# Trends for Integrated Isolated DC/DC Conversion in Automotive Applications

**Jeff Morroni, PhD**

**Texas Instruments -- Kilby Labs**

# Introduction

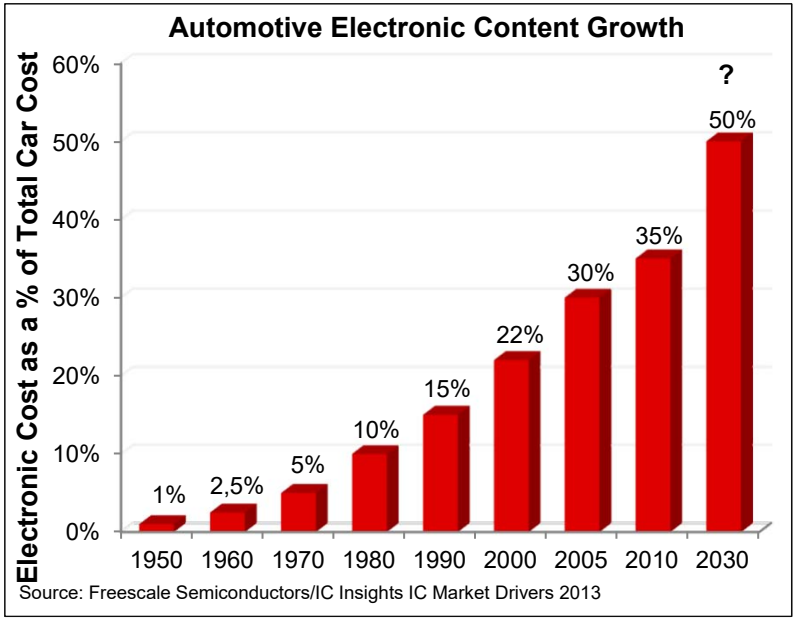
- Jeffrey Morroni
  - Director of Kilby Labs Power Management
  - PhD in Power Electronics from University of Colorado, Boulder
  - Joined TI with the National Semiconductor acquisition
  - Based in Dallas

# Cars of the Future…Now

***2000 Model Year Toyota Camry***


***2020 Model Year Toyota Camry Hybrid***

# Automotive Drive for More Electronics



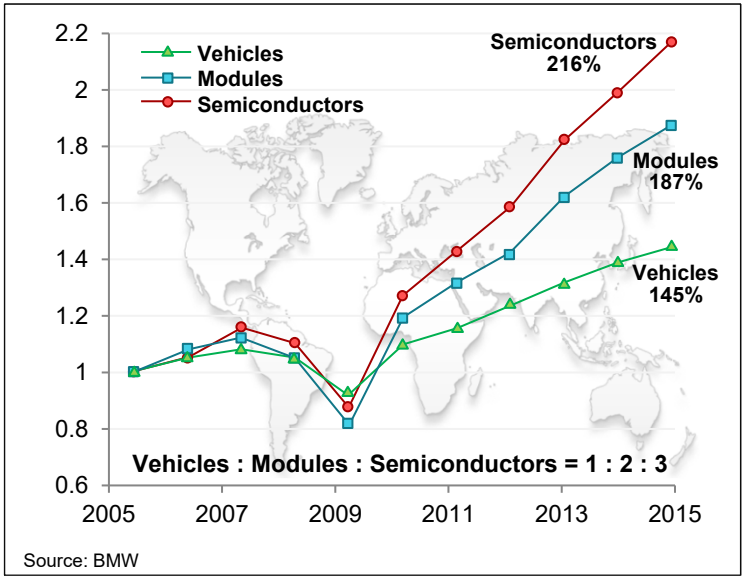

- Electronic systems account for 1/3 of new vehicles cost
- 41% analog IC and 39% microcontroller

**More than 8000 Semiconductor devices in a car**

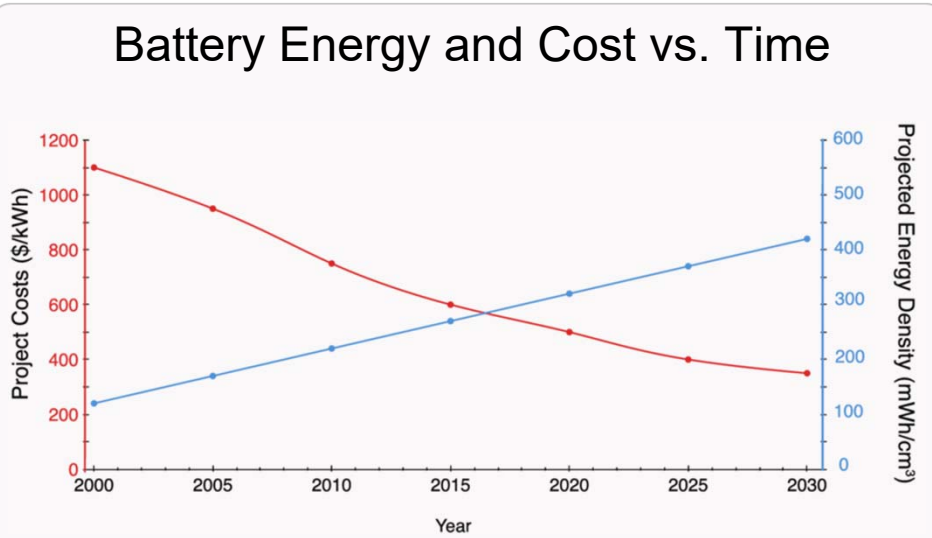
**Power Management:**

Battery Management
Adaptive lighting
POL Power…

Wireless Power
Universal charger



# Moore vs. Goodenough




*Source: Enabling technologies for autonomous MAV operations

- Battery energy density have doubled every ~120 months
- Transistors have historically doubled every 24 months
- If batteries had followed Moore's law
  - 300 mile range
  - $1 battery
  - That would fit in the palm of your hand!

- More electronics, similar batteries → Power management innovations required to sustain

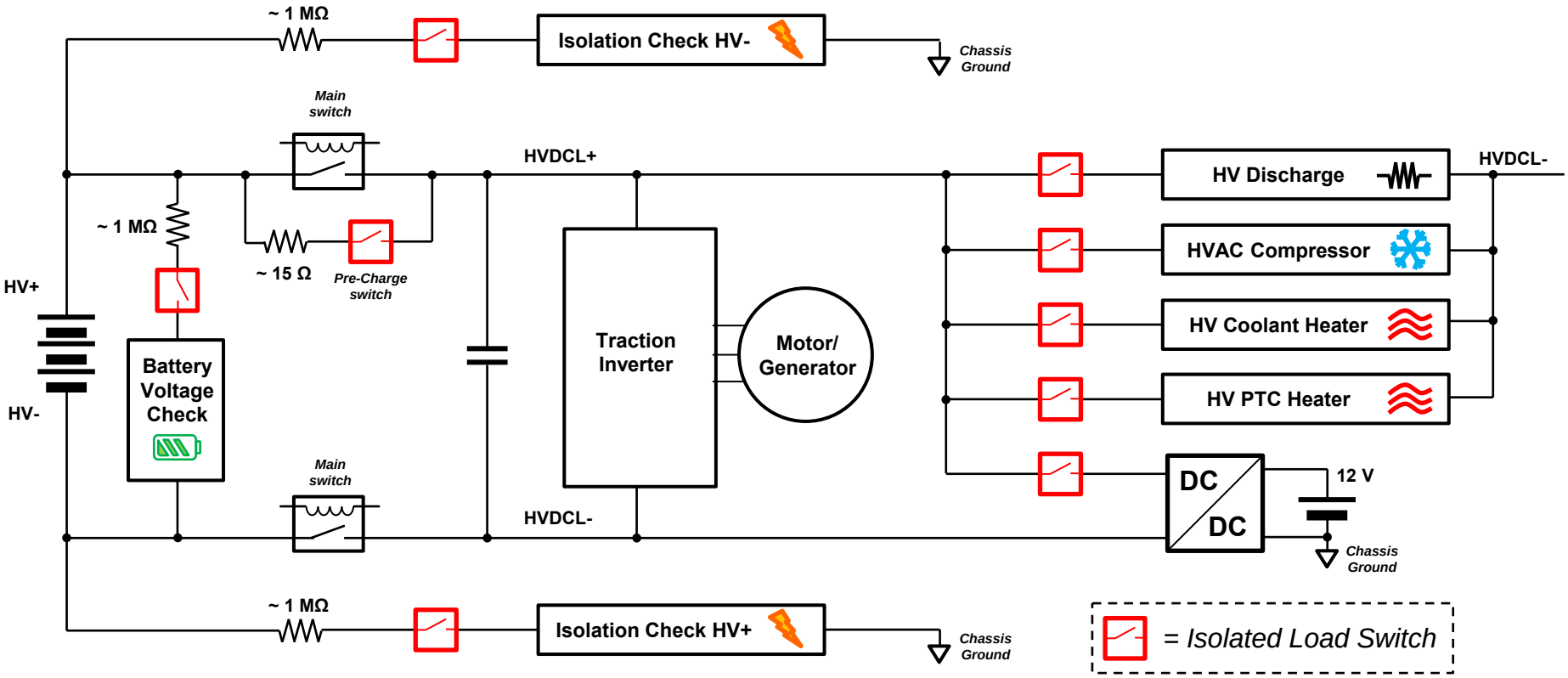
# EV/HEV Needs High Voltage Power Products

| HEV/EV Needs | Vehicle Implications | Power System Implications |
|---|---|---|
|  |  |  |
| Longer Range | Light Weight | |
| Faster Charging | Higher Power | ▪ Efficiency<br>▪ Power Density<br>▪ Low EMI<br>▪ Smaller Magnetics<br>▪ Lesser Cooling<br>▪ WBG Switches<br>▪ HV isolation |
| Affordable | Battery utilization | |
| Passenger Safety | HV Isolation | |

Driving a path towards more power supplies on chip

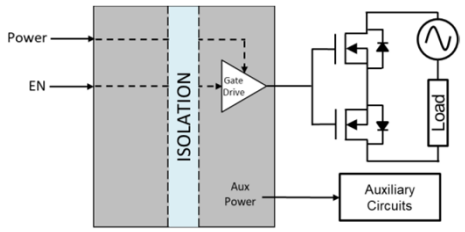
# Application for Solid State Relays

# Automotive EV/HEV Application Overview

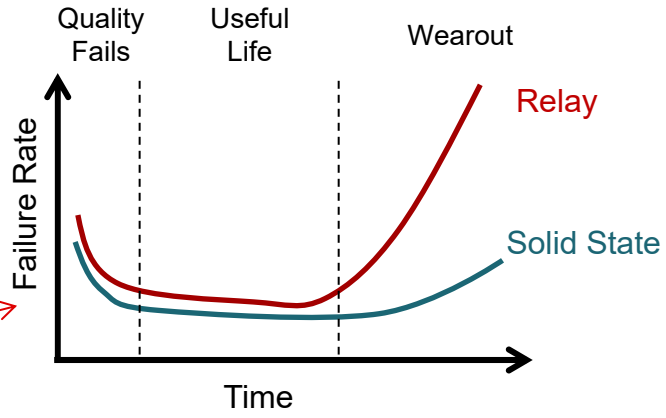


# Relay Limitations in Automotive

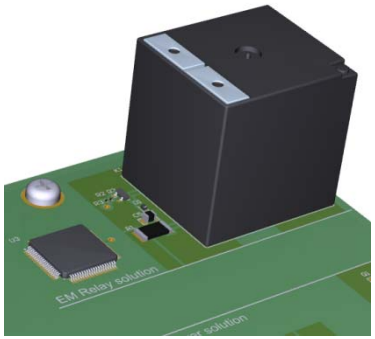
## *What is a Relay?*



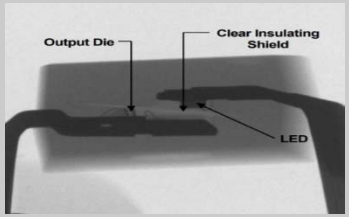
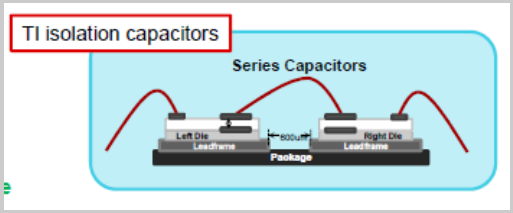
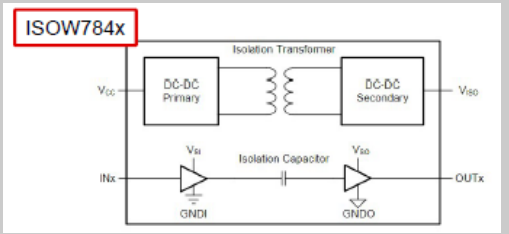

***Power Supply on a chip***




- **Old challenges**
  - Reliability in the environment
    - High vibration
    - Dusty and humid environment
  - Bulky
- **New Challenges**
  - EV driving increased need
  - Fast responses
  - High voltages



# Path Towards Higher Power and Efficiency

| | Opto-Couplers | Silicon Capacitors | Integrated Transformers |
|---|---|---|---|
| |  Source: https://www.allaboutcircuits.com/technical-articles/beyond-the-optocoupler-understanding-digital-isolators/ |  |  |
| Power Xfr | Very low | Low/Expensive | High |
| Op Temp | -40C → 100C/125C | -40C → 125C | -40C → 125C |
| Op Temp | -40C → 100C/125C | -40C → 125C | -40C → 125C |
| Prop Delay | Very Large | Large | Small |

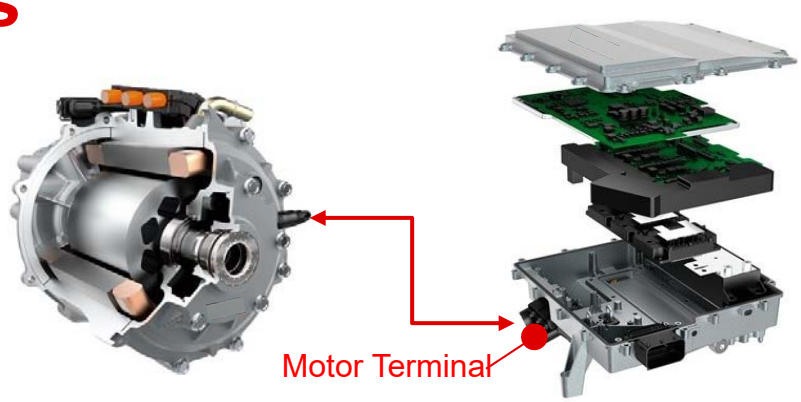
***Preferred technology will depend on application needs***

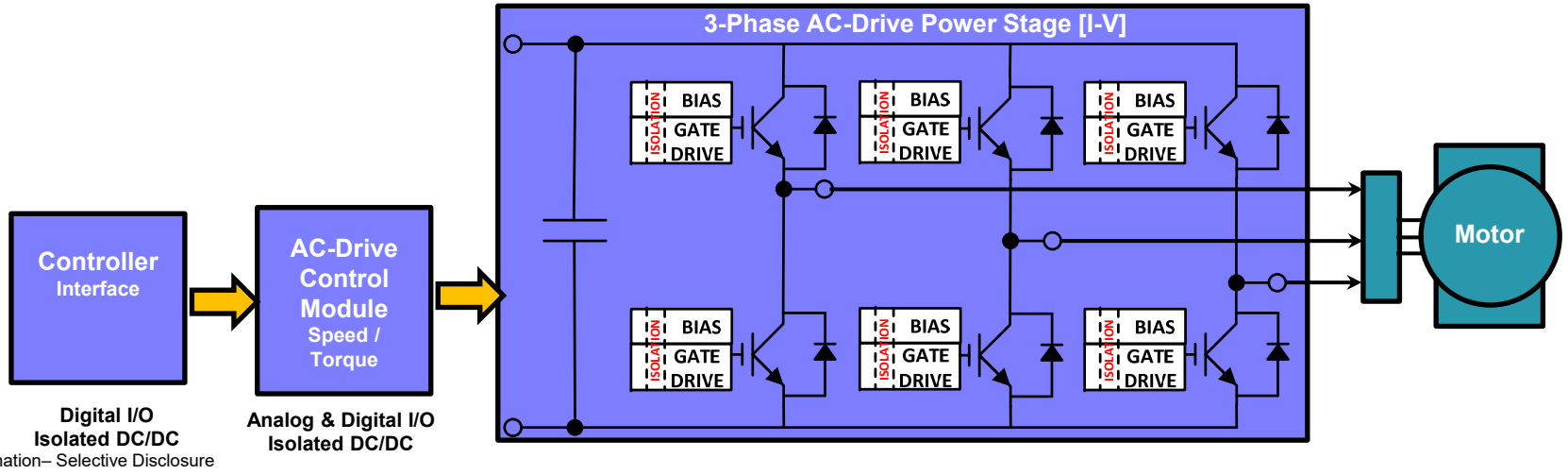
# Application for Isolated Bias Supplies

# HEV/EV Traction Inverter Bias

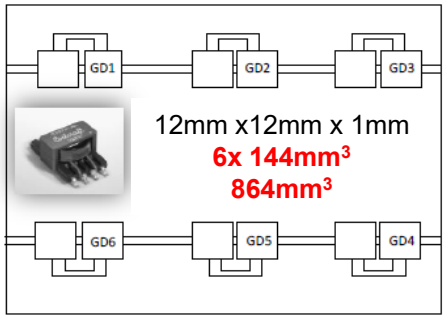
## Enabling Requirements

- Very small size → very high frequency
- Low temperature rise → high efficiency
- Low EMI → Stringent auto requirement
- High isolation → Safety critical

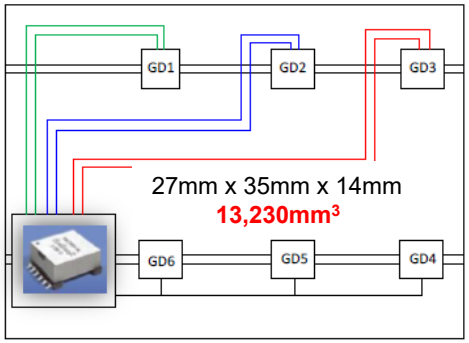


# Distributed Power Vs. Centralized Power




***Distributed Power***




***Centralized Power***

***Advantages of Separate Power Supply per Gate Driver:***

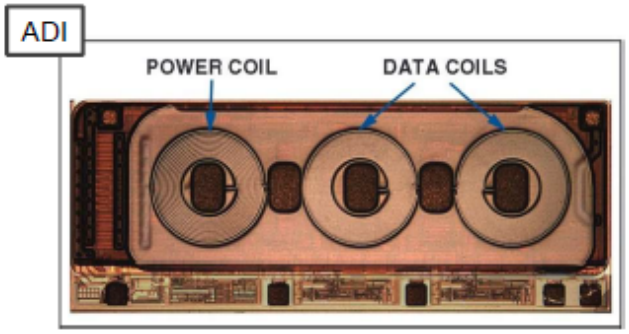
- **Improved power density**
- **Reduce EMI**
  - Compact routing is good for emission suppression
  - Low EMI techniques in integrated power converters
- **Simplifies PCB layout**
  - Avoid multi-layer PCB with HV and LV line interaction
- **Better bias power quality**
  - Avoid cross regulation issues and eliminate need for post-regulator
- **Distributed weight**
  - Resistant to mechanical vibrations
  - Reduce the transformer profile
- **Distributed power loss for easy cooling**

# Path Towards Distributed Bias: Efficiencv

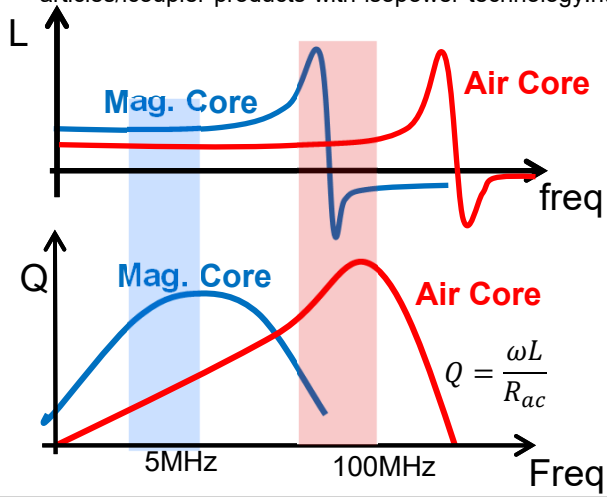
**Enabling Requirements**

- Very small size → very high frequency
- Low temperature rise → high efficiency

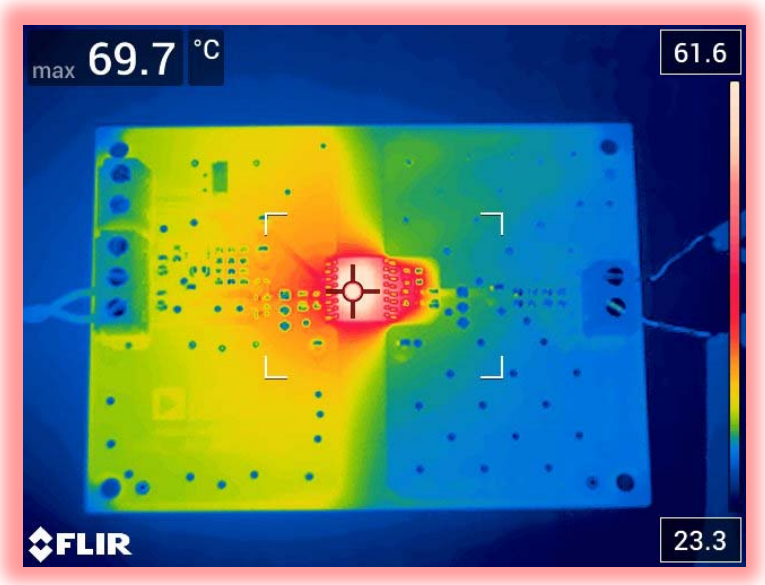
- Air core solutions can have very high Q, but at very high frequency
- Magnetic integration enables a better trade-off
  - High Q
  - At much lower frequency



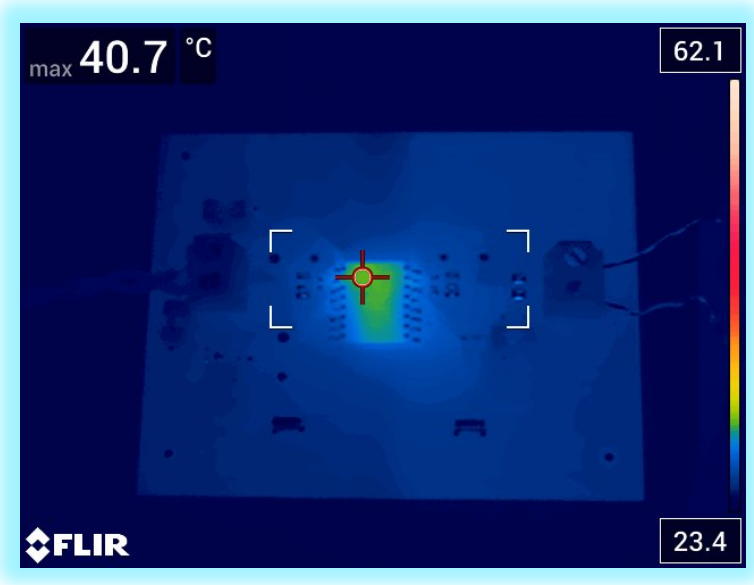

Source: https://www.analog.com/en/technical-articles/icoupler-products-with-isopower-technology.html



# Better efficiency, thermal performance → higher density



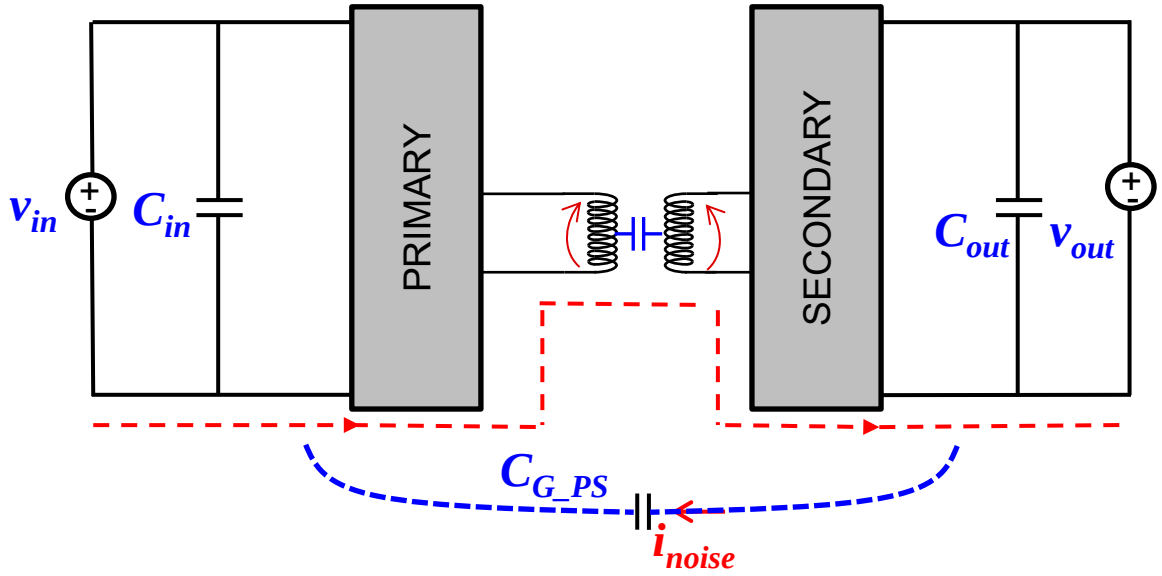

Air Core Solution

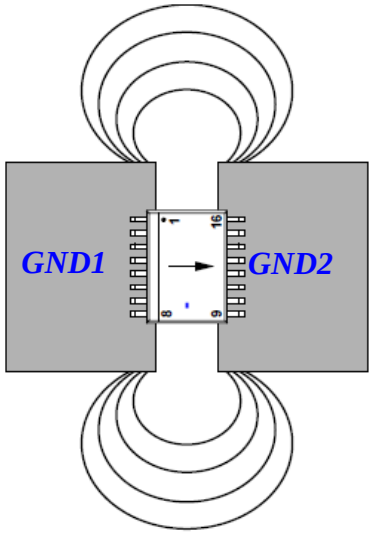



Magnetic Core (*UCC12050)*

**5 Vin, 5 Vout, 100 mA, 25°C**

# Path Towards Distributed Bias: EMI




- **Methods to minimize EMI**
  - **Reduce pri-sec capacitance:** Transformer optimization
  - **Minimize the dv/dt:** Symmetric drives/topologies
  - **Reduce the dipole gain:** Additional external cap, stitching capacitors
  - **Filters:** Ferrite beads, pre/post regulators

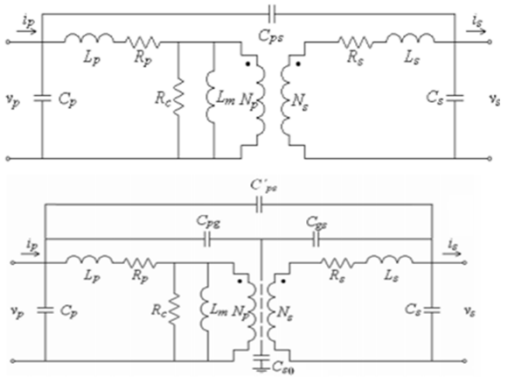
# Reducing Common Mode Currents: Faraday Shields

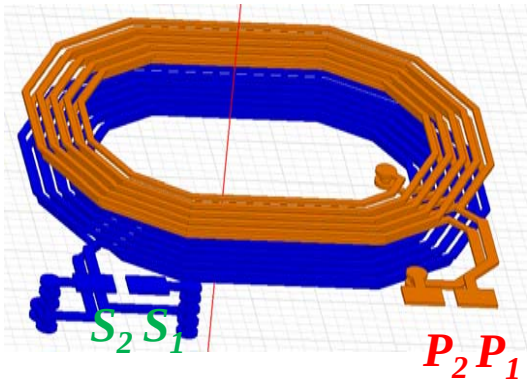
**Faraday shields:**

- Allow magnetic fields to pass
- Are grounded on either side of the isolation barrier

**Benefits**:

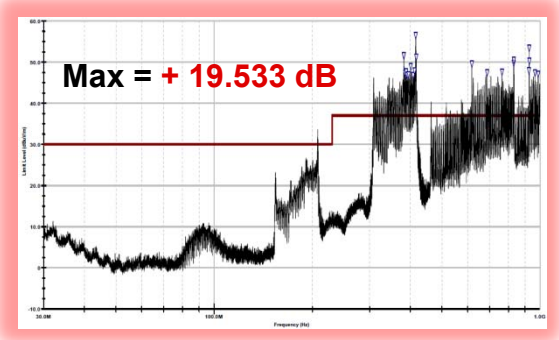
- Reduced noise from capacitive coupling
- Not available in discrete components with similar size



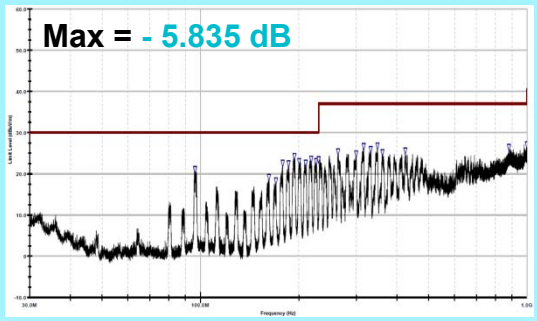



# Better EMI performance = higher power density

***Aircore solution @ 100 mA***:




***Magnetic Core (UCC12050) @ 100 mA***:




- **Same (apple-to-apple) EVM configuration: no ferrite beads , no LDO, no stitch capacitors, on two-layer PCB**
- Tested to CISPR32 Class B Limit, in 10 m chamber

# Conclusions

- Expansion of electronics in automotive is driving the need for integrated power management
- Isolation is critical for EV systems with high voltage present
- Two leading examples of that are solid state relays and distributed bias generation for EVs
- Density (thermals) and EMI are critical requirements to enable the trends
- Fully integrated, isolated power supplies have the opportunity to address these issues