓TDR time domain reflectometry
- ✓Temperature sensor
- ✓BIST built in self test
- ✓Error and event counters

Electrostatic discharge sensor

Electronics are decreasing in size and thus becoming more susceptible to stress causing performance interruption and damage.

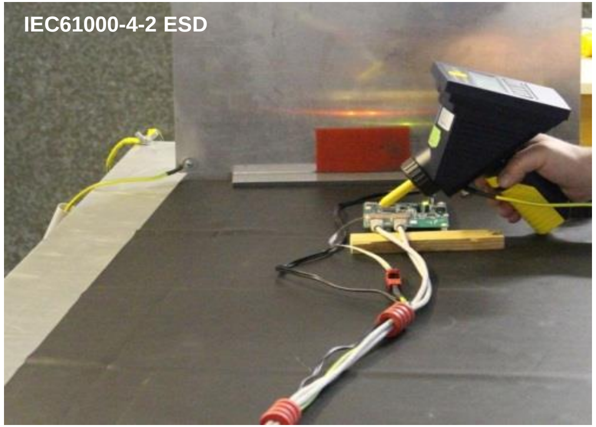
ESD events are particularly damaging when not accounted for, however, it is not always easy to predict an event or know how long an event will last.

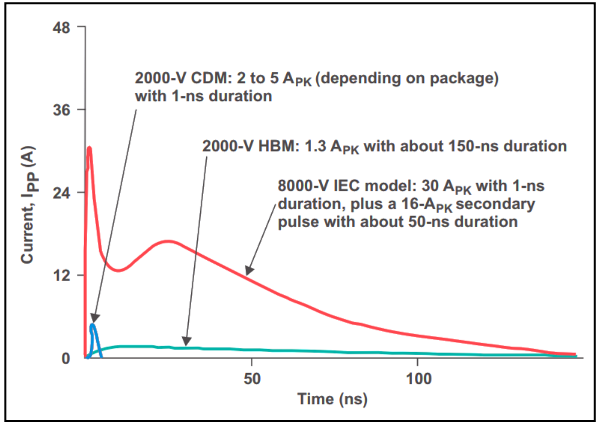
What if you could:

- ***determine the exact moment an ESD event occurred?***
- ***identify the pins an ESD event reached?***

<u>**DP83TC811 features patent pending ESD Sensor**</u>

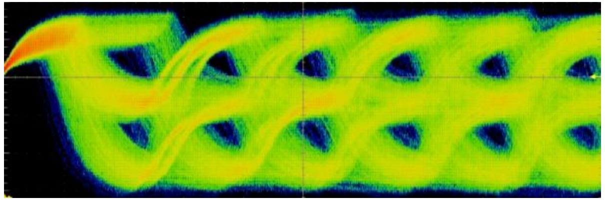
- xMII ESD detection and counter
- MDI ESD detection and counter
- ESD event interrupt flag
- Counters immune to device reset
- Detects any level of ESD

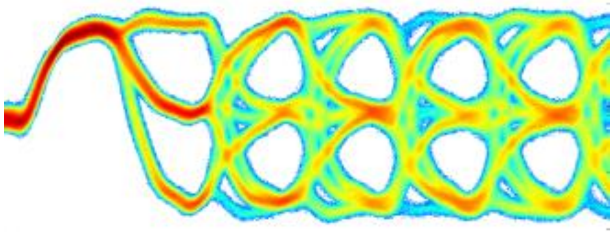




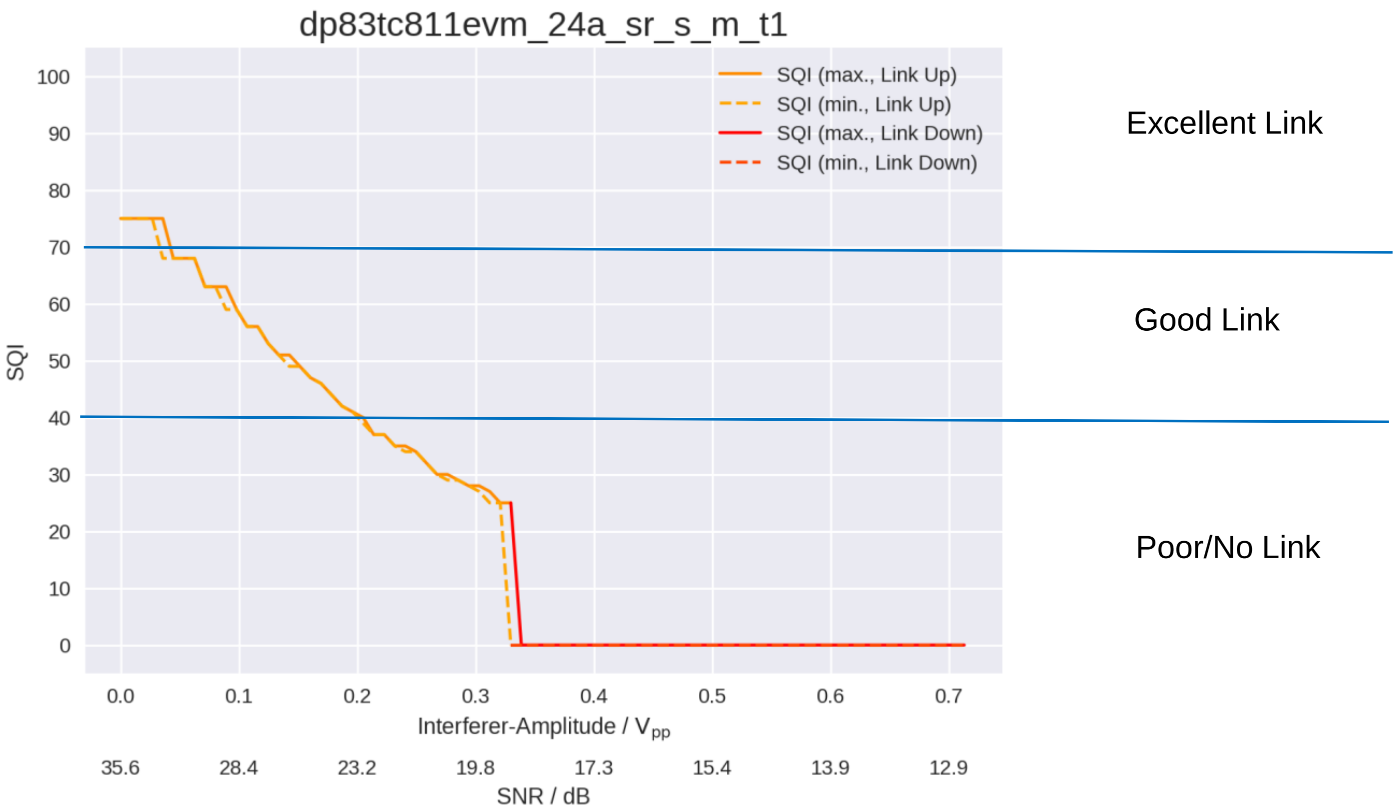
Signal quality indication (SQI)

- **SQI works with an active link**
  - Based on SNR (Signal-to-Noise Ratio)
- **Allows real-time channel health**
  - Monitoring of short term events
  - Long-term monitoring for an early indication of signal degradation
- **Interesting channel effects can be detected**
  - Adjacent channels
  - Electrical transient events
  - Effect of mechanical bending





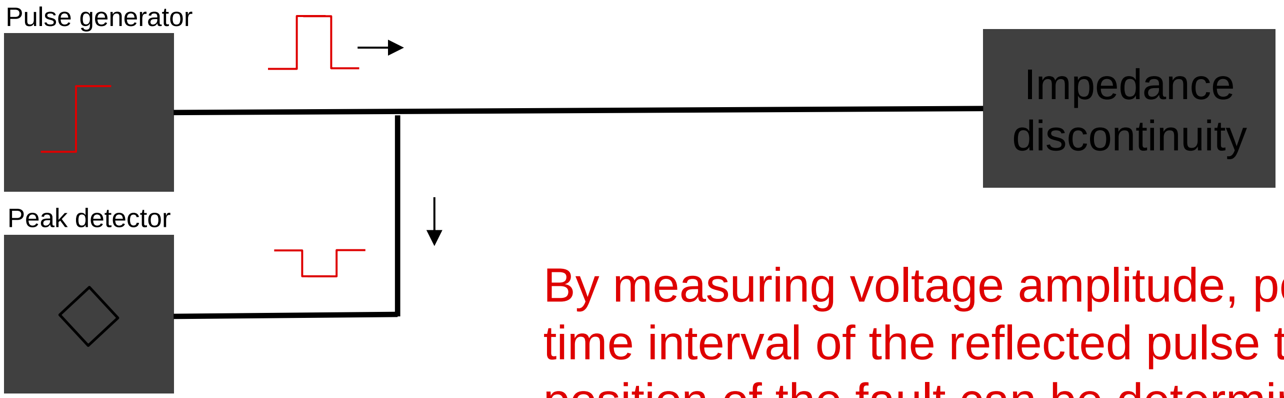
Signal quality indication (SQI)



TEXAS INSTRUMENTS

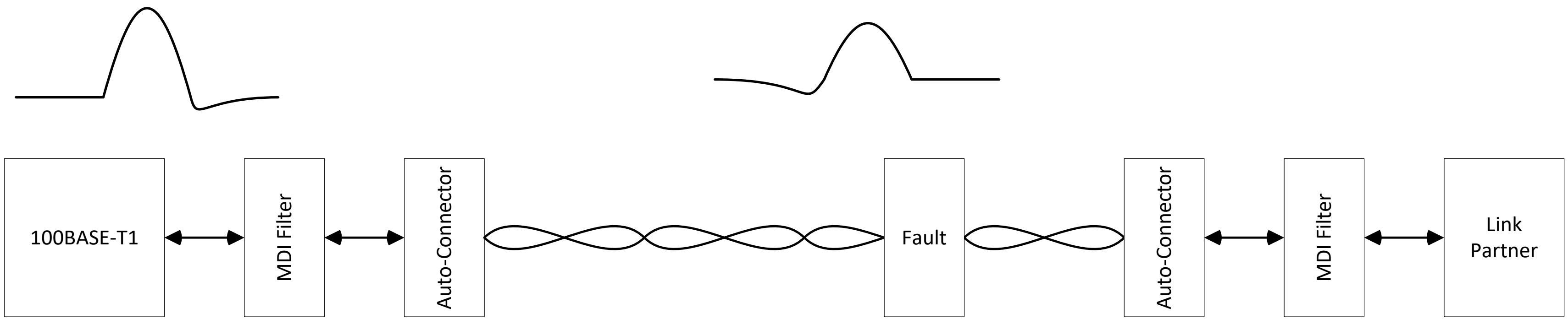
Time domain reflectometry (TDR)

- Method to test cable condition when link is down
- Proven technology in telecommunications, powerline and industrial Ethernet
- TDR is implemented in automotive Ethernet PHYs



By measuring voltage amplitude, polarity, and time interval of the reflected pulse the nature and position of the fault can be determined.

Time domain reflectometry (TDR)



$$\rho = \frac{Z_L - Z_O}{Z_L + Z_O}$$

$$Distance = \nu_\rho \times \frac{T}{2}$$

Z_O = Line Impedance

Z_L = Load Impedance

ν_ρ = velocity of propagation for the cable

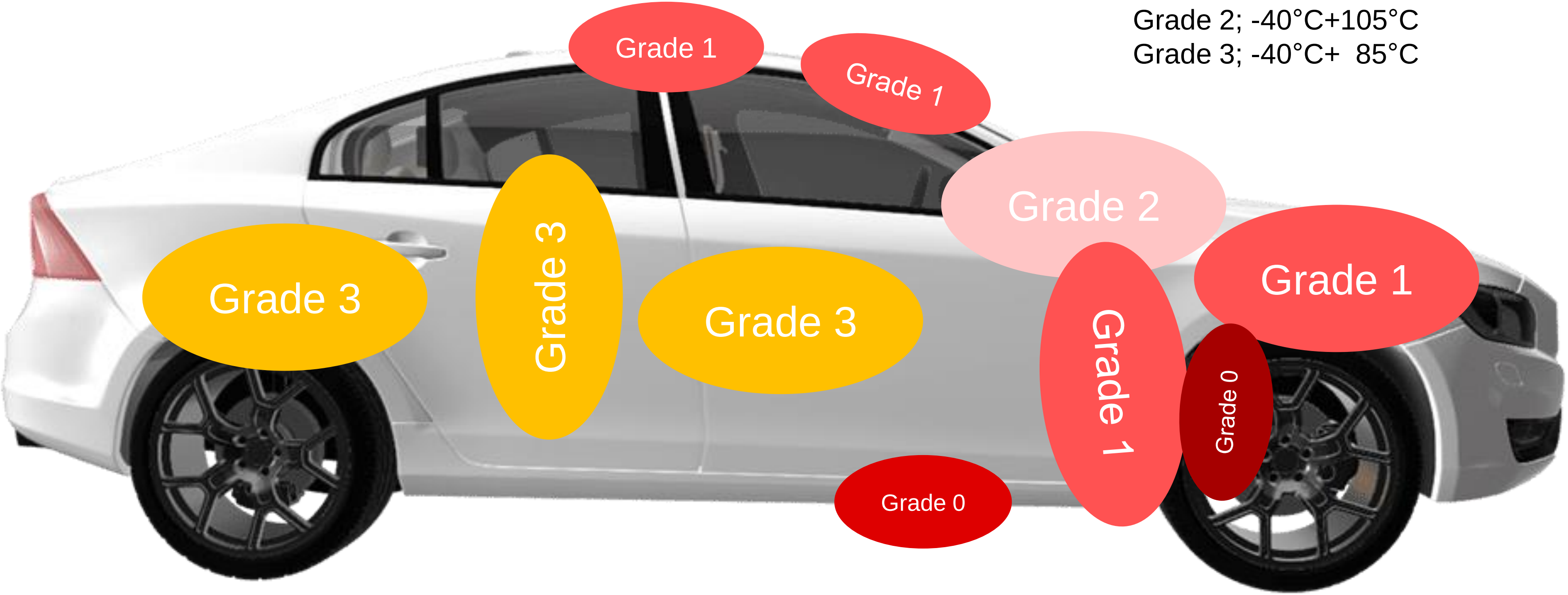
T = total transit time from pulse generation to fault condition and back

Which faults can be covered today?

Fault configuration	Raw TDR locations	Raw TDR amplitudes	TDR fault	SNR [dB], SQI, SQS
Normal	[0 0 0 0]	[0 0 0 0]	None	31.6, 75, 3
Inverted	[0 0 0 0]	[0 0 0 0]	None	31.6, 75, 3
D+ open	[9 16 0 0]	[78 -13 0 0]	Open	—, 0, 0
D– open	[9 16 0 0]	[78 -13 0 0]	Open	—, 0, 0
Both open	[9 16 0 0]	[81 -10 0 0]	Open	—, 0, 0
Cross short	[9 16 0 0]	[-80 13 0 0]	Short	—, 0, 0
D+ short to GND	[0 0 0 0]	[0 0 0 0]	None	29.8, 68, 2
D– short to GND	[0 0 0 0]	[0 0 0 0]	None	29.8, 68, 2
Both short to GND	[9 16 0 0]	[-79 10 0 0]	Short	—, 0, 0

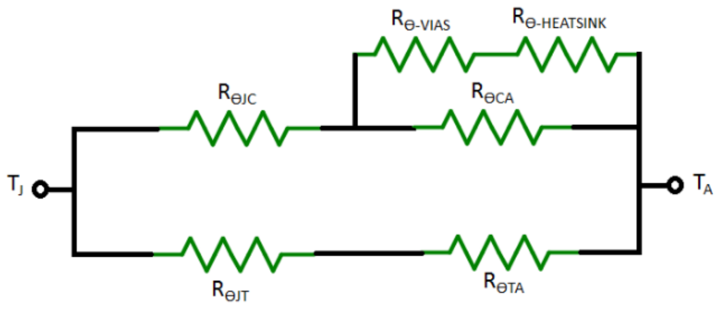
Typical automotive temperature grade

Grade 0; -40°C+150°C
Grade 1; -40°C+125°C
Grade 2; -40°C+105°C
Grade 3; -40°C+ 85°C

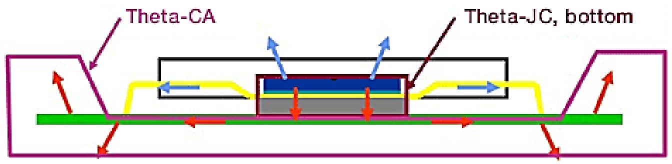


Ambient & junction temp

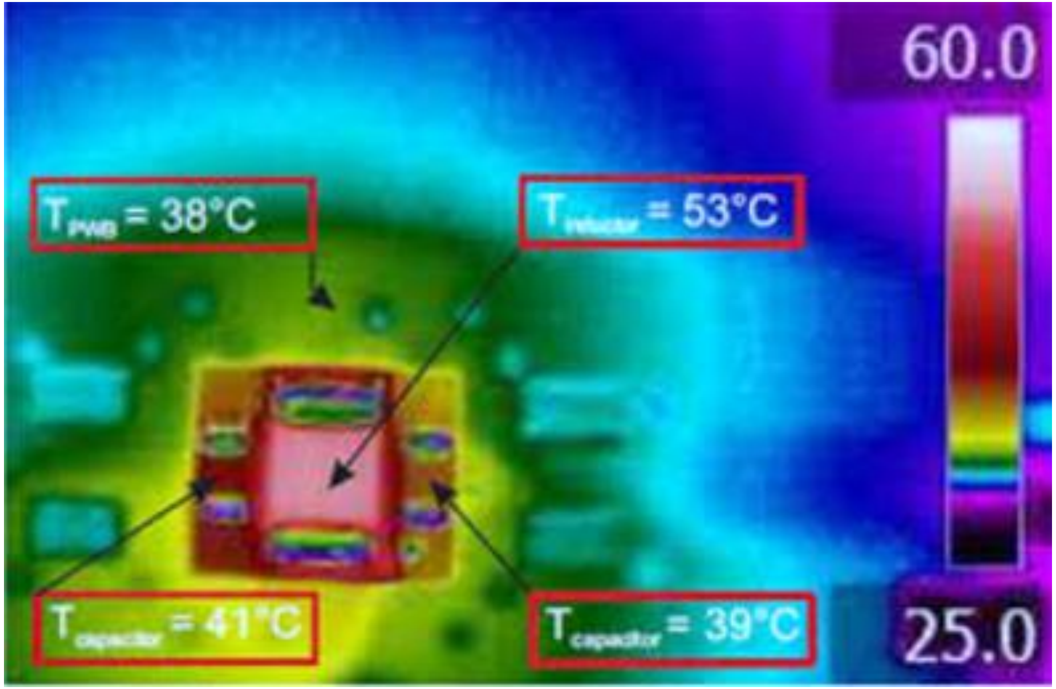
- AEC-Q100 temp grades spec ambient temp (T_A)
- Junction temp is critical parameter for semiconductors (T_J)
- Junction temp is estimated using thermal resistances, power disp, ambient temp
- Complex Si devices can be difficult to rate
  - Variable device power consumption based on use case can change ambient temp requirement



Theta-JT	Junction to top of package
Theta-TA	Top of package to ambient
Theta-JC	Junction to case
Theta-CA	Case to ambient



Example: temperature plot



Temperature and voltage sensors

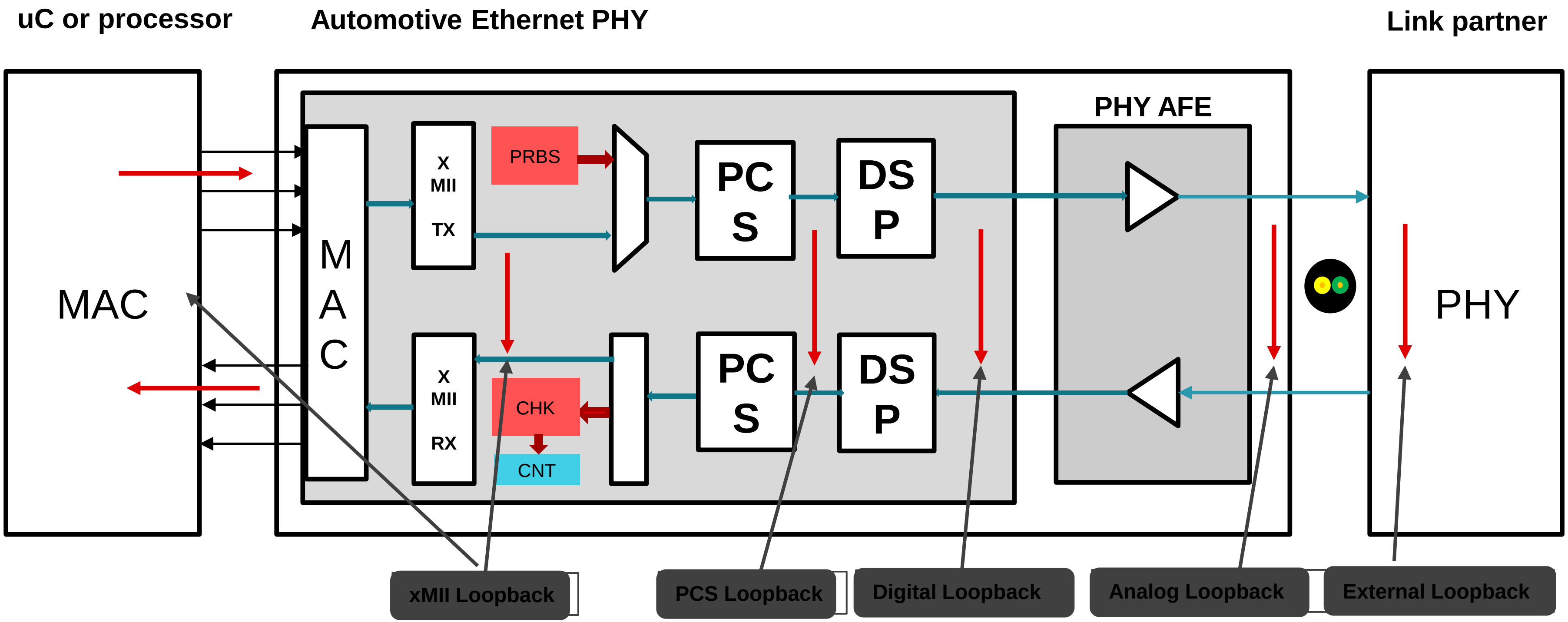
Temperature Sensor

- Over-temperature detection and interrupt flag
- Programmable interrupt trigger
- Real-time monitoring with wide range sensing: -40C to +165C (T_J)

Voltage Sensor

- Over-voltage and under-voltage detection on V_{CORE} & V_{IO} and interrupt flags
- Programmable interrupt triggers
- Real-time monitoring with wide range sensing: -16.5% to +9%

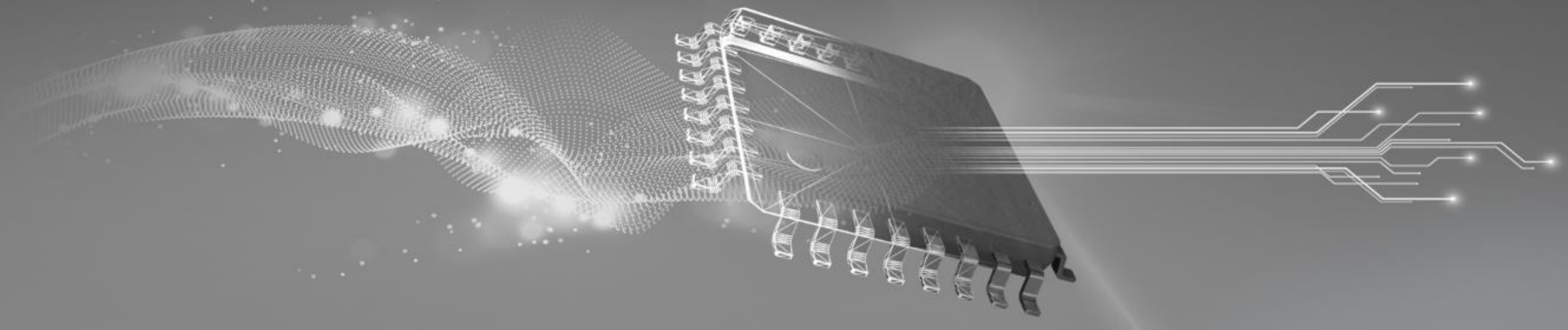
Built in self-test and loopback (BIST)



Error and event counters

- **RX_ER counter**
  - Detection of code-group errors on the reception of packets from a link partner
  - Detects corruption of the coding and sends notification to the MAC
- **False carrier counter**
  - Detection of false start of frames
  - If corruption on the line occurs, it can be viewed as the beginning of a frame
- **Link drop counter**
- **Link-up timer**
- **FEC counter**
  - Forward error correction is applicable to 1000BASE-T1
  - You can implement log of errors and even error corrections made
- **PRBS counter**
  - Used for debug and bring-up

TI TECH DAYS

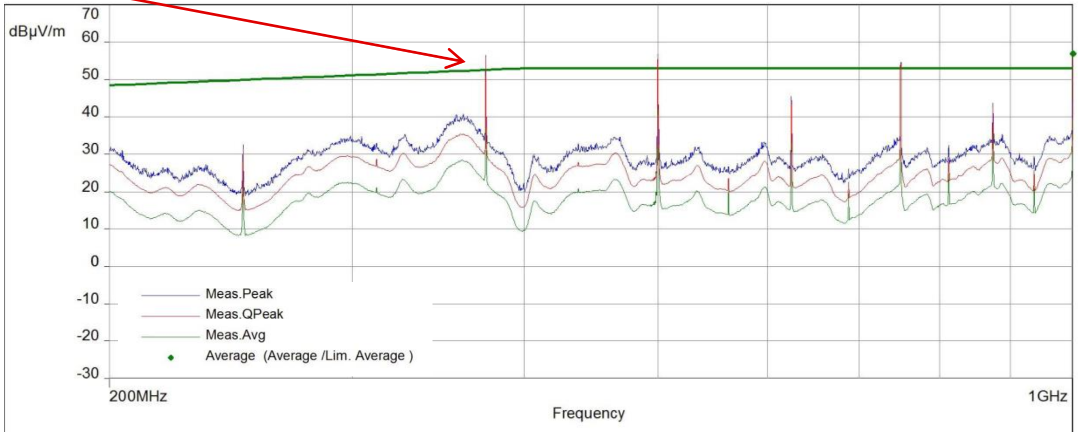


EMC considerations for robust systems

Texas Instruments

EMC overview

- Electromagnetic compatibility
  - Noise generation (source)
  - Noise propagation (path)
  - Noise reception (sink)
- ‘Noise’ is unintended energy change to a signal
- Each OEM has their own limit levels in regards to generation and reception
  - While most are based off CISPR, OEMs tend to have more stringent requirements



Source – path – sink

Source

- Periodic or transient signals

Sink

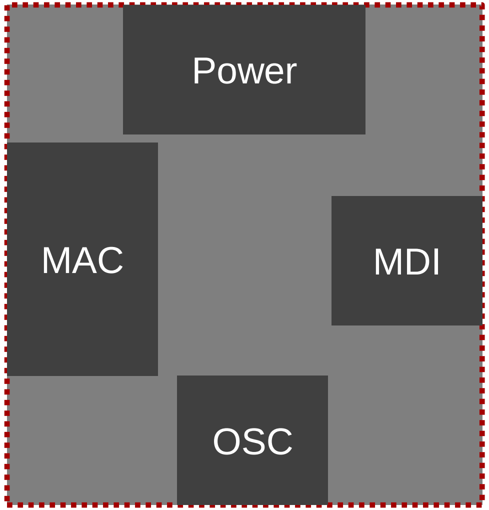
- Usually the first thing identified
  - packet loss
  - link loss
  - Complete IC failure (ESD, EOS)
- Noise sensitivity vs strong emitter

Paths

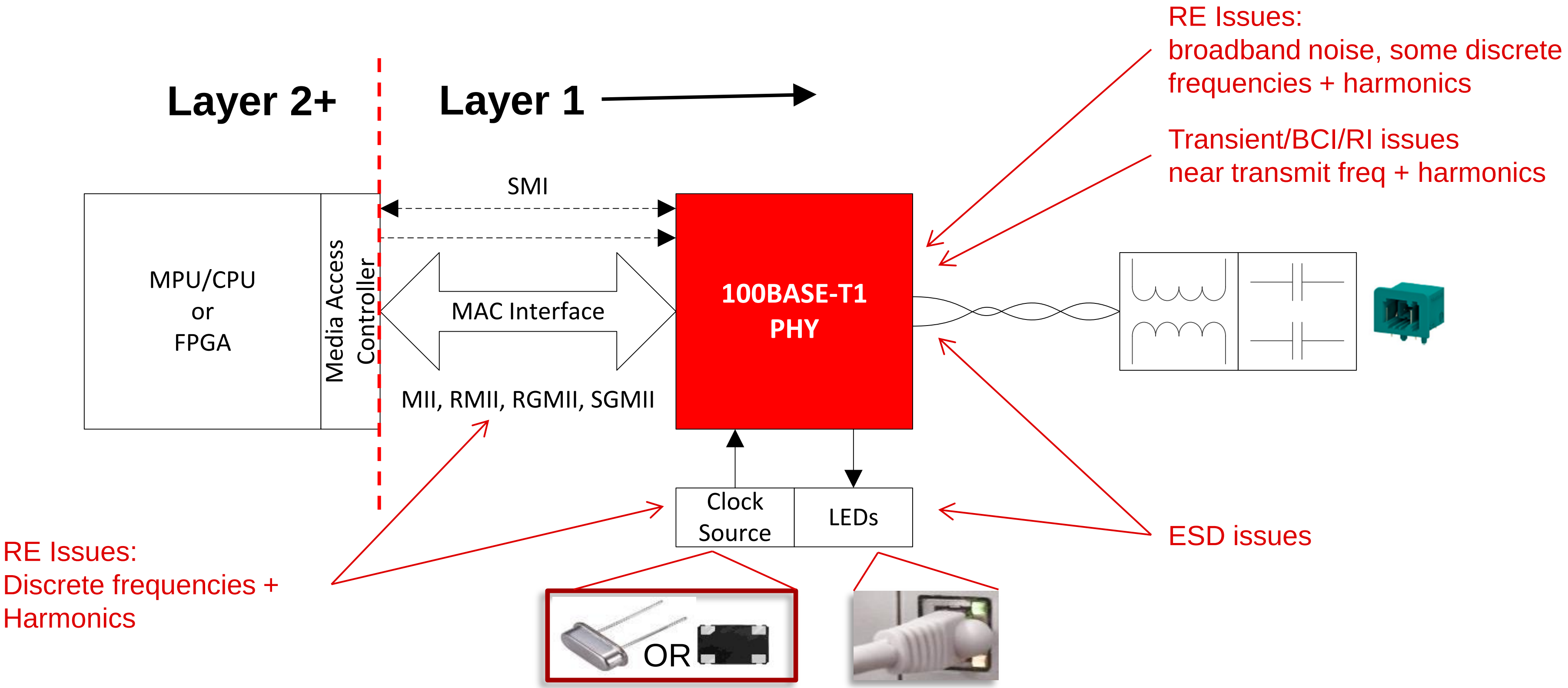
- 4 possible paths:
  - **Conductive Coupling**
    - Conductive Connections
  - **Radiated**
    - Antennas
  - **Inductive Coupling**
    - Loops
  - **Capacitive Coupling**
    - Conductive Surfaces

Sources and sinks for radiation/immunity

- **Power**
  - Critical on emissions
- **MDI**
  - Critical on emissions and immunity
- **OSC**
  - Critical on emissions and immunity
- **MAC**
  - Critical on emissions

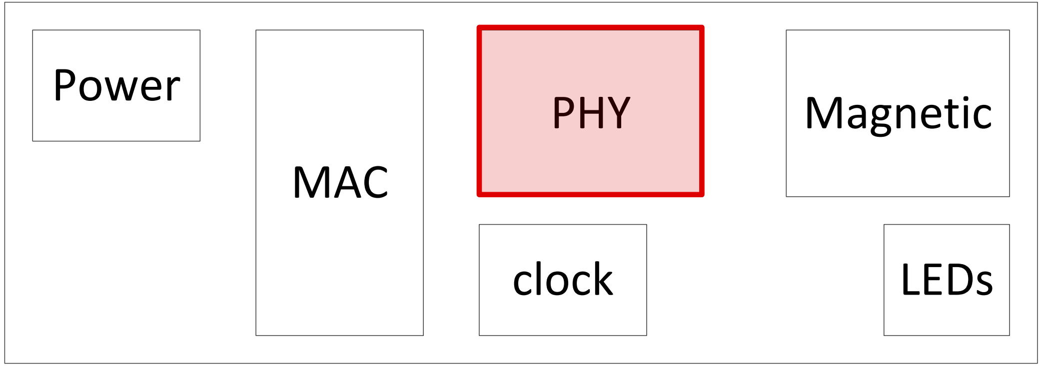


High level PHY implementation



Board zoning

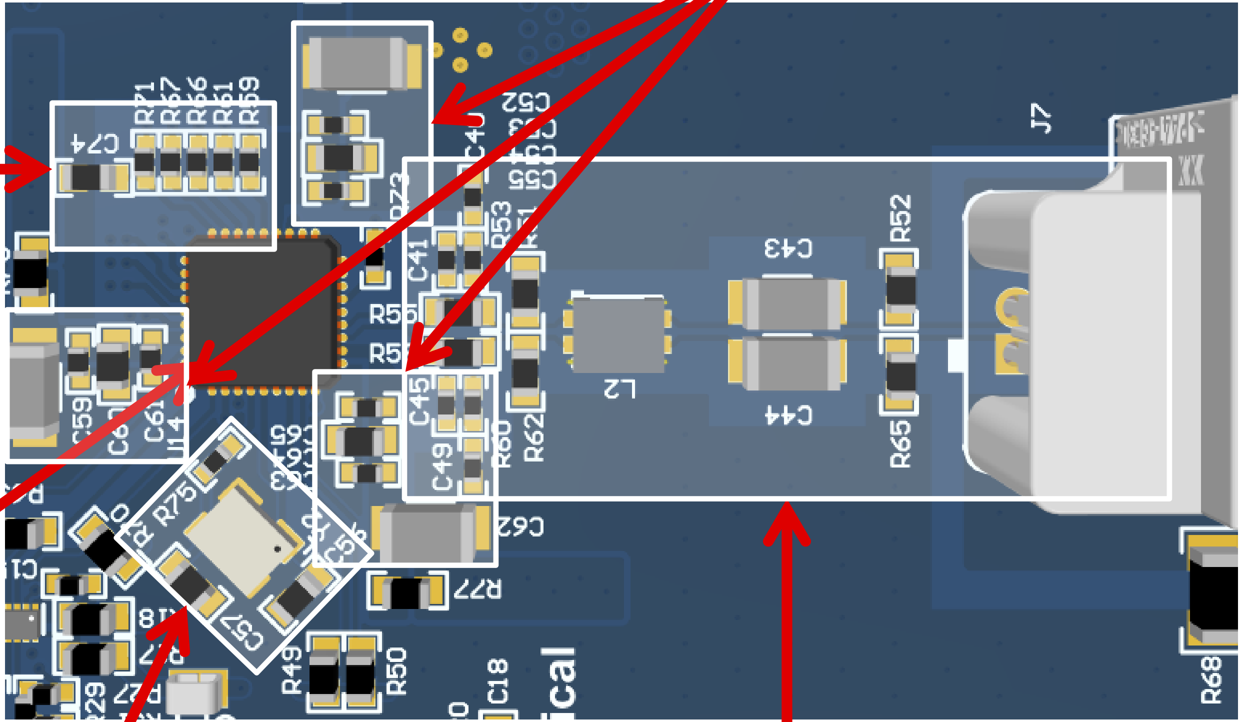
- Identify key components in the design, centrally locate them
- Differential signaling should be routed first
- High frequency paths close to destination and away from analog signals
- Lower frequency can be moved further away



Parts placement

Supply
Decoupling

Series
Ω



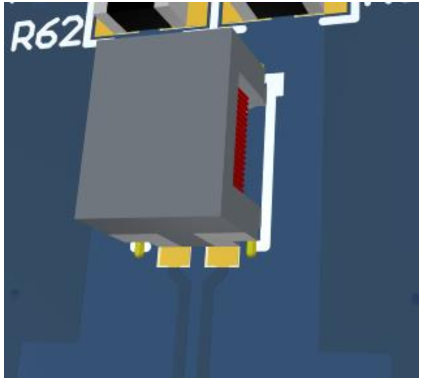
PHY

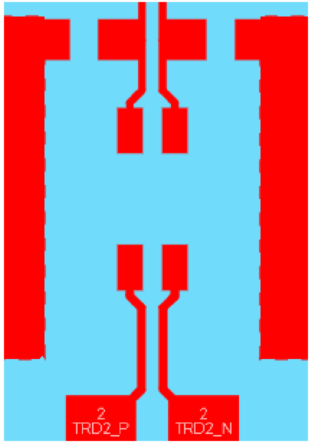
Clock

MDI

Board recommendations

- **6 layer board or higher**
  - Enables buried xMII traces
  - Does not compromise ground reference planes
    - Solid ground planes under all signal lines is critical to minimize RE and improve RI
    - Shortens ground loops
    - Simplifies length matching
- **Impedance Controls**
  - 100 Ω differential for SGMII lines
  - 50 Ω reference to ground for single-ended xMII and SMI lines
  - 100 Ω differential for MDI lines
- **Metal removal on top layer under CMC**





Board recommendations

- **PHY power supply decoupling caps should be kept near the device**
  - Small ceramic capacitors should be placed closer to the supply pins to shunt high frequency noise out of the PHY
  - Digital supply pins are notoriously noise due to high frequency switching
    - Ferrite beads aid in reducing emissions
    - Bulk capacitance is needed between PHY and ferrite bead to prevent brownout
- **No metal between differential pair**
- **No floating metal**
- **No stubs on high frequency critical signals**
  - If stubs are unavoidable, they should be short as possible
- **All TX traces should be matched and also the RX traces**
- **Anti-pads under large footprint SMDs; improve impedance continuity**

Board recommendations

- Place the PHY in a way, that you have a straight and short path to the connector
- If you have freedom on placement keep the xMII path as short as possible. In case this is not possible evaluate if you can use SGMII
- Route all high speed connections first
  - MDI Interface
  - xMII Interface
  - Clock
  - Power
  - Rest

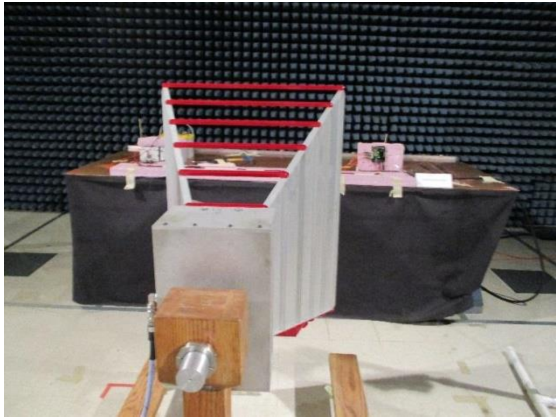
EMC troubleshooting techniques

- **Divide and conquer!**
  - Shut the PHY off
    - EN pin, PWDN pin if available
    - Though SMI power the device off
  - Disable all unused GPIOs (i.e. LED Blink, CLKOUT)
  - Disable the xMII
    - You can still keep an internal loopback enabled for data transmission and reception
  - Disable the MDI
- **Modify the DUT orientation and configuration**
  - Helps identify board layout deficiencies (you will need the layout on hand to reference)
  - Try different harness configurations to see if the issue is on the signal or supply lines
- **Place DUT in a metal enclosure to eliminate board contribution**

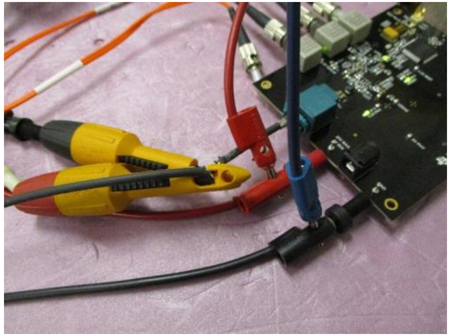
Common automotive EMC tests for PHYs

- Radiated emissions
- Radiated immunity
  - ALSE
  - Reverberation
- Transient immunity
  - DCC
  - Parallel wire
  - ESD
- Bulk current injection

Radiated Emissions



Radiated Immunity

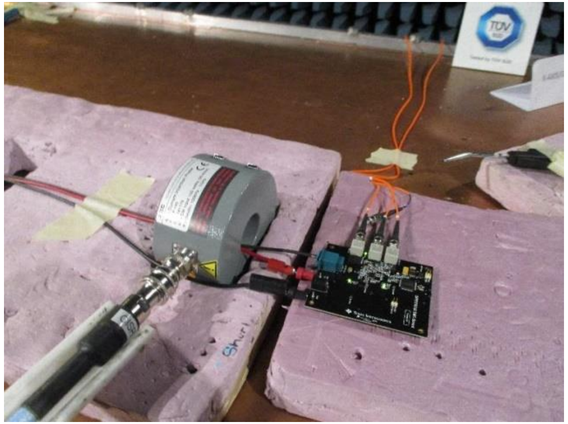


Direct Clamp Coupled

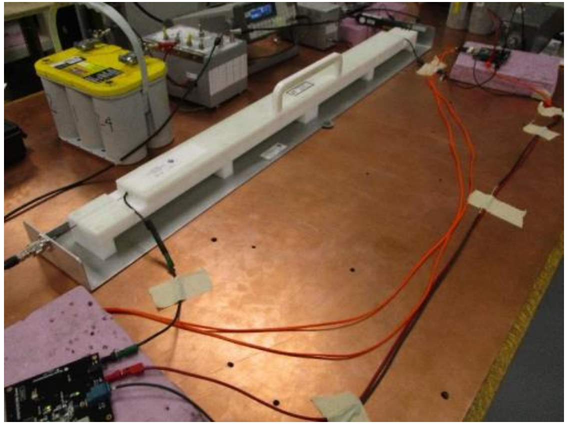
Reverberation

Common automotive EMC Tests for PHYs

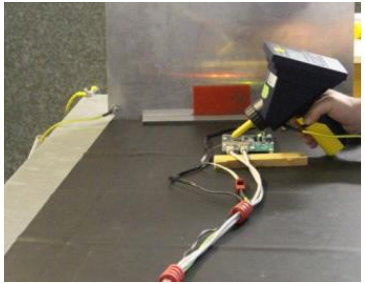
- **Radiated emissions**
- **Radiated immunity**
  - ALSE
  - Reverberation
- **Transient immunity**
  - DCC
  - Parallel wire
  - ESD
- **Bulk Current injection**



Bulk Current Injection



Parallel Wire



ESD

Resources

- Diagnostic Tool Kit Video Link!
- Find more information on device product page
  - For e.g.: http://www.ti.com/product/DP83TC811S-Q1
- Reference Design Files available for download on ti.com
- Type ‘ethernet/’ in your web browser for Ethernet Sharepoint.
- Have a question? e2e.ti.com

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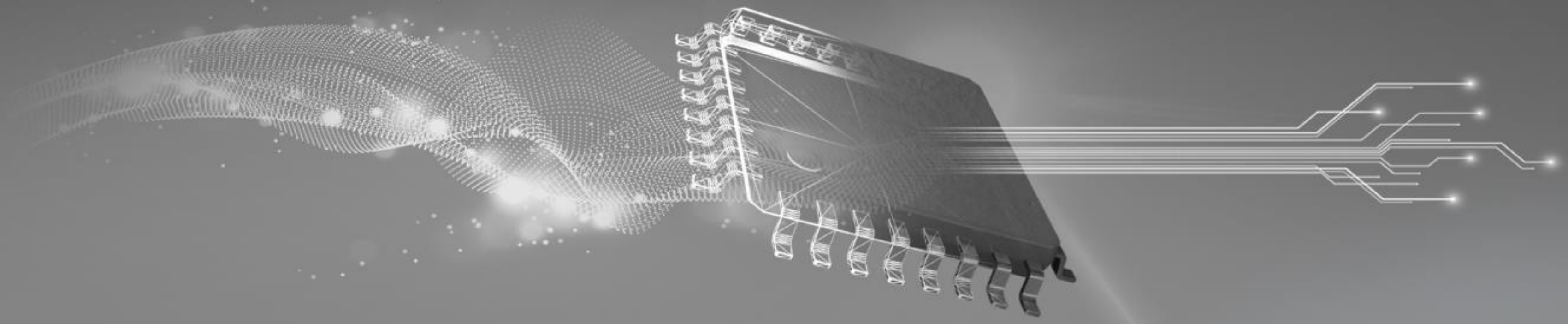

Q&A