



Nexperia
Application Guide
Automotive



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Introduction

This application guide has been created as a resource to identify specific design issues and the standard products (diodes, bipolar transistors, MOSFETs, ESD protection and Logic devices) required.

The guide covers 14 of the most common applications addressing the automotive market segment.

For each application, you will find the following:

- A** A brief overview of the application: As a few categories are broad, this will help you understand the key concepts and technical challenges involved in the design of the application.
- B** Design Considerations: List of topics to consider to identify the various types of devices (Standard Products) that are likely to be found in the application.
- C** Block Diagram: All diagrams illustrated are typical and your specific application may vary. The purpose of the diagram is to identify the numerous Standard Products that are commonly in the design application.
- D** Product/Value table: This table calls out the general device types found in the application, as well as specific part numbers when possible. These specific part numbers were identified as the most common part numbers used for the application.

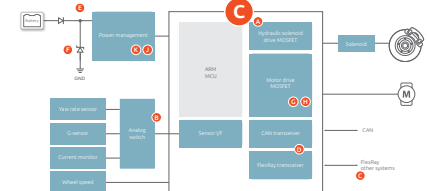
Automotive

Active Safety

A Automotive Active Safety includes systems for Brake Assist, Traction Control, Electronic Stability Control (ESC), Anti-Lock Braking Systems (ABS), Electronic Power Steering (EPS), and Lane Detection Control (LDC). These systems have in common multiple processors connected to a wide array of input sensors that output to electrical and hydraulic systems. The diagram below illustrates an ABS system, others similar.

B Design considerations

- › What is the operating voltage of the MCU? (selects the correct Logic Family)
- › How many analog inputs sensors are present? (consider an Analog Switch)
- › What is the power requirement of the output solenoid? (selects proper Power MOSFETs)
- › Are there other voltage domains present? (Level Shifter)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



Product	Use value
A Power MOSFETs	Drives brake solenoid and motors
B Analog Switch (74VHC14-Q100, 74VHC125-Q100)	Reduces number of analog inputs required on MCU
C Level Shifter (74VHC14-Q100)	Connects different voltage nodes between systems
D ESD Protection (ESD10CAN)	General purpose ESD protection (Pin-to-Pin protection LIN ESD Protection)
E P-N Bipolar Schottky Barrier Diode (SMBJ5.0A, SMBJ5.0CA)	Reverse battery protection (DC voltage blocking diode Free-wheeling 3 phase inductor)
F TVS Diode (PTVS Family, PTVS33V10U)	Transient voltage surge protection
G Schottky Barrier Diode (SMBJ5.0A, SMBJ5.0CA)	Free-wheeling diode for DC-DC inductive load
H General purpose RES and Matched Pair Transistors (BQW22)	Signal level shifter, constant current monitor
I Small Signal MOSFET (P or N Channel)	High RDS(on) = 1k used for signal control, level shifting Low RDS(on) = 1k used for load switch control
J CA-Transistor (low Voltage, PNP/BJT033P)	Linear regulator and load switch control

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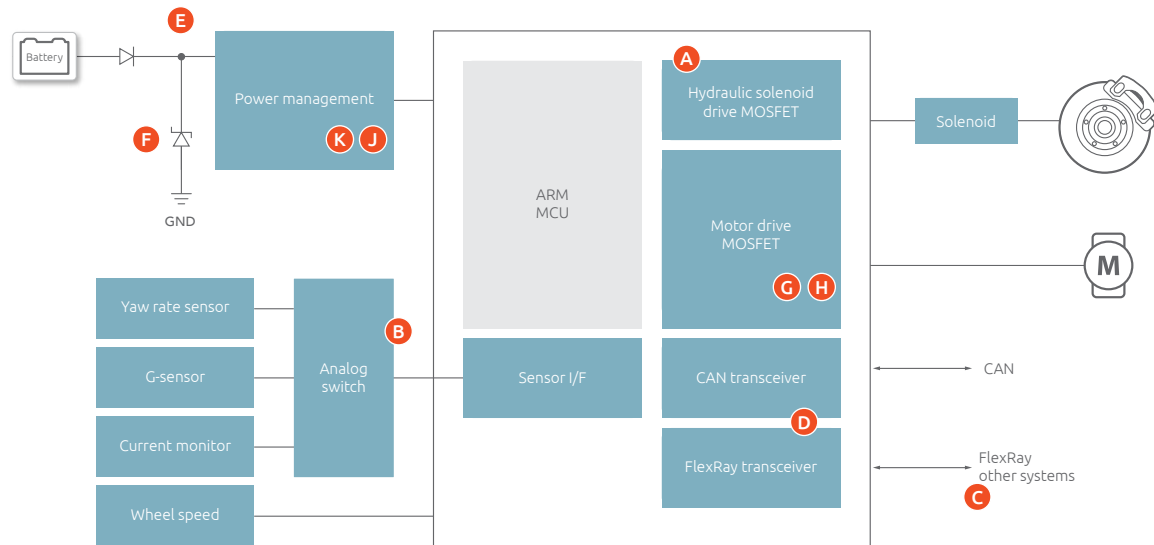


Active Safety

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Design considerations

- › What is the operating voltage of the MCU? (selects the correct Logic family)
- › How many analog inputs sensors are present? (consider an Analog Switch)
- › What is the power requirement of the output solenoid? (selects proper Power MOSFETs)
- › Are there other voltage domains present? (Level Shifter)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Power MOSFETs	Drives brake solenoid and motors
B	Analog Switch (74HEF4067-Q100, HEF4051-Q100)	Reduces number of analog inputs required on MCU
C	Level Shifters (74AVC1T45-Q100)	Connects different voltage nodes between systems
D	ESD Protection (PESD1CAN-U)	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD Protection
E	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family, PMEG6010ELR)	Reverse battery protection DC voltage blocking diode Freewheeling 3-phase isolator
F	TVS Diode (PTVS family, PTVS33VP1UP)	Transient voltage surge protection
G	Schottky Barrier Diode (PMEG4050ETP)	Free-wheeling diode for DC-DC and inductive load
H	General purpose RETS and Matched Pair Transistors (PUMH9)	Signal control, MOSFET driver, constant current monitor
J	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
K	GA-Transistor (Low Vcesat, PHPT60603PY)	Linear regulator and load switch control

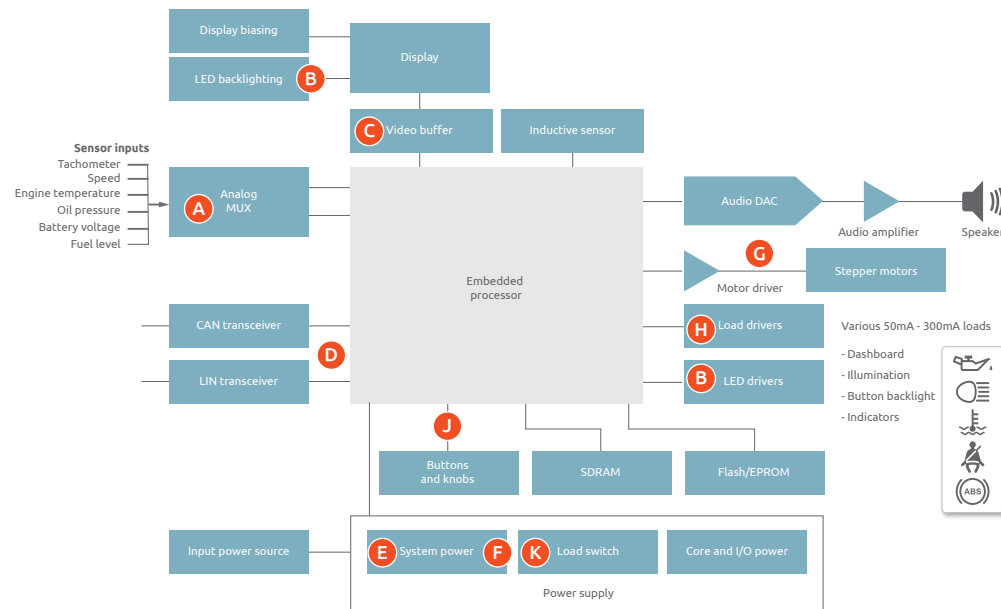


Analog Gauge Replacements

Analog gauge replacements include gauges to the automotive, marine, motorcycle, and personal water craft market. Multiple gauges, also known as an instrument cluster, have a variety of input sensors and output displays, such as LED, LCD, VFD, and mechanical displays.

Design considerations

- › What is the analog input voltage range? (determine analog MUX requirements, # of channels)
- › What is the MCU operating voltage and system rail voltages? (selects Logic family and Level Shifters)
- › What is the display output type? (LED/LCD/VFD require different output voltage/current)
- › Is there a size constraint? (Small gauges may require special device packaging)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Analog Switch 74HC/HEF4051-Q100)	8-channel analog input MUX for multiple sensors
B	LED Driver (NPIC6CS96-Q100)	For driving LEDs, VFD: up to 30V and 100 mA per channel
C	Level Shifter (74AVC1T45-Q100)	Level shifter between low-volt MCU and 5 V sensors
D	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
E	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
F	TVS Diode (PTVS family)	Transient voltage surge protection
G	Schottky Barrier Diode (PMEG family)	Free-wheeling diode for DC-DC and inductive load
H	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor
J	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
K	Transistor (Low Vcesat)	Linear regulator and load switch control

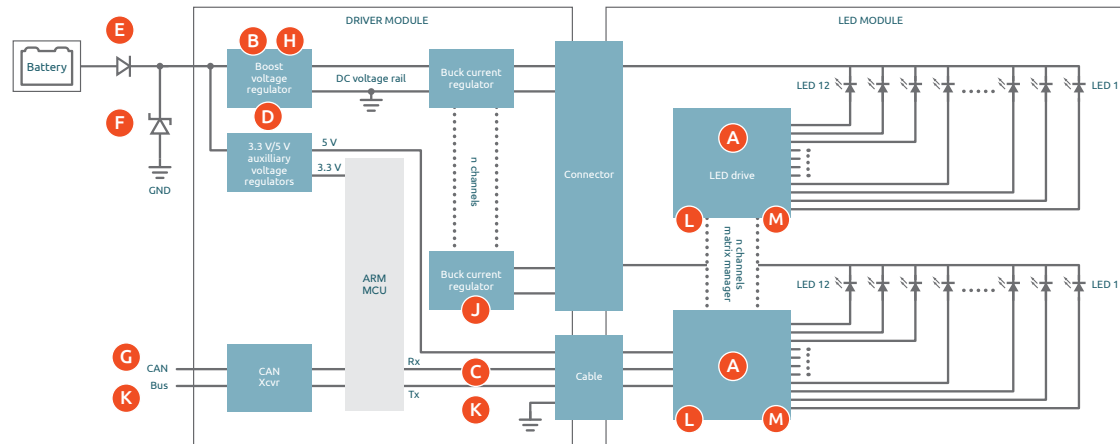


Automotive Lighting

Automotive lighting encompasses several major systems in the car: exterior (headlight/taillight), interior (dome, ambient), and instrumentation (LED backlight). Incandescent lighting is being replaced by LED Lighting, covering a variety of drive methods.

Design considerations

- › What is the wattage of LED? (determines the drive method)
- › Is there an MCU or is this a standalone application? (NPIC LED driver)
- › What is the LED array voltage? (determines MOSFET)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	LED Driver (NPIC6C4894-Q100, 74HCT4094-Q100, 74HCT595-Q100)	Direct drive of low watt LEDs (turn signals, etc.)
B	Power MOSFETs	High power LED driver
C	Level Shifter (74AVC1T45-Q100)	Connection between MCU and high voltage section
D	Transistor (Low Vcesat) (PBSS5260PAPS)	Linear regulator and load switch control and LED dimming control
E	PN Rectifier (PNS40010ER) Schottky Barrier Diode (PMEG6020ELR)	DC voltage blocking diode
F	TVS Diode (PTVS33VP1UP)	Transient voltage surge protection
G	ESD Protection (PESD1CAN-U)	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
H	Schottky Barrier Diode (PMEG family, PMEG6020ELR)	Free-wheeling diode for DC-DC buck/ Boost converter (asynchronous or synchronous)
J	General purpose RETS and Matched Pair Transistors (PUMH9)	Signal control, MOSFET driver, constant current monitor
K	Small Signal MOSFET (P or N Channel, PMPB215ENEA)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
L	MOSFET (P or N channel, e.g. PMPB9SENEA, PMPB100XPEA)	Low RDS(on) < 1 used for drive of medium power LEDs
M	PBSS series	Low VCE(sat) transistor, 20V – 60V 1A – 2A

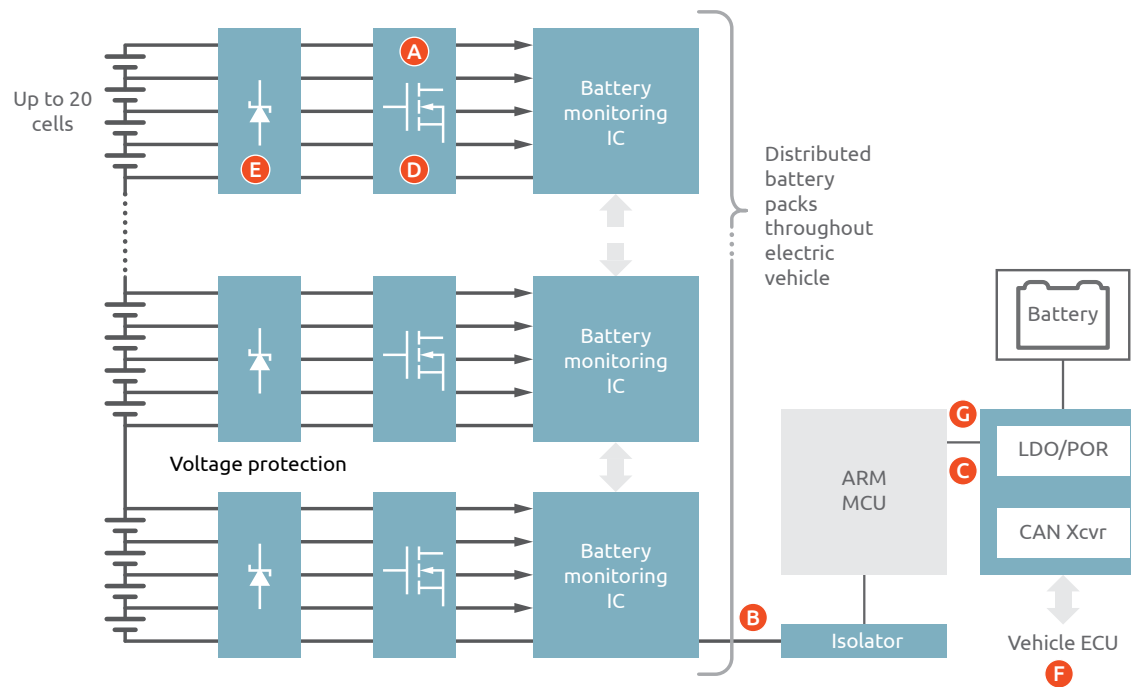


Battery Management for Electric Vehicles

Automotive battery management is critical for hybrid and all-electric vehicles. Battery Management includes the on-board charging system, load management, and battery balance.

Design considerations

- › What is the total number of battery cells? (determines the number of duplicate monitor circuits)
- › What is the IC operating voltage? (HC for 5 V, HEF for 12 V Logic, etc.)
- › Are there multiple voltage supplies (Level Shifters)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Power MOSFETs	Current control for cells
B	Level Shifter (74AVC1T45-Q100)	Level shift between voltage nodes
C	High Voltage Logic (74HEF4001-Q100)	Logic signals at 12 V supply
D	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control in battery voltage cell balancing
E	TVS Diode (PTVSxP1UTP)	Transient voltage surge protection
F	ESD Protection (PESD1CAN-U)	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
G	General purpose RETS and Matched Pair Transistors (PUMH9)	Signal control, MOSFET driver, constant current monitor

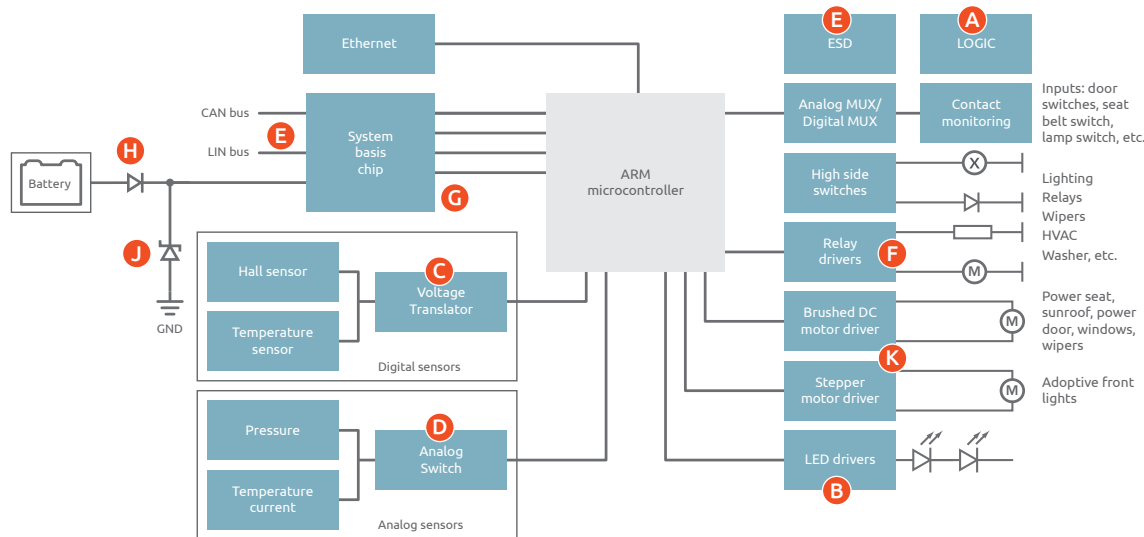


Body Control Module (BCM)

Body control modules are distributed throughout a vehicle to control features such as power seats, power windows, door locks, and other functions with basic motor control. There are multiple BCM's in today's modern vehicle.

Design considerations

- › What voltage do the BCM nodes operate at? (determines Logic family, MOSFET requirements)
- › What is the current requirement of the loads? (determines MOSFET sizes)
- › What is the type and voltage of the inputs? (determines Level Shifters, Analog Switch requirements)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	High Voltage Logic (HEF-Q100 family)	Operates at 12 V
B	LED Driver (NPIC6C596-Q100)	Low cost LED drive solution
C	Level Shifter (74AVC1T45-Q100)	Connecting 12 V sensors to 5 V MCU
D	Analog Switch (-Q100 selection)	For audio control, sensor inputs
E	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
F	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control and LED dimming
G	Transistor (Low Vcesat)	Linear regulator and load switch control and LED dimming control
H	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
J	TVS Diode (PTVS Family)	Transient voltage surge protection
K	Power MOSFETs	For motor control

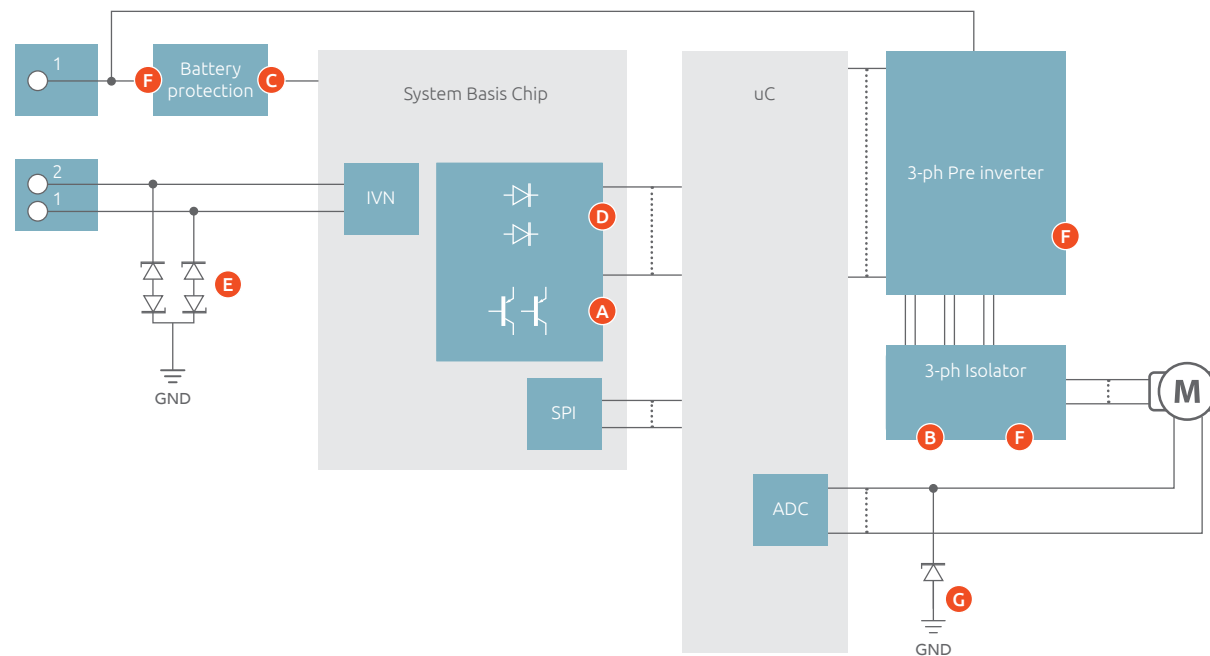


Electrical Power Steering (EPS)

Electrical Power Steering is beginning to replace traditional belt-driven hydraulic power steering systems. Advantages include improved packaging, less parasitic engine losses and improved performance.

Design considerations

- › What is the size of the vehicle? (determines power requirements of MOSFETs)
- › How is the unit ESD protected during both assembly/repair and normal operation?
- › What is the supply voltage? (equal to 12V or greater?)



	Product	Use value
A	Low $V_{CE(sat)}$ transistor (PHPT60603PY)	Linear voltage regulation
B	Schottky rectifier (PMEG050V150EPD)	Freewheeling 3-phase isolator
C	Schottky rectifier (PMEG10020ELR)	Reverse polarity protection
D	Schottky rectifier (PMEG4020EPK, PMEG3020EJ)	DC/DC conversion
E	ESD protection (PESD2IVN-U)	CAN ESD protection
F	Power MOSFET	Motor drive / isolator
G	ESD protection (PESD3V3S1UL)	ESD protection on motor connector

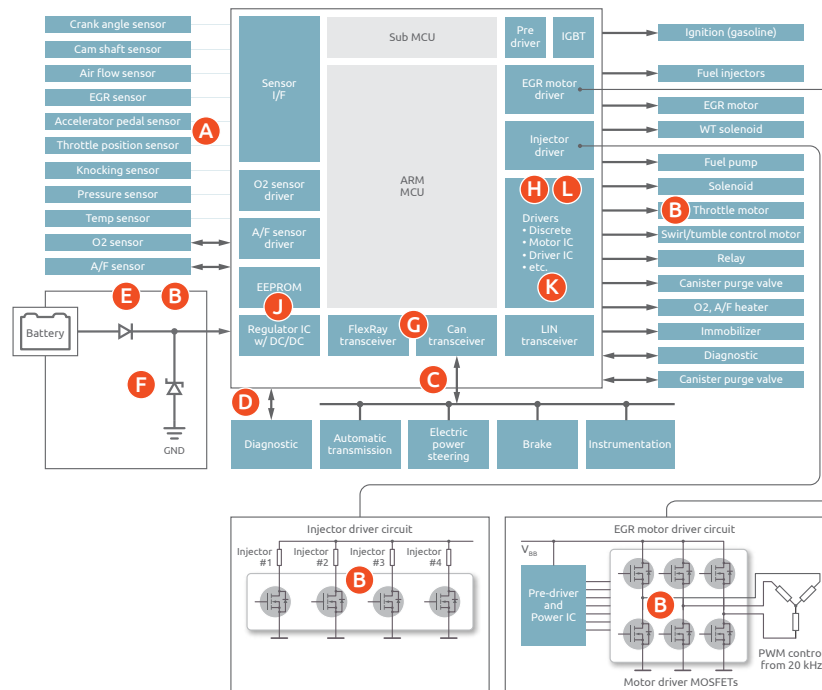


Engine Control Unit (ECU)

The function of the ECU is to meet performance, emissions, and fuel economy requirements. Subsystem components include the fuel injection system and ignition requiring inputs from a large number of sensors.

Design considerations

- › How many sensor inputs? (determines need for Analog MUX Switches)
- › What is the number and type of outputs? (determines MOS devices)
- › What is the operating voltage of ECU? (determines HEF, HC, etc Logic family)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Analog Switch (74HC4066-Q100)	Multiplexing many analog inputs to MCU
B	Power MOSFETs	Control of solenoids, pumps, etc.
C	Level Shifter (74AVC1T45-Q100)	Level shift between various devices
D	High Voltage Logic (HEF -Q100 family)	Direct connect to 12 V supplies
E	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
F	TVS Diode (PTVS family)	Transient voltage surge protection
G	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
H	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
J	Schottky Barrier Diode (PMEG family)	Free-wheeling diode for DC-DC buck/ Boost converter and inductive load
K	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor
L	Transistor (Low Vcesat)	Linear regulator and load switch control

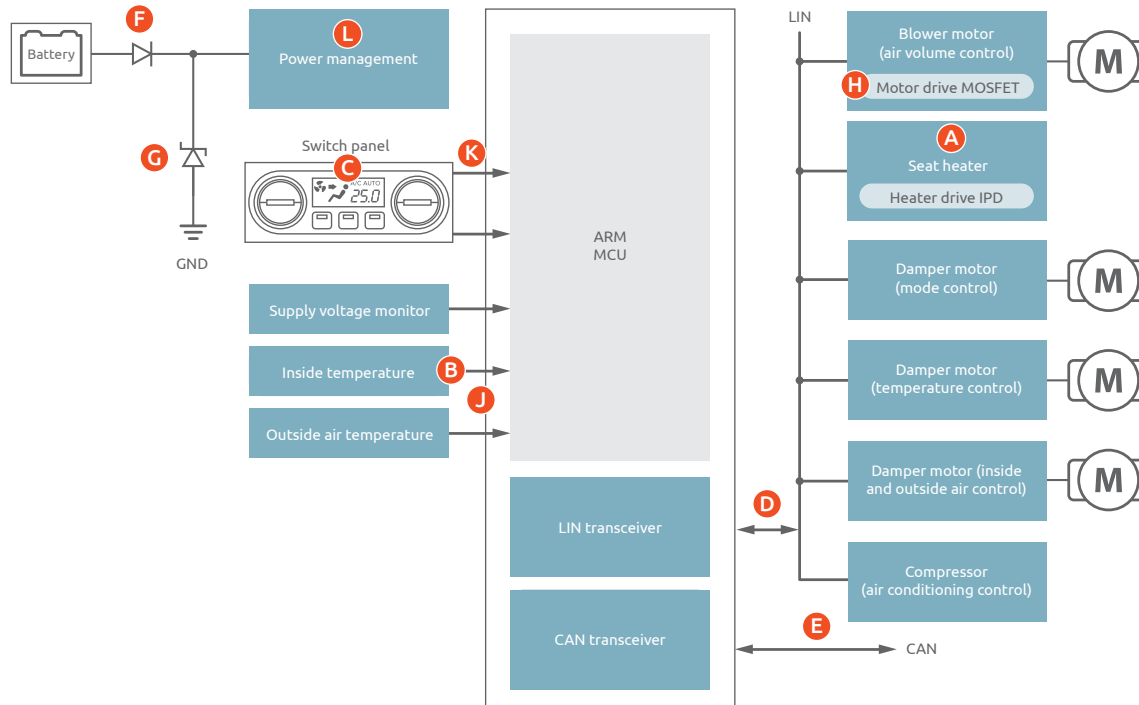


Heating Ventilation Air Conditioning (HVAC)

An automotive HVAC system controls the heating and cooling of the passenger compartment and defrosting the windshield. System control requires monitoring an array of temperature sensors that control fan motors and dampers.

Design considerations

- › How many sensor inputs? (opportunity for Analog Switch)
- › What are voltages of the control system and external devices? (Level Shifters)
- › What is the current draw of the fan and heater motors? (Power MOSFETs opportunity)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Power MOSFETs	Fan and motor drive
B	Analog Switch (74HC4066-Q100)	Temp sensor multiplexing
C	LED Driver (NPIC6C596-Q100)	LED drive for backlighting and panel indicators
D	Level Shifter (74AVC1T45-Q100)	Level shift between MCU and subsystems
E	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
F	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
G	TVS Diode (PTVS Family)	Transient voltage surge protection
H	Schottky Barrier Diode (PMEG family)	Free-wheeling diode for DC-DC and inductive load
J	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor
K	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
L	Transistor (Low Vcesat)	Linear regulator and load switch control

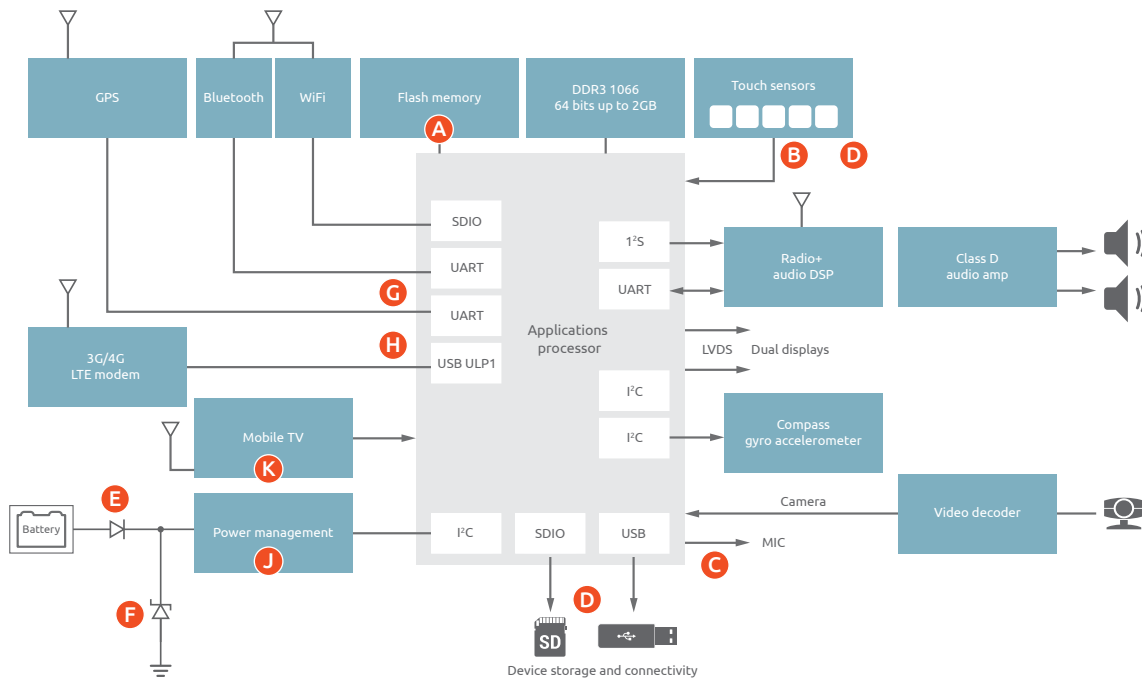


Infotainment

Infotainment systems provide entertainment to the driver and passenger, as well as, navigation and communications. Subsystems include GPS, Audio, WiFi, Bluetooth, and user interface.

Design considerations

- › What is the interface between system modules? (Level Shifters)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Level Shifter (74AVC1T45-Q100)	Connection between modules
B	Analog Switches (74HC4051-Q100)	Touch sensor input array
C	Low Voltage Logic (LVC-Q100 Family)	Low power general purpose logic
D	ESD Protection, Single and Multi-Line (PUSB3, PESD family)	General purpose ESD protection for high speed data lines. CAN ESD protection and protection for various user interfaces
E	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
F	TVS Diode (PTVS family)	Transient voltage surge protection
G	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor
H	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
J	Transistor (Low Vcesat)	Linear regulator and load switch control
K	Power MOSFETs	Power management

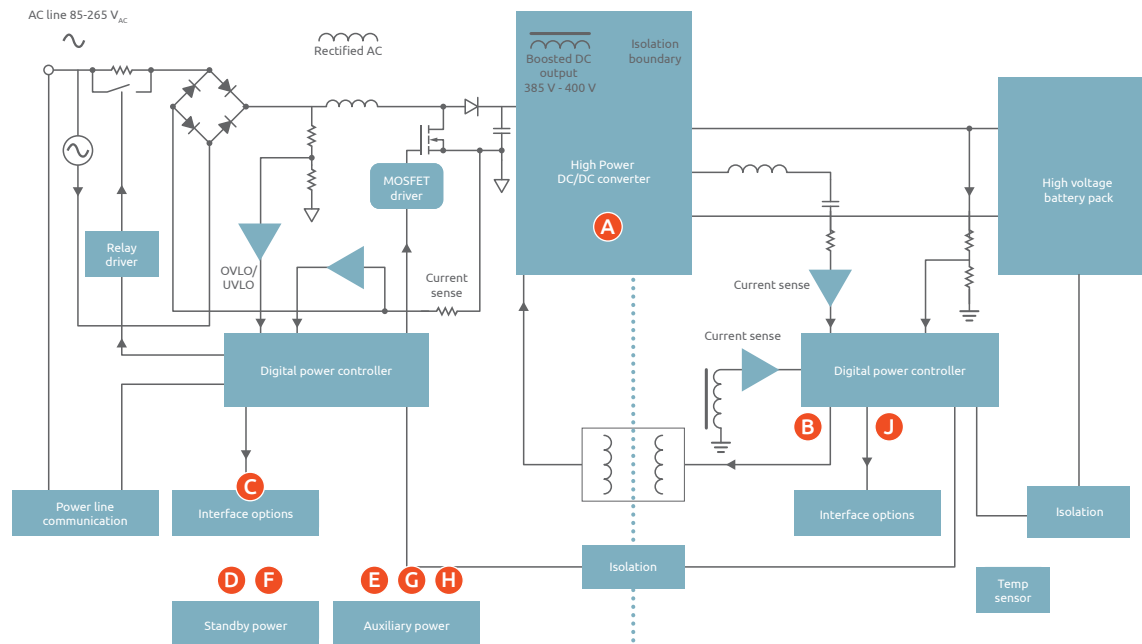


On-Board Charger

An On-Board Charging system maintains and charges the battery array in hybrid and electric vehicles.

Design considerations

- › What is the maximum operating voltage? (determines FET characteristics)
- › What is the MCU operating voltage and system rail voltages? (selects Logic family and Level Shifters)
- › How many cells are in battery array? (determines quantity charging sections)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Power MOSFETs	Battery charging circuits
B	High Voltage Logic (HEF-Q100 Family)	Direct high voltage connections
C	Level Shifter (74AVC1T45-Q100)	Connection between voltage domains
D	ESD Protection	General purpose ESD protection
E	PN Rectifier Schottky barrier diode	DC voltage blocking diode
F	TVS Diode	Transient voltage surge protection
G	Small Signal MOSFETs Pch or Nch	High $R_{DSon} > 1 \Omega$ used for signal control, level shifting Low $R_{DSon} < 1 \Omega$ used for load switch control
H	Schottky Barrier Diode PMEG series	Free-wheeling diode for DC-DC and inductive load
J	General Purpose RETS, & Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor

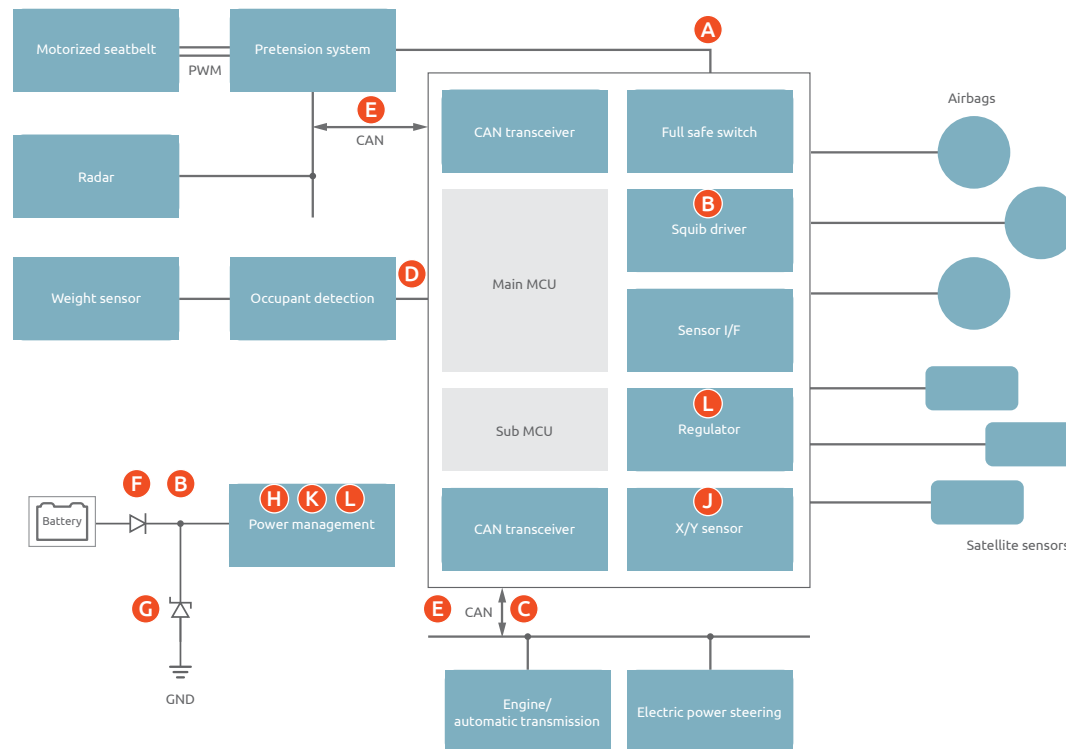


Passive Safety: Airbag

Passive safety systems are devices which require no user input to operate, such as the airbag and self-tensioning seatbelts.

Design considerations

- › How many and what type of input sensors are used? (opportunity for an Analog Switch)
- › What is the current requirement of the output devices? (Power MOSFETs requirements)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)
- › What are the system voltage rails? (Level Shifters)



	Product	Use value
A	High Voltage Logic (HEF-Q100 family)	Operates at unregulated 12 V supply
B	Power MOSFETs	Tensioning motors, squib activation
C	Level Shifter (74AVC1T45-Q100)	Connection of different nodes
D	Analog Switch (74HC4051-Q100)	Analog sensor multiplexing
E	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
F	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
G	TVS Diode (PTVS Family)	Transient voltage surge protection
H	Schottky Barrier Diode (PMEG family)	Free-wheeling diode for DC-DC and inductive load
J	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor
K	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
L	Transistor (Low Vcesat)	Linear regulator and load switch control

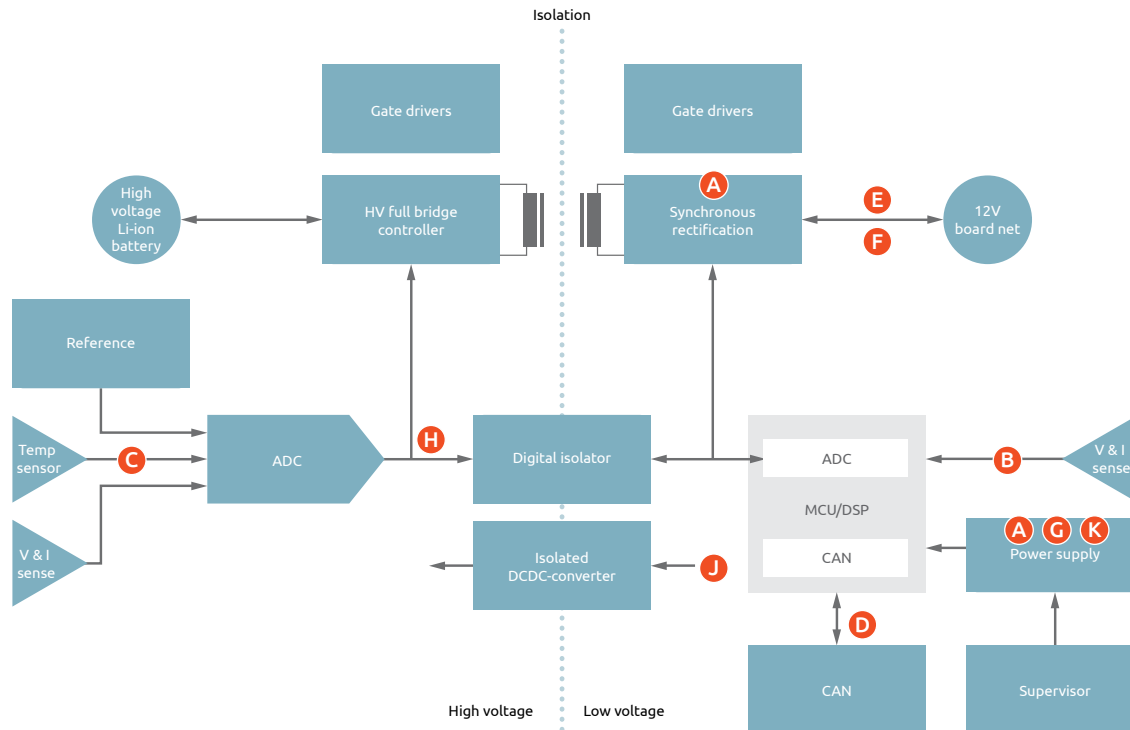


Power Block: DC-DC Converter

Automotive DC-DC converters are used for high-efficiency conversion between the 12 VDC battery voltage and high voltage systems.

Design considerations

- › What is the total system voltage? (determines FET parameters and Logic family)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Power MOSFETs	Power conversion
B	High Voltage Logic (74HEF4001-Q100)	Capable of operating directly on high voltage rails
C	Analog Switch (HEF4066-Q100)	Multiplexing many voltage sensors to MCU
D	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
E	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
F	TVS Diode (PTVS Family)	Transient voltage surge protection
G	Schottky Barrier Diode (PMEG family)	Free-wheeling diode for DC-DC and inductive load
H	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, Constant current monitor
J	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control
K	Transistor (Low Vcesat)	Linear regulator and load switch control

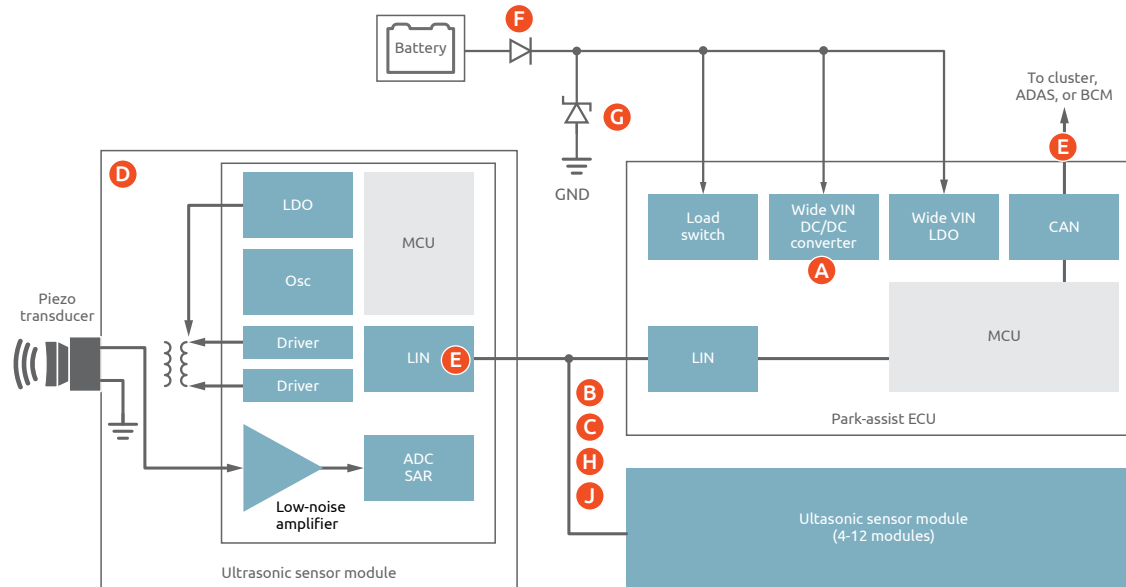


Sensors: Radar, LiDAR, Camera

Automotive sensors provide input to the Driver Assist System (DAS). These systems provides data for the systems that control and monitor blind spots, automatic parking, cruise control, and night vision.

Design considerations

- › How many input sensors? (determines number channels for Analog Switch and Level Shifters)
- › Is there a size constraint with the sensor? (use Mini Logic packaging to reduce footprint)
- › What are the system voltage rails? (Level Shifters)
- › What are the power requirements for the remote sensor? (consider AUP, AXP low power logic)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Power MOSFETs	Power conversion from 12 V supply rail
B	Analog Switch 74HC/HEF4051-Q100)	MUX input from multiple analog sensors to single MCU channel
C	Level Shifter (74AVC8T245-Q100)	Up to 8 channels of bidirectional translation between sensor and control module
D	Mini Logic Packages	Small logic packaging to fit into the sensor
E	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
F	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
G	TVS Diode (PTVS Family)	Transient voltage surge protection
H	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor
J	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting Low RDSon < 1 Ω used for load switch control

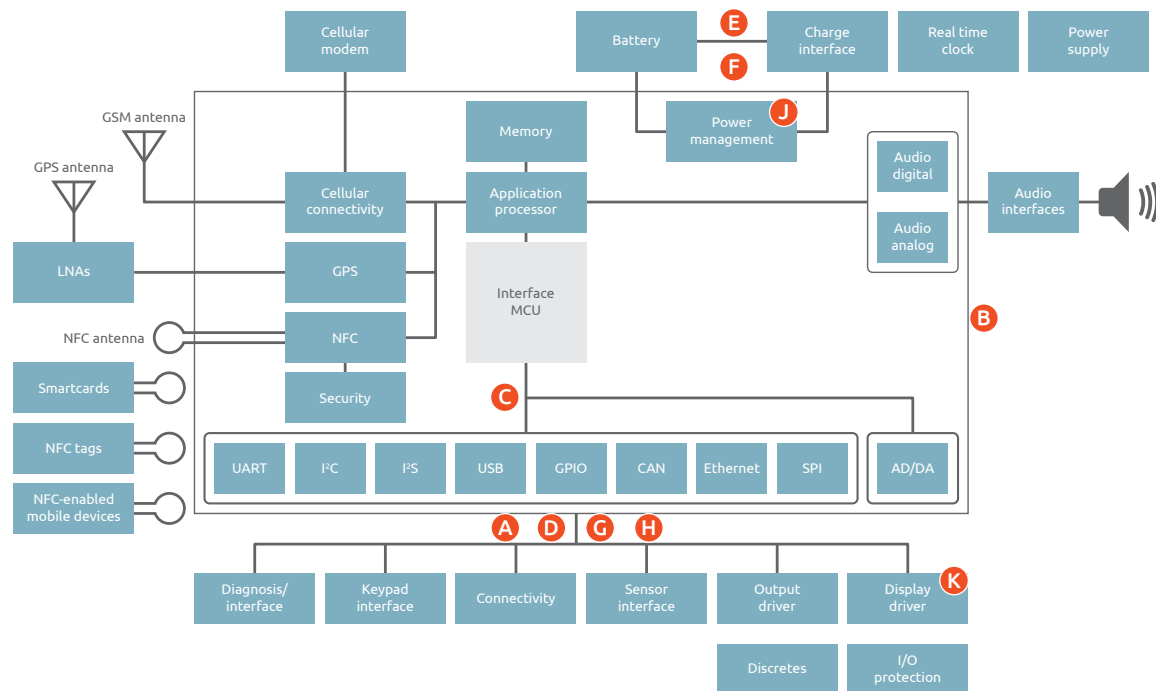


Telematics: e-Call, GPS, V2X

Telematics includes the various communications methods between the vehicle and the outside world, which may include V2x (Vehicle to Vehicle/Infrastructure), GPS, OnStar, cellular, etc.

Design considerations

- › What is the system voltage levels? (Level Shifters)
- › What are the operating frequencies? (selects Logic family)
- › How is the connector and system protected from ESD and voltage transient events? (ESD Protection)



	Product	Use value
A	Level Shifter (74AVC8T245-Q100)	Up to 8 channels of bidirectional translation between sensor and control module
B	Mini Logic Packages	Small logic packaging to fit in the module
C	Analog Switch (74HEF/HC4051)	MUX input from multiple analog sensors to single MCU channel
D	ESD Protection	General purpose ESD protection FlexRay ESD protection CAN ESD protection LIN ESD protection
E	PN Rectifier (PNS4001ER) Schottky Barrier Diode (PMEG family)	DC voltage blocking diode
F	TVS Diode (PTVS family)	Transient voltage surge protection
G	General purpose RETS and Matched Pair Transistors	Signal control, MOSFET driver, constant current monitor
H	Small Signal MOSFET (P or N Channel)	High RDSon > 1 Ω used for signal control, level shifting
J	Transistor (Low Vcesat)	Linear regulator and load switch control
K	LED Driver (NPIC6C596-Q100)	Low cost LED backlight driver

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