18060 IVN

Interfacing with Vehicle Networks: Best Practices

Agenda

- **Introduction to OBD**
  - Lab 1
- **Power Management**
  - Lab 2
- **Transceiver Design**
  - Lab 3
- **Avoiding Interference**

Class Objectives

- Describe OBD and its applications
- Access and interpret OBD data
- Explain power management and transceiver design considerations
- Recognize and avoid common design pitfalls

Class Objectives

- Choose an appropriate power management strategy
- Properly design OBD transceivers, using inexpensive discrete components
- Use an OBD simulator for development and testing

Class Objectives

- **Summarize the problems faced by the designers of OBD devices**

Introduction to OBD

Introduction to OBD

- What is OBD?
- Key Terms
- OBD applications
- Accessing OBD data

What is ‘OBD’?

- On-Board Diagnostics
- Computer-based system designed to control emissions
- Provides early warning through MIL (Malfunction Indicator Light)

What is 'OBD'?

What is ‘OBD’?

World Wide OBD Coverage

Argentina (domestic)	2008	India[2]	2013
Argentina (imports)	2009	Israel	2003
Australia (Petrol)	2006	Japan	2003
Australia (Diesel)	2007	Mexico	2007
Brazil (Petrol)[1]	2010	New Zealand (Petrol)	2006
Canada	1998	New Zealand (Diesel)	2007
China (Beijing - Petrol)	2008	Peru	2003
China (Country - Petrol)	2010	Russia	2010
China (Country - Diesel)	2011	South Korea	2007
European Union (Petrol)	2001	Taiwan	2008
European Union (Diesel)	2004	Thailand	2013
Hong Kong	2006	United States	1996

* The "year" indicates the first model year of compatibility. All later years are supported as well

* OBD legislation is designed for cars and light-duty trucks. For example, it applies to all vehicles weighing <14,000 lbs in the USA

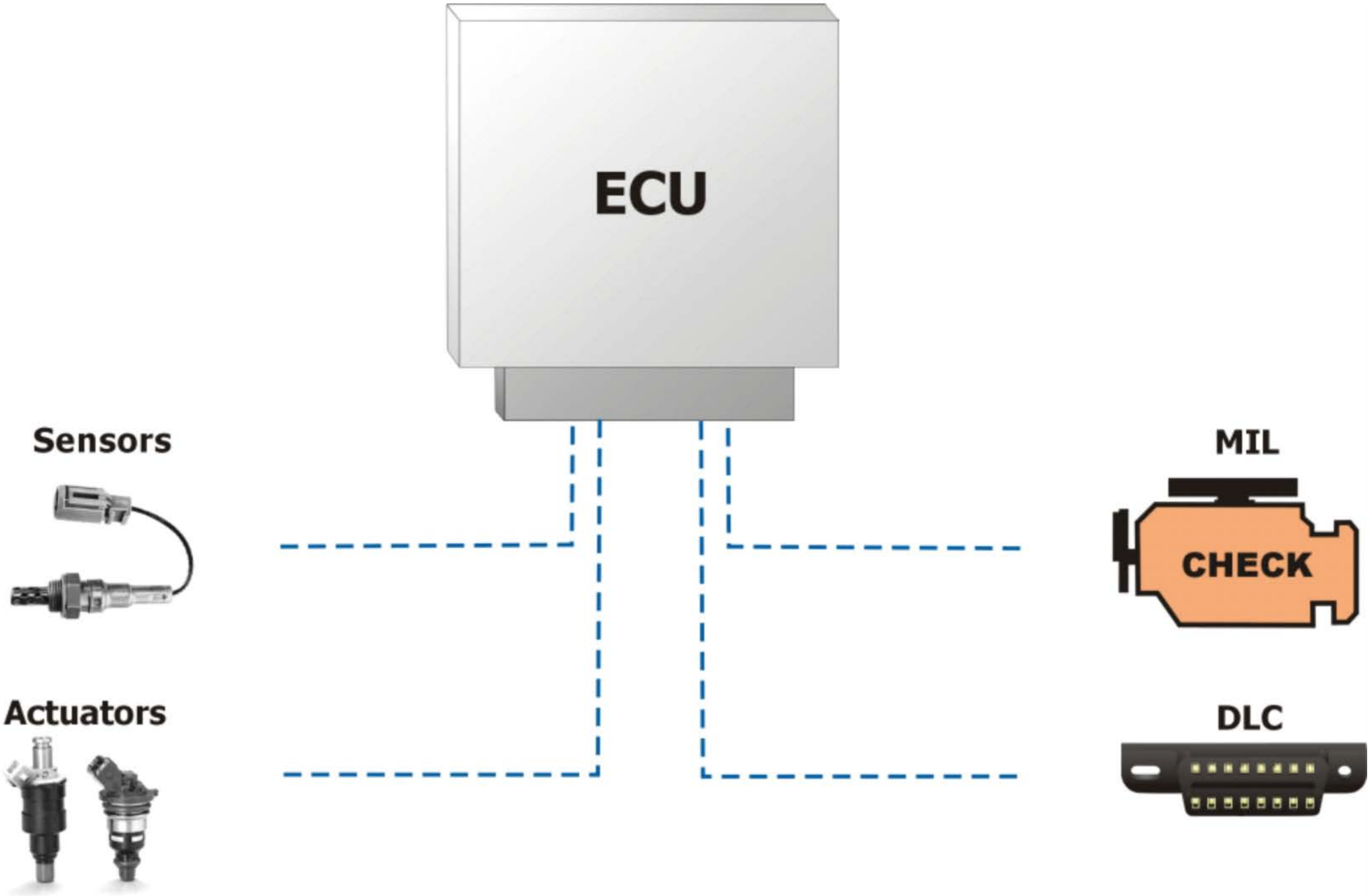
[1] Limited support from 2007

[2] Limited support from 2010

Key Terms

- **ECU:** Electronic Control Unit
- **MIL:** Malfunction Indicator Light ("Check Engine")
- **DLC:** Diagnostic Link Connector ("OBD Port")
- **DTC:** Diagnostic Trouble Code
- **CAN:** Controller Area Network

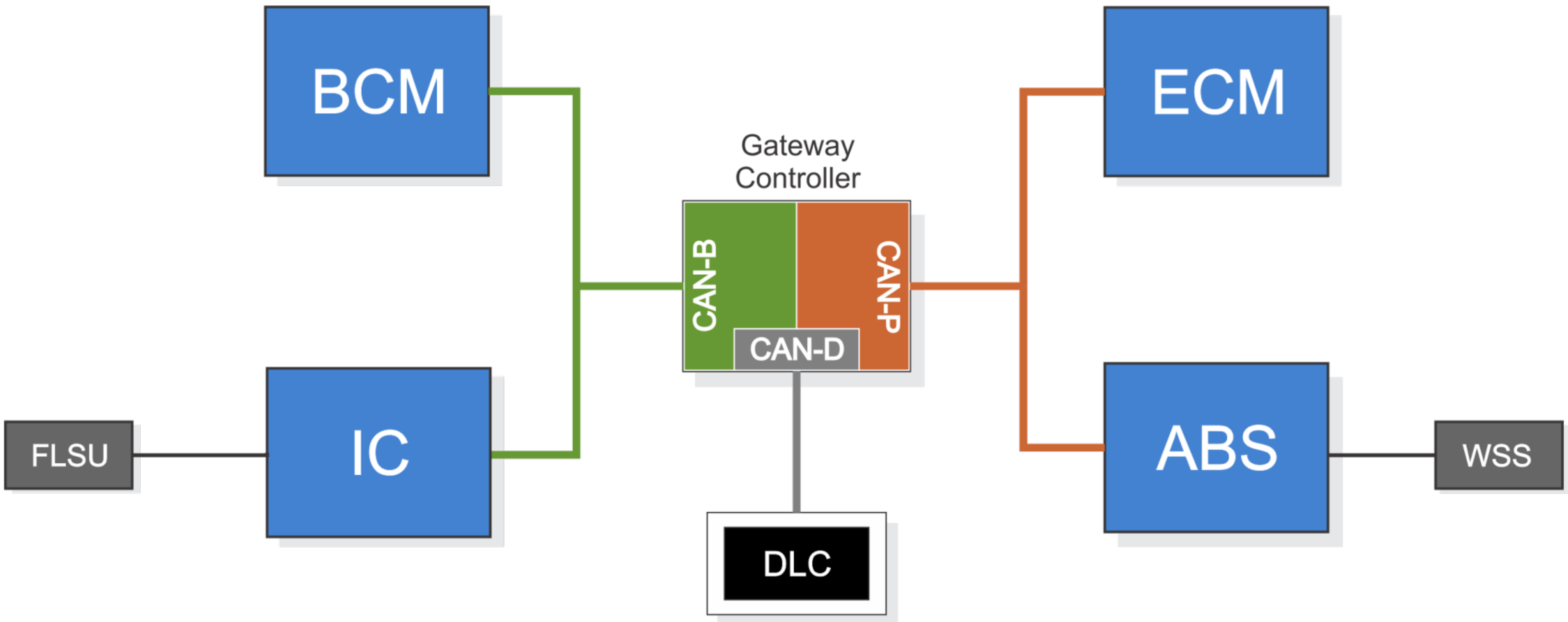
Electronic Control Unit



ECU Types

- **PCM:** Powertrain Control Module
- **ECM:** Engine
- **TCM:** Transmission
- **BCM:** Body
- **Other:** ABS/ESC, SRS, HVAC, immobilizer, etc

Network Example



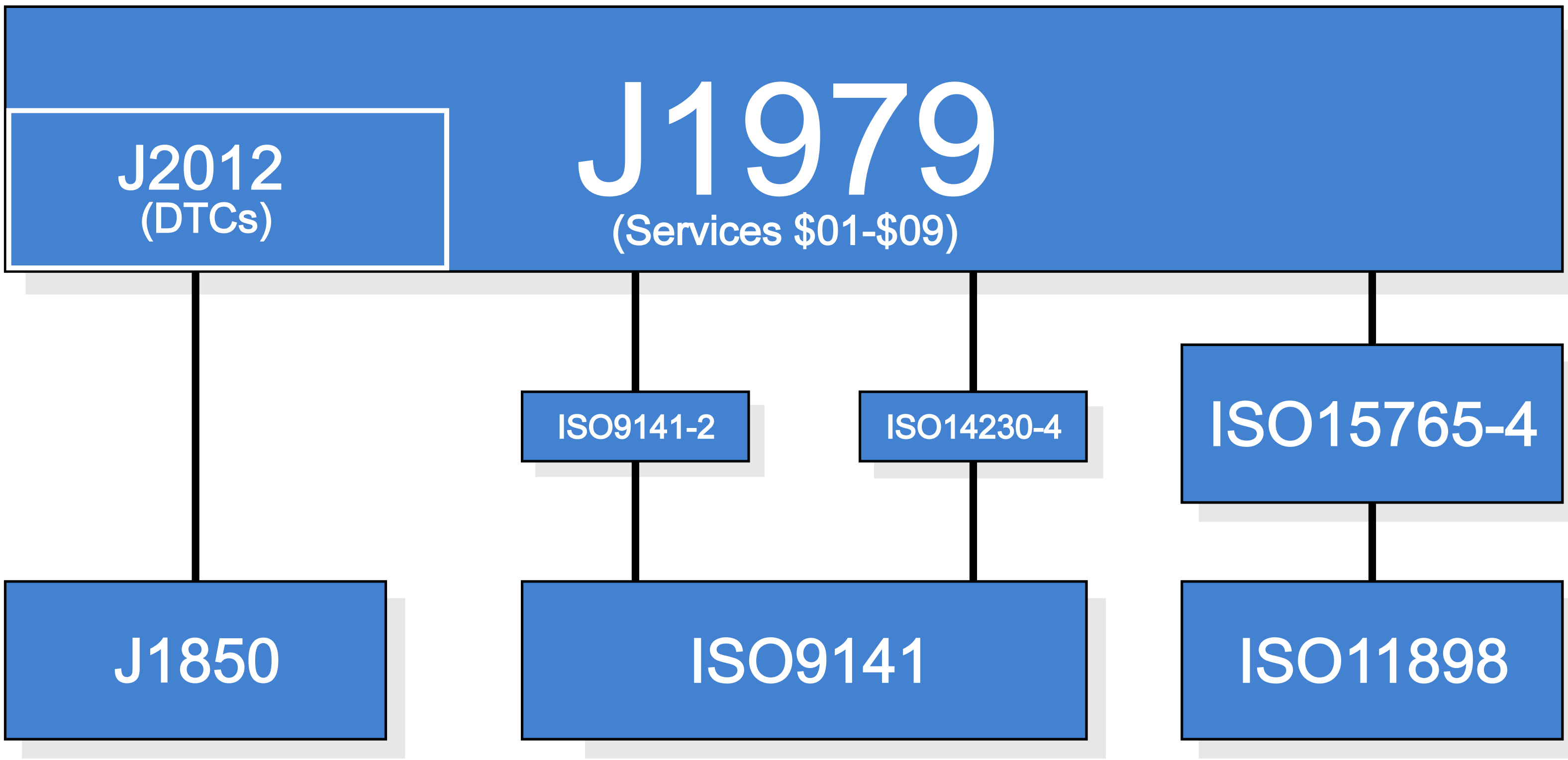
OBD Applications

- Diagnostics
- Performance Tuning/Reflashing
- Fleet Management
- Telematics/Vehicle Tracking
- Usage-based Insurance (UBI)
- Driver Behavior Monitoring/Feedback

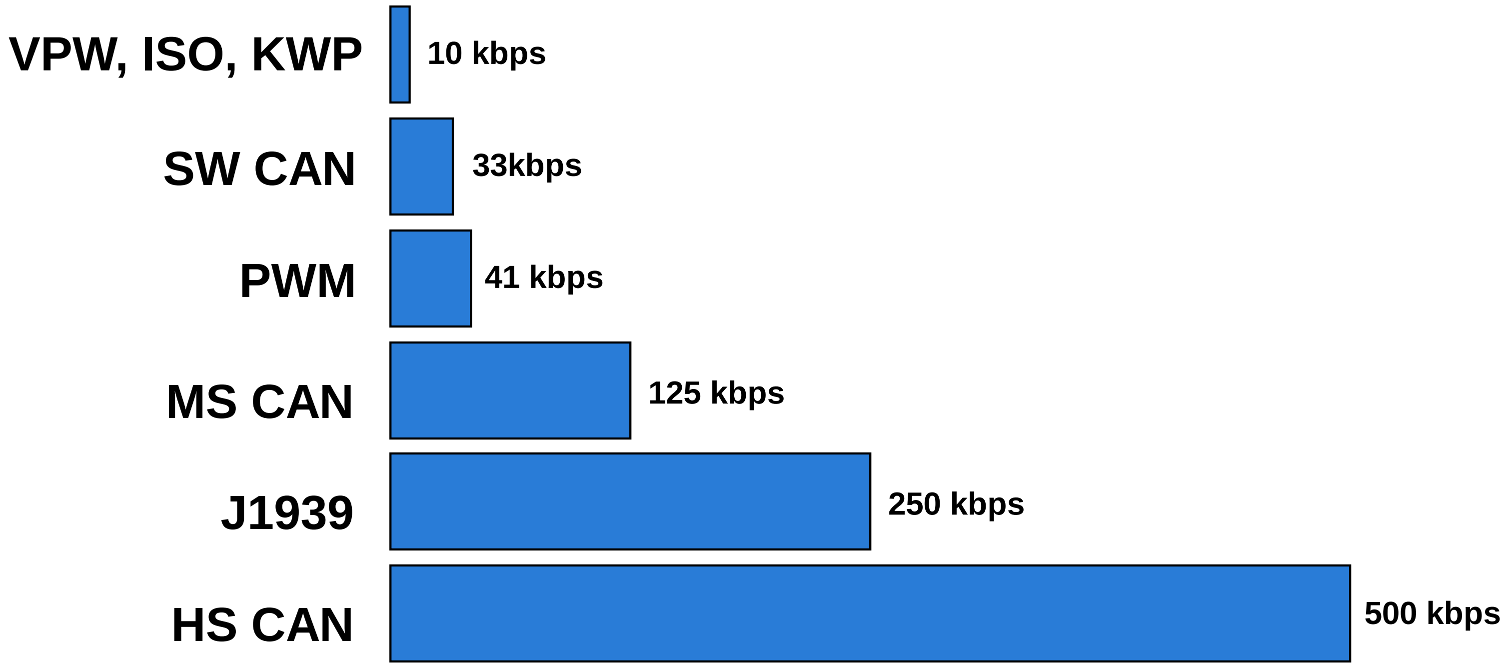
OBD Protocols

- **Legislated:**
  - SAE J1850 VPW & PWM
  - ISO 9141-2
  - ISO 14230-4
  - ISO 15765-4 (HS CAN)
  - SAE J1939 (HD CAN)
- **Proprietary**
  - GMLAN, Ford MSC, etc

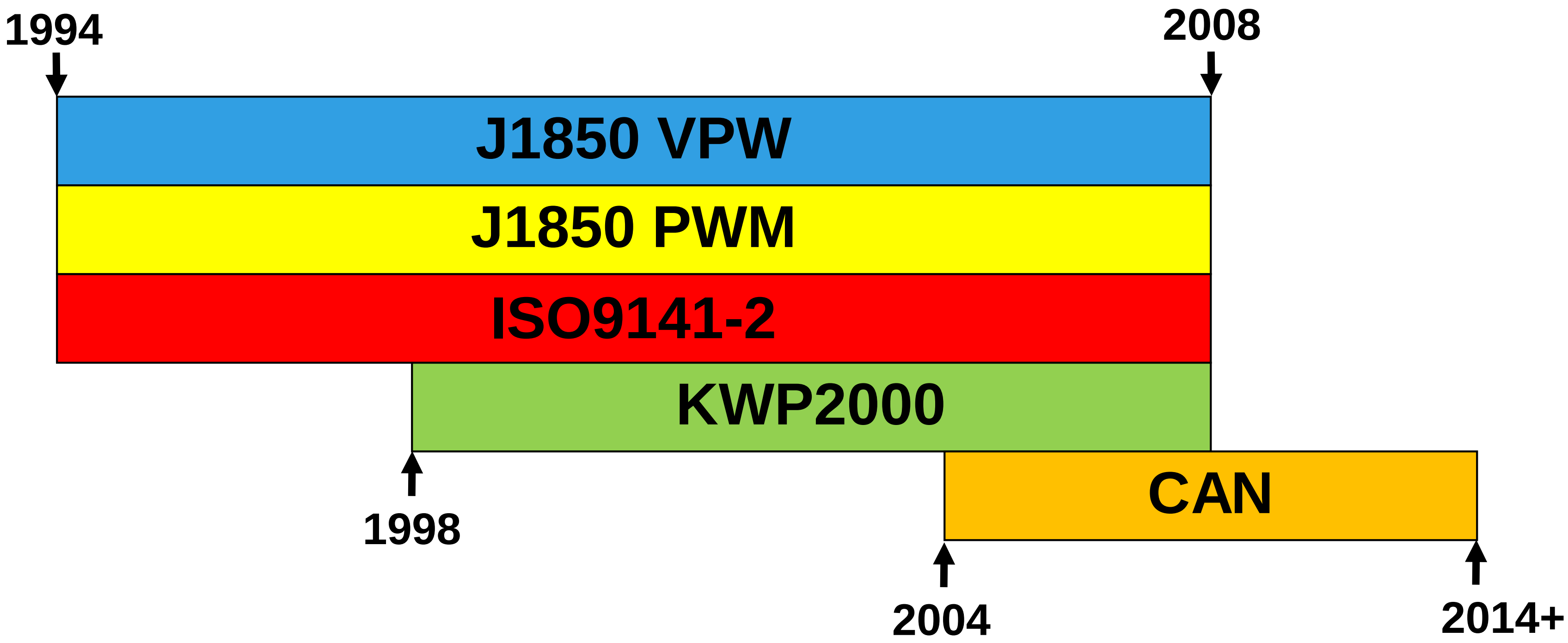
OBD Protocols



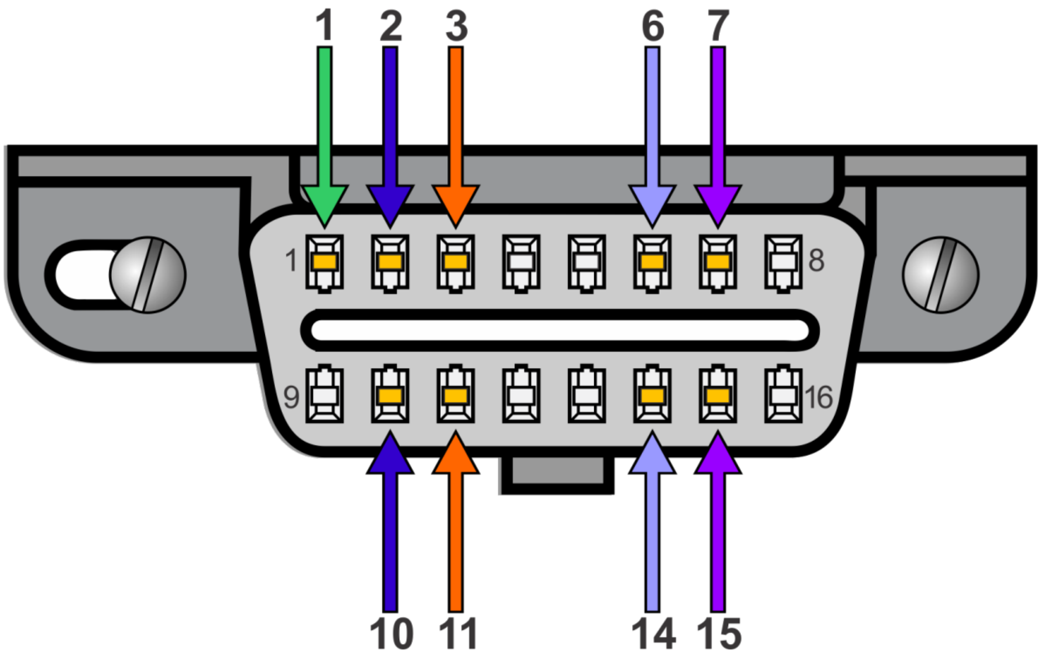
OBD Protocols



OBD Protocols

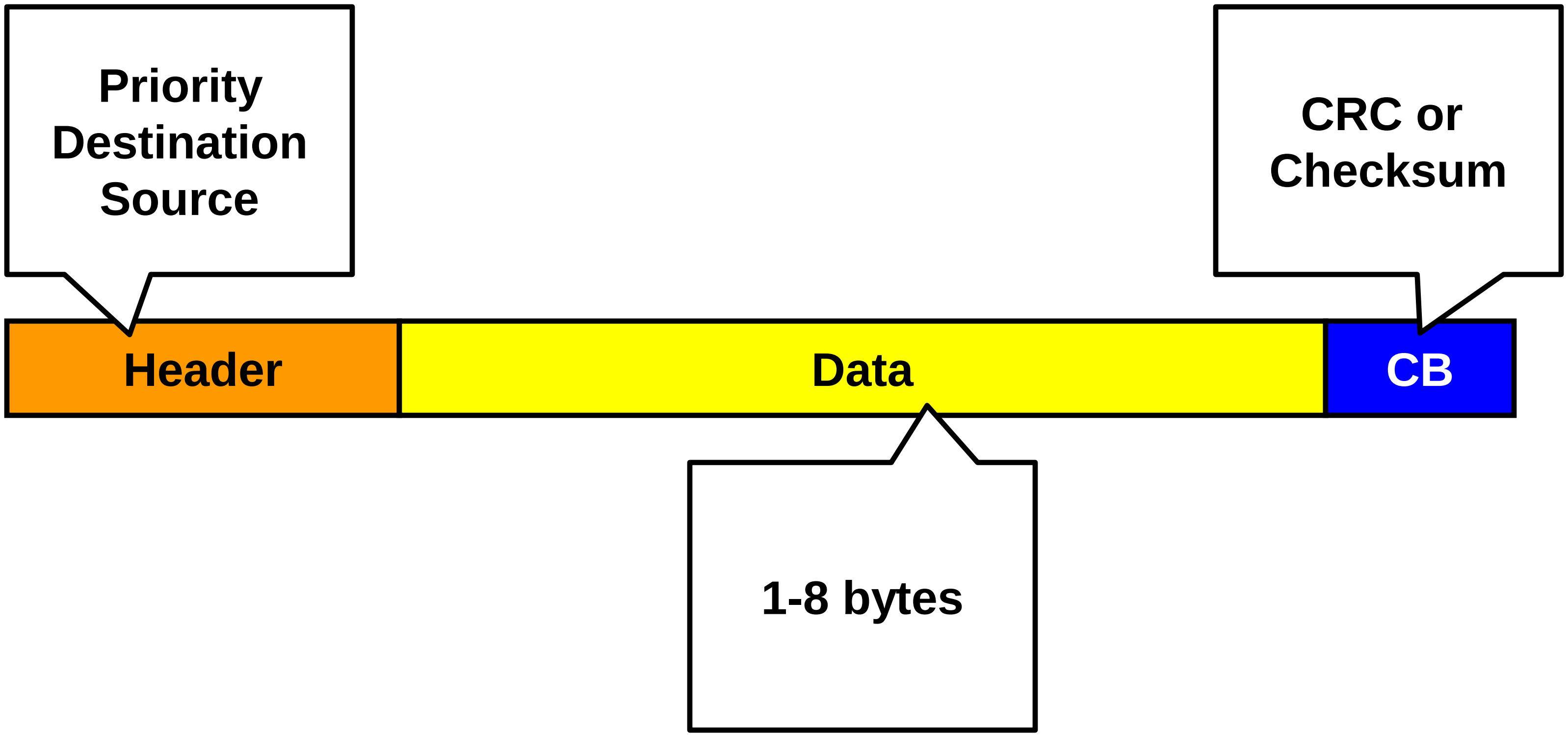


Diagnostic Link Connector



1	Single Wire CAN (Low-speed GMLAN)
2, 10	J1850 Bus+/Bus-
3, 11	CAN_HI/CAN_LO (Ford MSC)
6, 14	CAN_HI/CAN_LO (HS CAN)
7, 15	K-line/L-line (ISO & KWP)

OBD Frame Format



OBD Frame Format

Header Bytes (Hex)			Data Bytes								
Priority/Type	Target Address (hex)	Source Address (hex)	#1	#2	#3	#4	#5	#6	#7	ERR	RESP
Diagnostic Request at 10.4 kbit/s: SAE J1850 and ISO 9141-2											
68	6A	F1	Maximum 7 data bytes							Yes	No
Diagnostic Response at 10.4 kbit/s: SAE J1850 and ISO 9141-2											
48	6B	ECU addr	Maximum 7 data bytes							Yes	No
Diagnostic Request at 10.4 kbit/s (ISO 14230-4)											
11LL LLLLb	33	F1	Maximum 7 data bytes							Yes	No
Diagnostic Response at 10.4 kbit/s (ISO 14230-4)											
10LL LLLLb	F1	ECU addr	Maximum 7 data bytes							Yes	No
Diagnostic Request at 41.6 kbit/s (SAE J1850)											
61	6A	F1	Maximum 7 data bytes							Yes	Yes
Diagnostic Response at 41.6 kbit/s (SAE J1850)											
41	6B	ECU addr	Maximum 7 data bytes							Yes	Yes

Header Bytes	CAN Frame Data Field							
CAN Identifier (11 or 29 bit)	#1	#2	#3	#4	#5	#6	#7	#8

OBD-II Services

- **Legislated (SAE J1979):**
  - \$01: Real-time parameter data
  - \$02: Freeze frames
  - \$03: Stored DTCs
  - \$04: Clear/Reset
  - \$05: O2 sensor monitoring

OBD-II Services

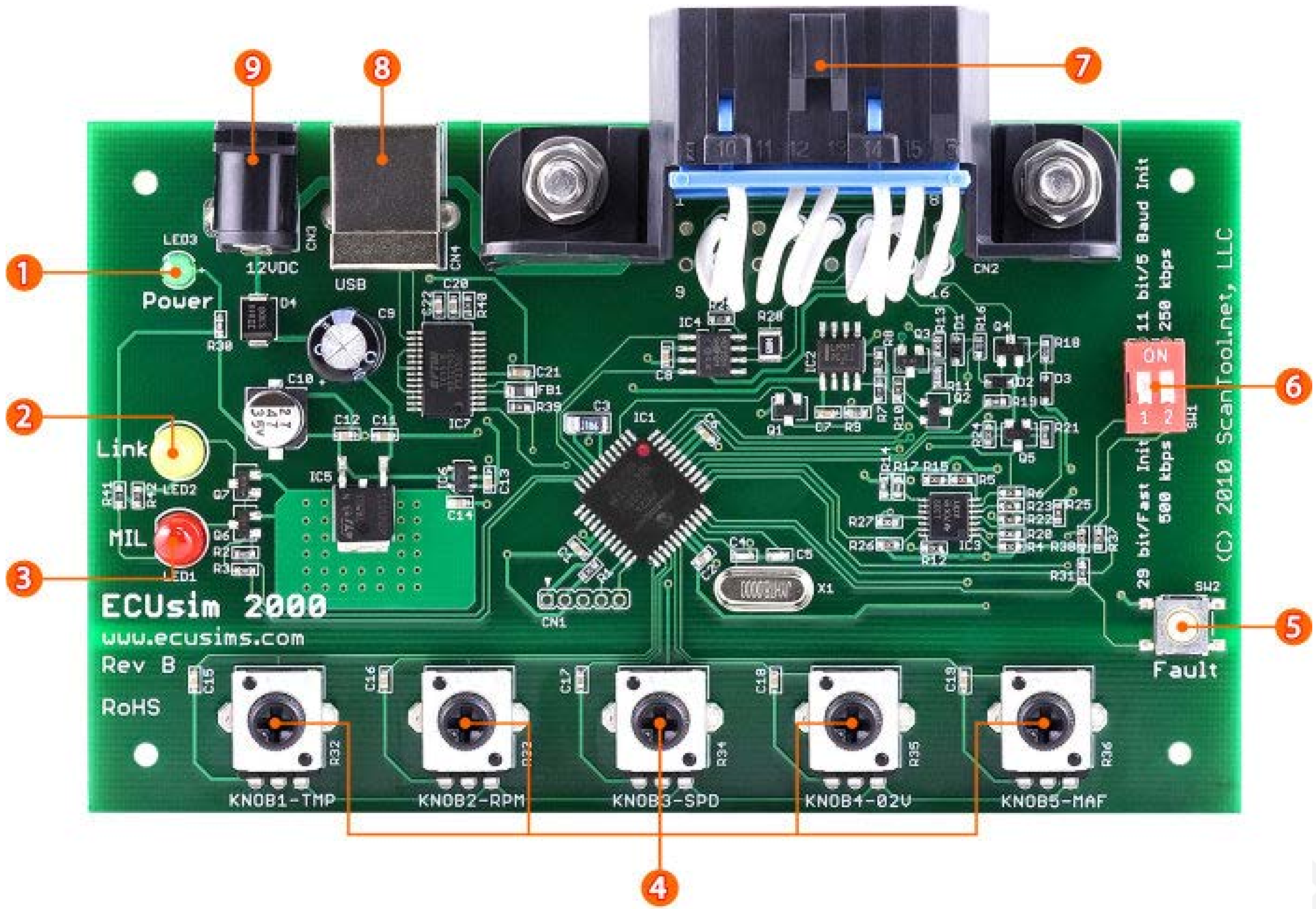
- **Legislated (SAE J1979):**
  - $06: Specific monitored systems
  - $07: Pending DTCs
  - $08: Evaporative leak test
  - $09: VIN, CAL ID, IPT
  - $0A: Permanent DTCs
- **Enhanced (SAE J2190):**
  - $10-$3F

Lab 1:
Access OBD data

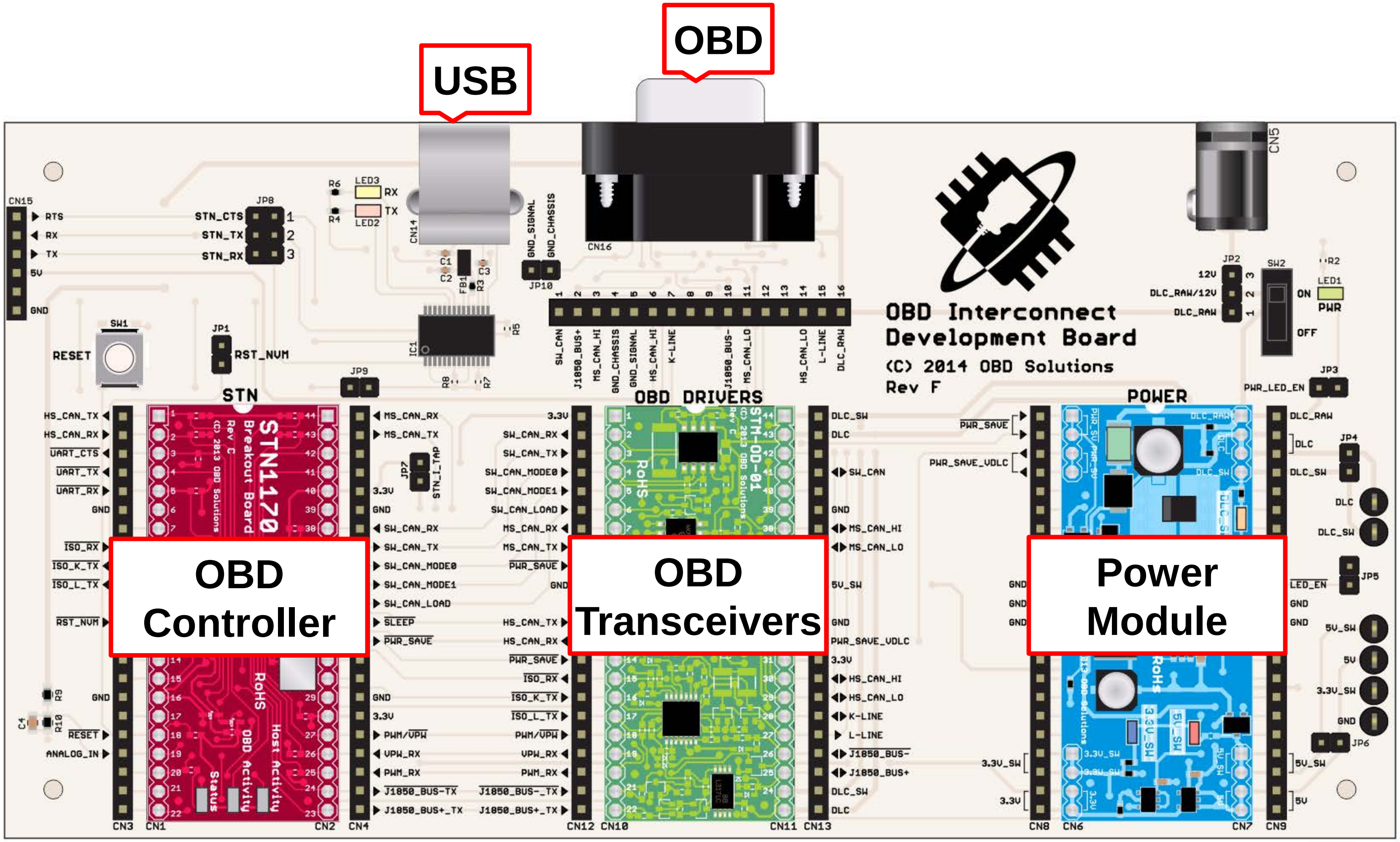
Lab 1 Objectives

- **Become familiar w/ dev tools**
- **Establish connection with the simulator**
- **Request and interpret data: vehicle speed, RPM, DTCs, VIN**

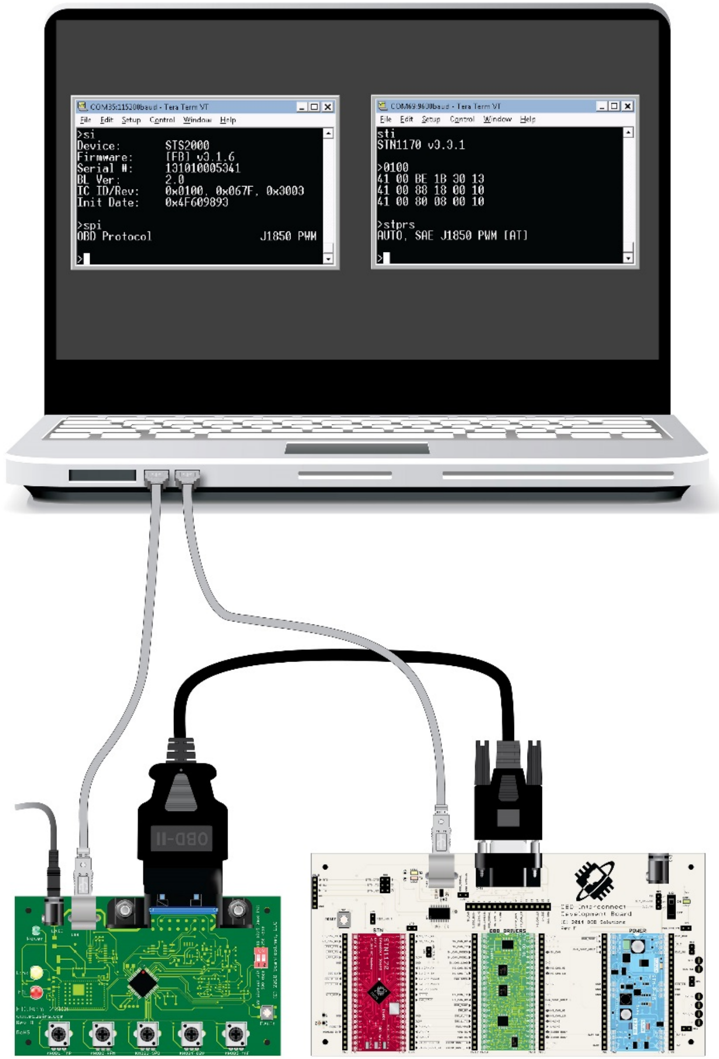
Lab 1: OBD Simulator



Lab 1: OBD Dev Board



Lab 1: Connection Diagram



Lab 1: Vehicle Speed

Request: **01 0D**

Response: **41 0D <A>**

PID (hex)	Description	Data Byte	Min. Value	Max. Value	Scaling/Bit	External Test Equipment SI (Metric) / English Display
0D	Vehicle Speed Sensor	A	0 km/h	255 km/h	1 km/h per bit	VSS: xxx km/h (xxx mph)
	VSS shall display vehicle road speed. Vehicle speed may be derived from a vehicle speed sensor, calculated by the ECU using other speed sensors, or obtained from the vehicle serial data communication bus.					

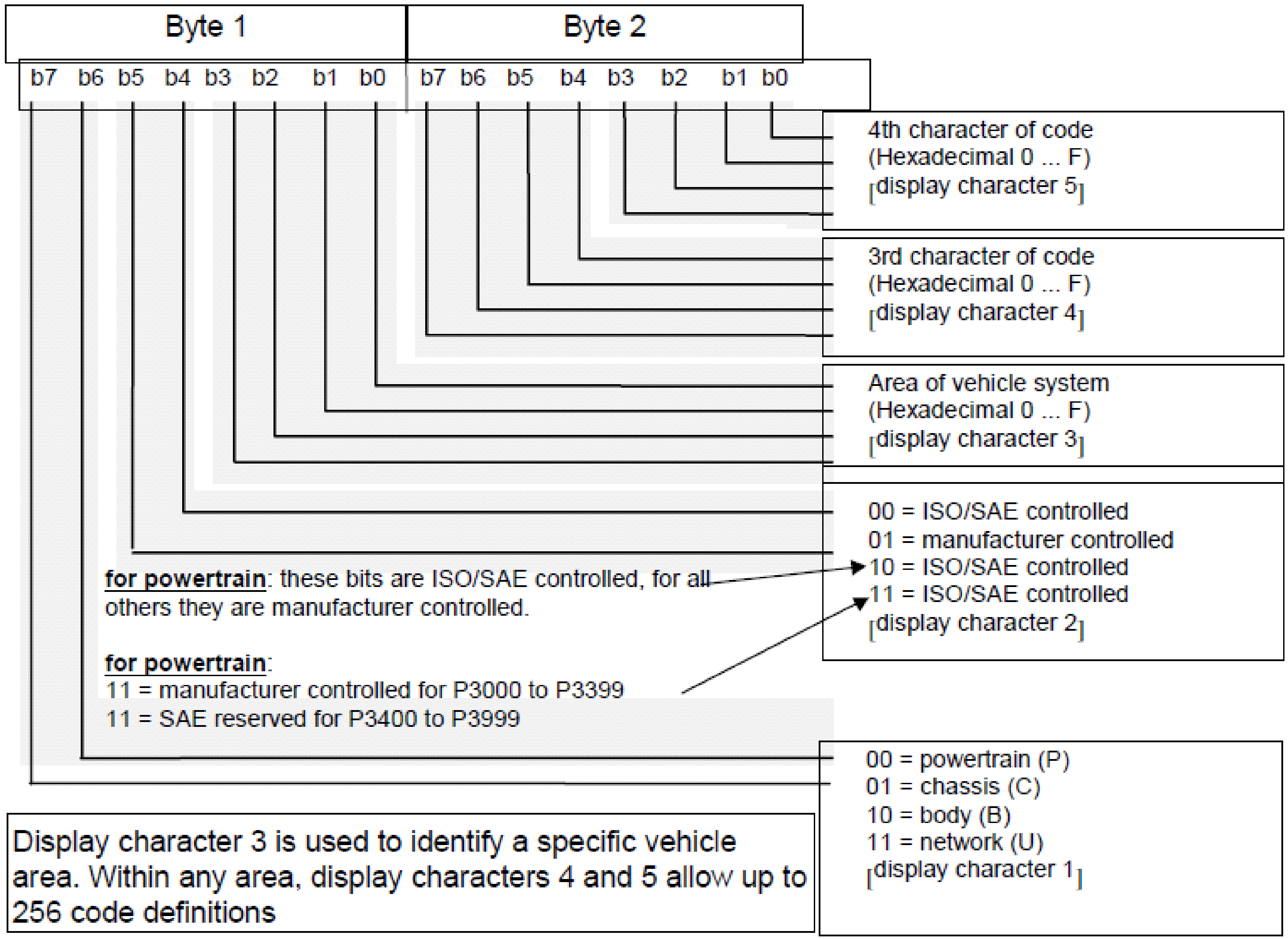
Lab 1: Engine Speed (RPM)

Request: 01 0C

Response: 41 0C <A> <B>

PID (hex)	Description	Data Byte	Min. Value	Max. Value	Scaling/Bit	External Test Equipment SI (Metric) / English Display
0C	Engine RPM	A, B	0 min^{-1}	16383.75 min^{-1}	1/4 rpm per bit	RPM: xxxxx min^{-1}
	Engine RPM shall display revolutions per minute of the engine crankshaft.					

Lab 1: DTC structure

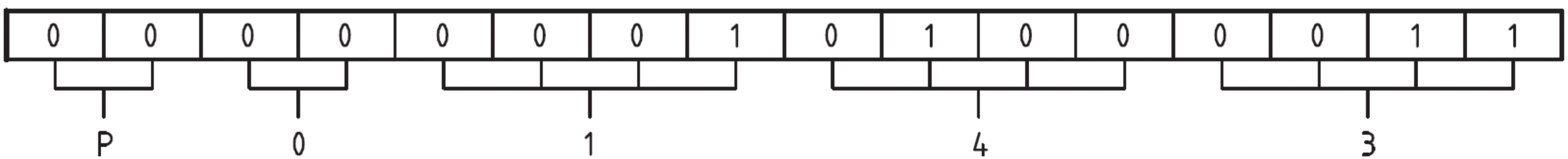


Lab 1: Stored DTCs

Request: 03

Response: 43 <DtcCount*><DTC (2 bytes>

Example DTC encoding:



***CAN only. DtcCount is the number of stored DTCs.**

Lab 1: VIN

Request: **09 02**

Response: **49 02 <MsgCount*><VIN>**

InfoType (Hex)	Description	Scaling	External Test Equipment SI (Metric) / English Display
02	**Vehicle Identification Number**	17 ASCII characters	VIN: XXXXXXXXXXXXXXXXX
	For vehicles that provide electronic access to the VIN, it is recommended to report it using this format for ease of use by the external test equipment intended either for vehicle diagnostics or Inspection/Maintenance programs. Each of the 17 characters in each VIN shall be one of the letters in the set: [ABCDEFGHJKLMNPRSTUVWXYZ] ($41 - $48, $4A - $4E, $50, $52 - $5A), or a numeral in the set: [0123456789] ($30 - $39). For ISO 9141-2, ISO 14230-4 and SAE J1850, the response consists of the following messages: – Message #1 shall contain three (3) filling bytes of $00, followed by VIN character #1; – Message #2 shall contain VIN characters #2 to #5 inclusive; – Message #3 shall contain VIN characters #6 to #9 inclusive; – Message #4 shall contain VIN characters #10 to #13 inclusive; – Message #5 shall contain VIN characters #14 to #17 inclusive. For ISO 15765-4, there is only one response message, which contains all VIN characters without any filling bytes.		

***Non-CAN protocols only. MsgCount is the frame number (starting with 01).**

Lab 1: ASCII Chart

ASCII Code Chart

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2		!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL

Lab 1 Summary

- OBD uses “request/response” method of information exchange
- Large chunks of data may be spread over several OBD frames
- More than one ECU may respond to a functional request
- ISO 15765-4 supports multi-frame responses as true “messages”

Power Management

Power Management

- Power supply configurations
- Load dump protection
- Sleep Strategies
- Wake-up Strategies
- Common Pitfalls

Power Supply Configurations

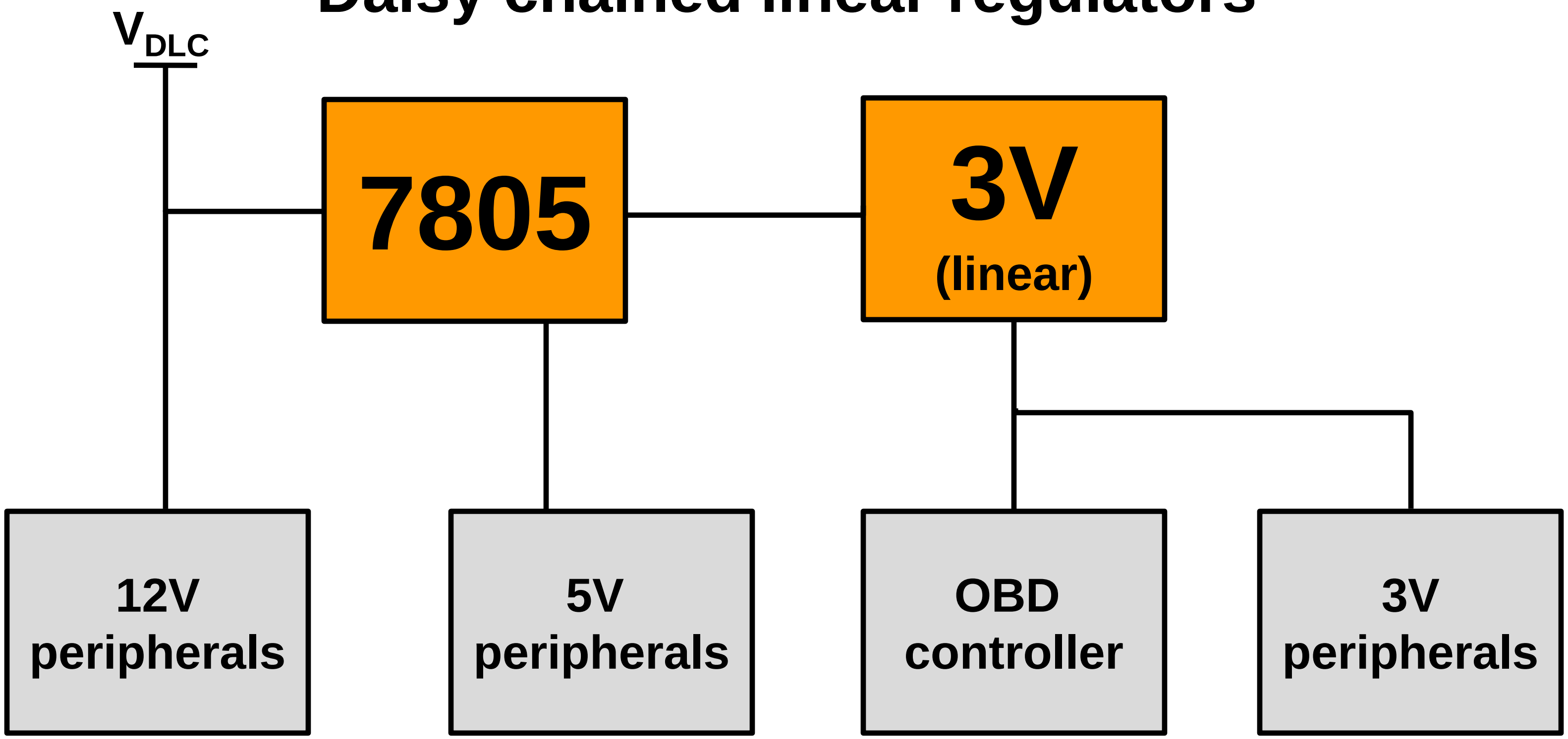
- **Considerations:**
  - Current consumption
    - **Peak**
    - **Operating**
    - **Sleep (quiescent)**
  - Power dissipation
  - Physical size
  - Functional requirements

Power Supply Configurations

- Daisy-chain vs. Parallel
- Linear and/or SMPS
- Peripherals always on or switched off in sleep

Power Supply Configurations

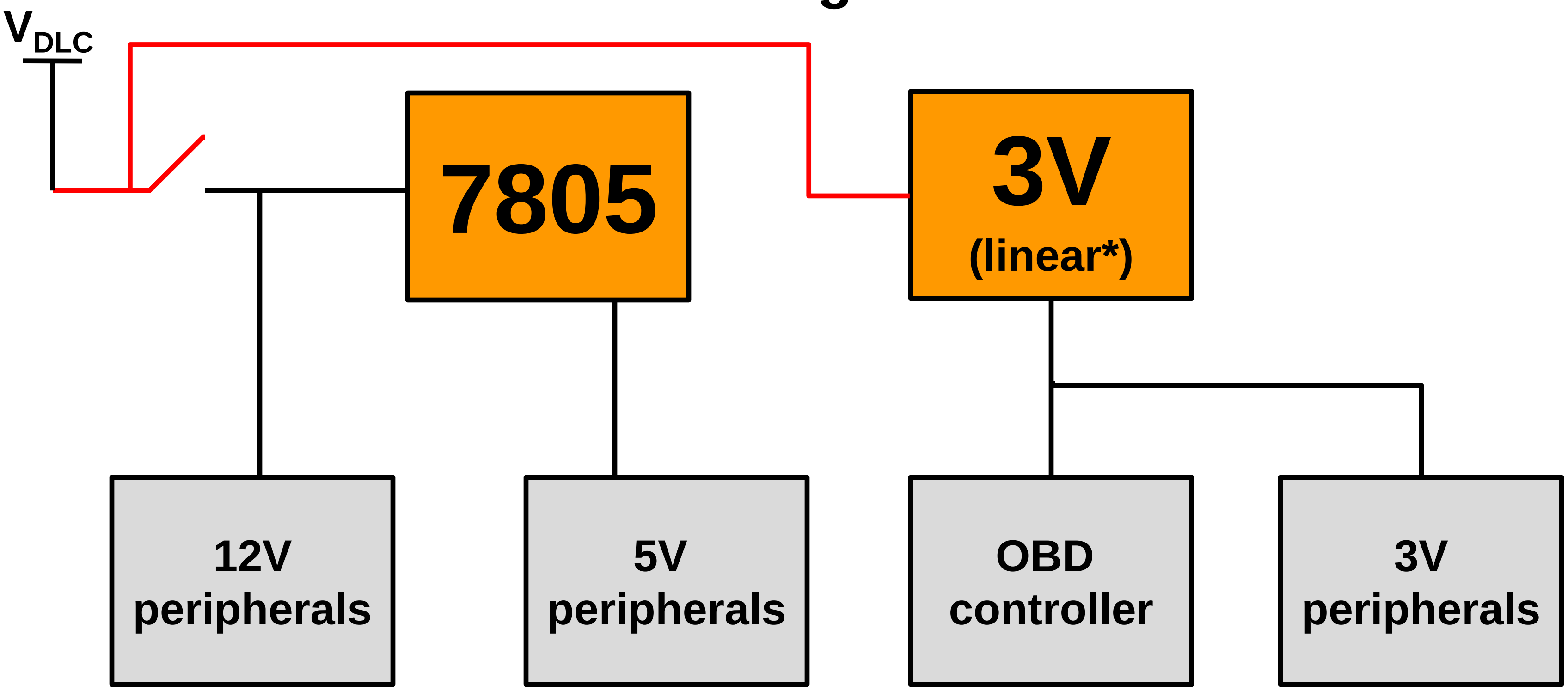
Daisy chained linear regulators



+ Low cost, low part count
- High sleep current, high power dissipation

Power Supply Configurations

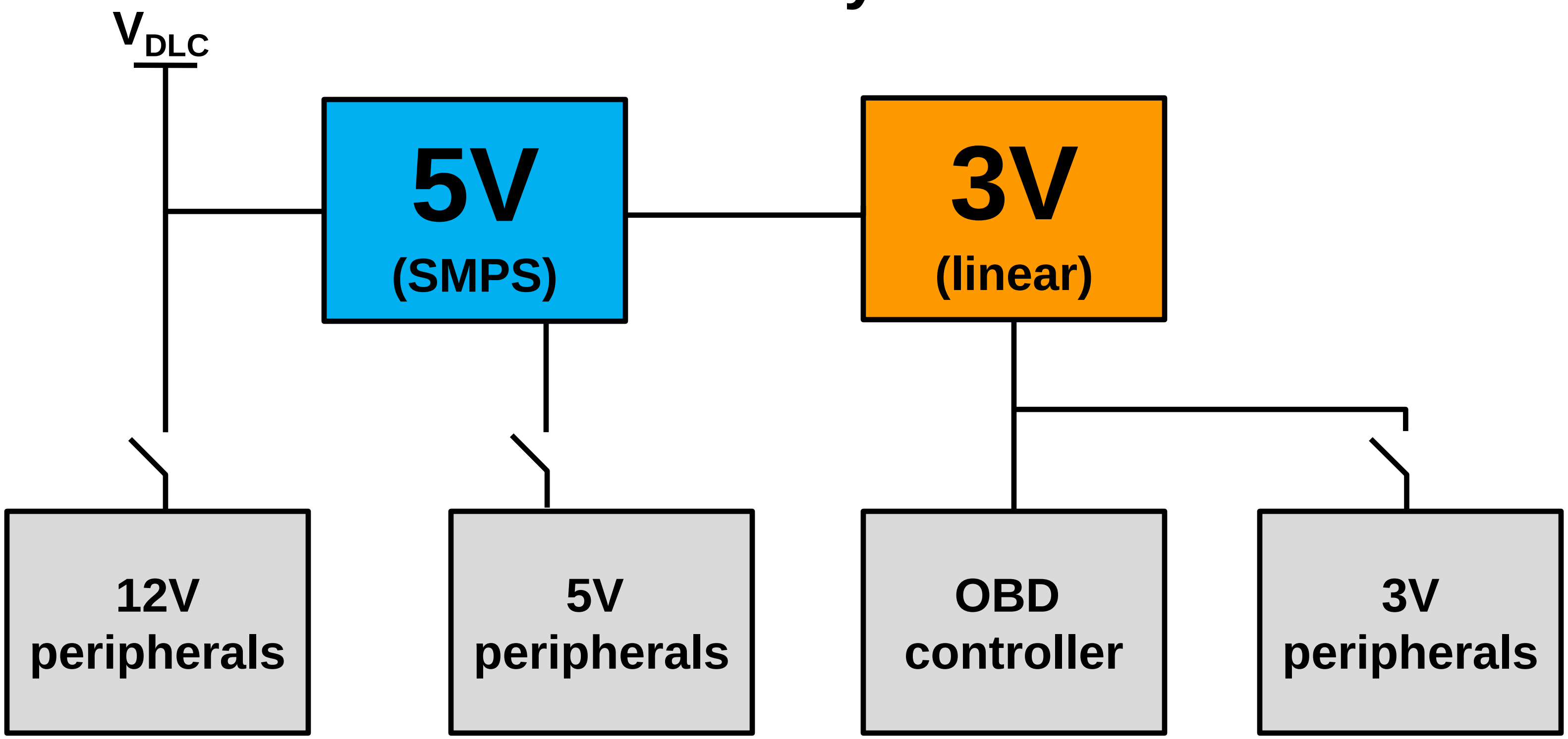
Parallel linear regulators w/ switch



+ Low sleep current
- High power dissipation
* Must use a 3V regulator with low I_Q and a high V_{MAX}

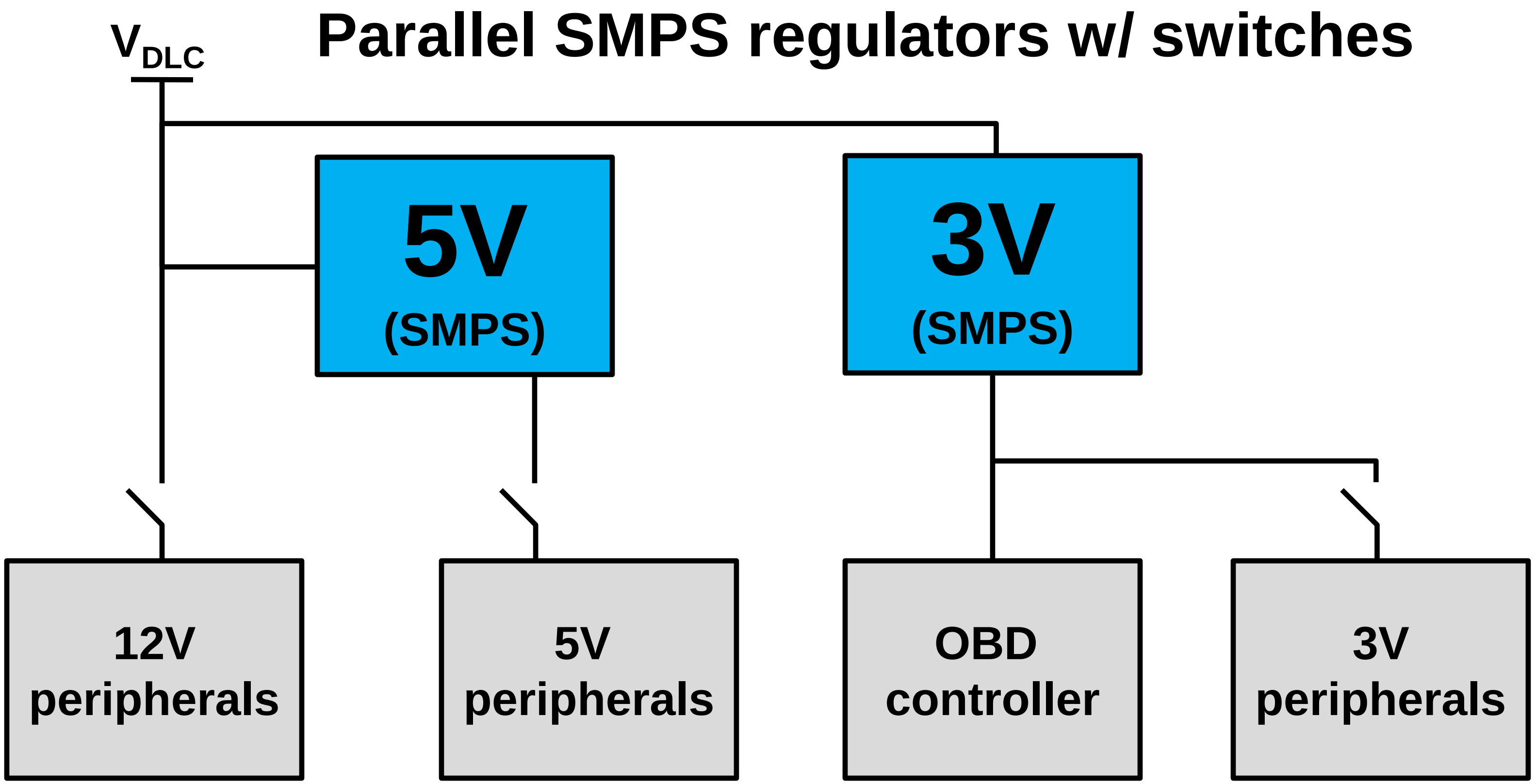
Power Supply Configurations

SMPS/linear daisy chain w/ switches



Good balance of cost, part count. Can use a low-V_{MAX} regulator for 3V, low ripple on 3V rail.

Power Supply Configurations



Expensive, but appropriate for applications that require high current capability on the 3V power rail.

Load Dump Protection

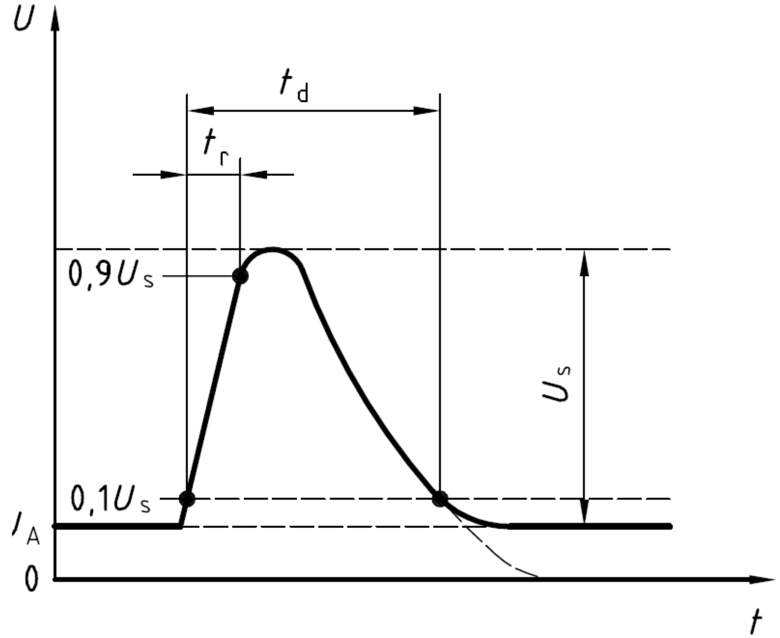
- **Load Dump**
  - Battery disconnected while being charged by alternator
  - Causes: cable corrosion, poor connection, or intentional disconnection with the engine running
  - Most new alternators use diodes to suppress (clamp) the pulse

Load Dump Protection

- **Load Dump Pulse**
  - Described in ISO 7637-2
  - Pulse 5a (unsuppressed)
  - Pulse 5b (suppressed)

Load Dump Protection

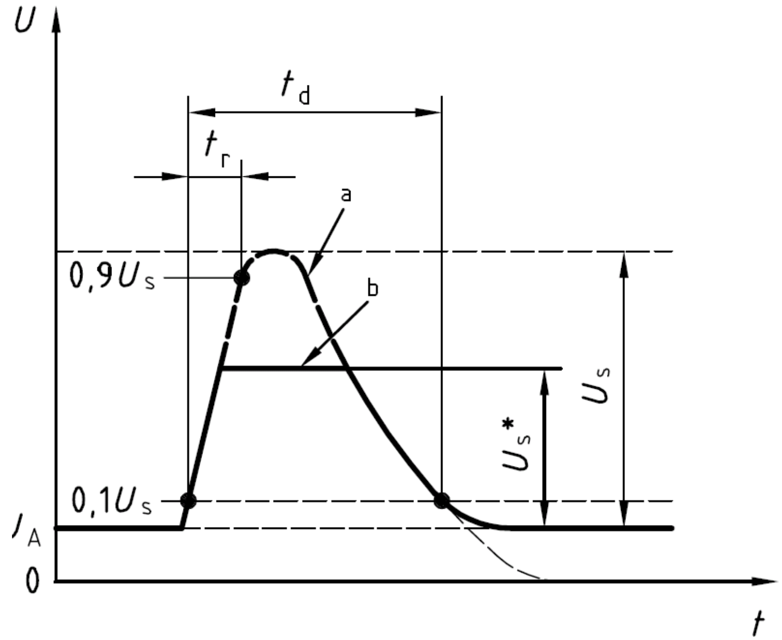
- **Pulse 5a**



Parameter	12 V system	24 V system
U_s	65 V to 87 V	123 V to 174 V
R_i	0,5 Ω to 4 Ω	1 Ω to 8 Ω
t_d	40 ms to 400 ms	100 ms to 350 ms
t_r	$\left(10\,^{0}_{-5}\right)$ ms	

Load Dump Protection

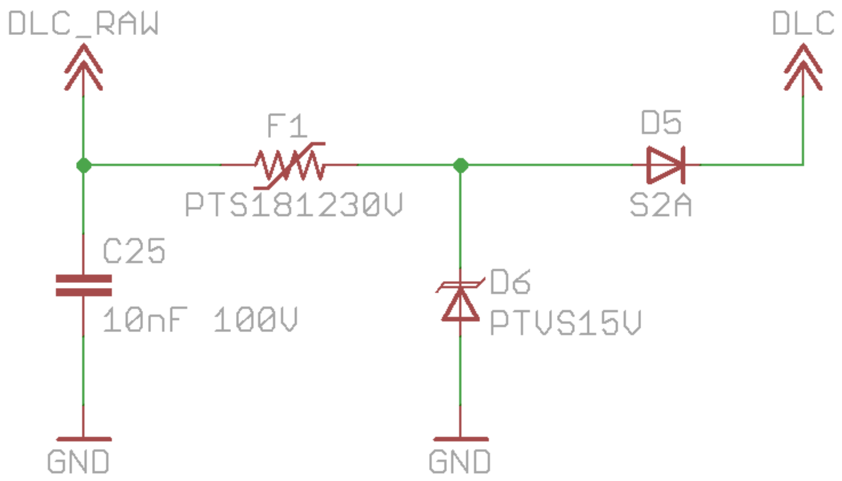
- **Pulse 5b**



Parameter	12 V system	24 V system
U_s	65 V to 87 V	123 V to 174 V
U_s*	As specified by customer	
t_d	Same as unsuppressed value	

Load Dump Protection

PTC/TVS

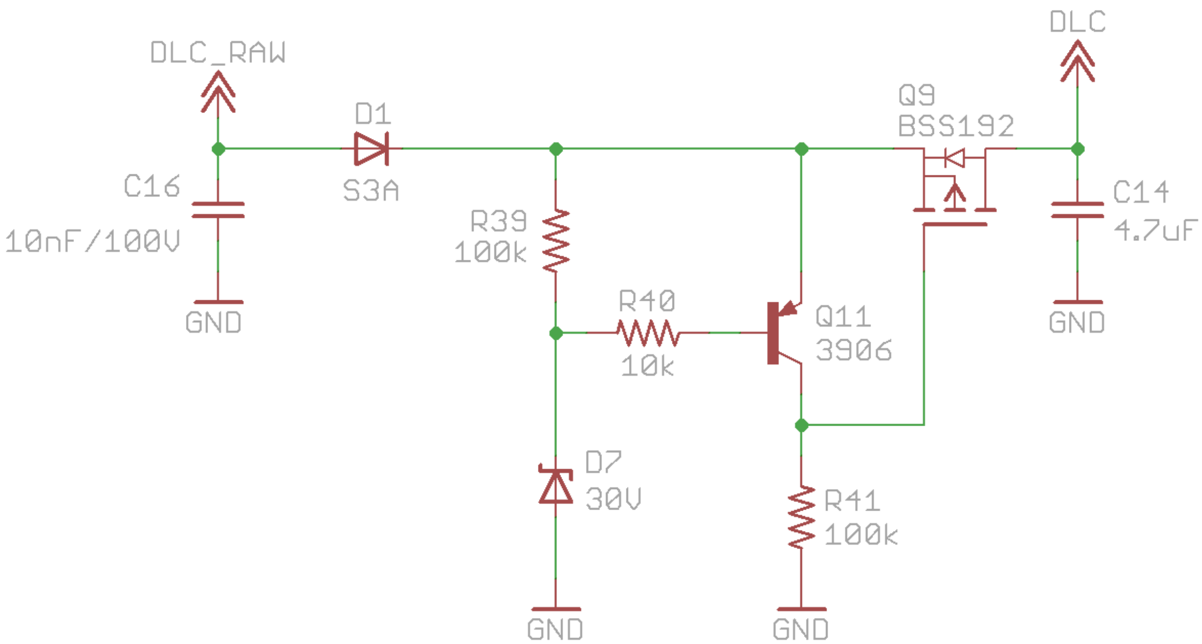


Load Dump Protection

- **Pros:**
  - Simple
  - Low part count
- **Cons:**
  - Bulky
  - Relatively expensive
  - Gets bulkier/more expensive >60V

Load Dump Protection

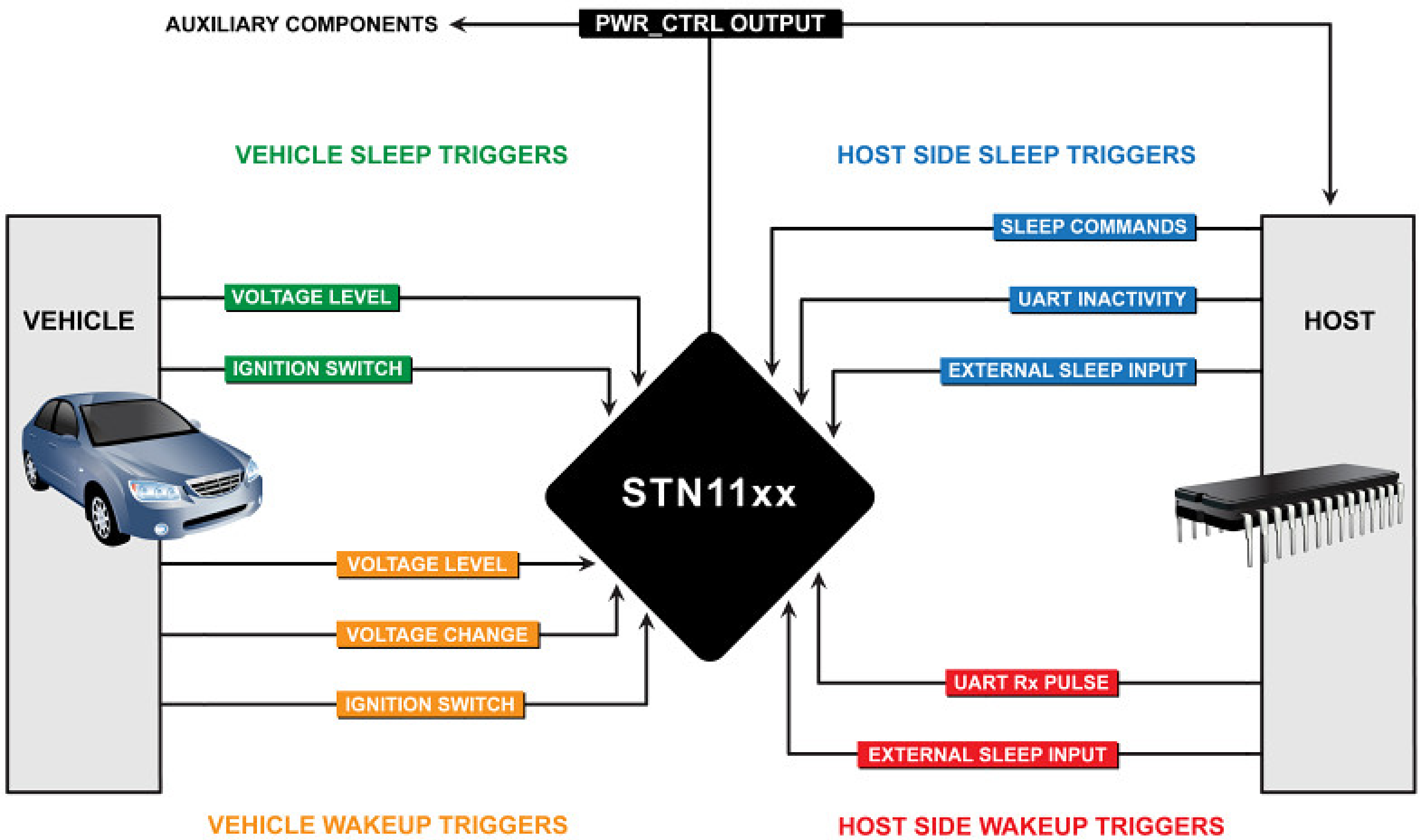
Transistor-based



Load Dump Protection

- **Pros:**
  - Inexpensive
  - Can be smaller than PTC/TVS
  - V_{max} >90V easily achieved
- **Cons:**
  - Higher part count

Sleep/Wakeup Triggers



Sleep Strategies

- **Sleep on:**
  - Voltage below threshold
  - Communication timeout
  - Explicit “SLEEP” command or level
- **Always set up wake-up triggers, first**

Wake-up Strategies

- **Wake up on:**
  - Voltage level
  - Voltage change
  - Comm activity
  - External input pin

Common Pitfalls

- Interrogating ECUs while engine is off
- Leaving peripherals switched on in sleep
- Improper regulator selection (I_Q and I_{PEAK})
- Insufficient heatsinking

Lab 2: Sleep/Wakeup

Lab 2 Objectives

- Configure wake-up triggers
- Configure device to go to sleep after 30 seconds of inactivity
- Wake device up via UART
- Put the device to sleep via UART command
- Use voltage change for wake-up

Lab 2 Summary

- **Use multiple sleep and wake-up triggers for most reliable operation**
- **Ensure wake-up triggers are enabled, *before* enabling sleep triggers**

Transceiver Design

Transceiver Design

- Design Considerations
- J1850 transceiver
- ISO/KWP transceiver
- Common pitfalls

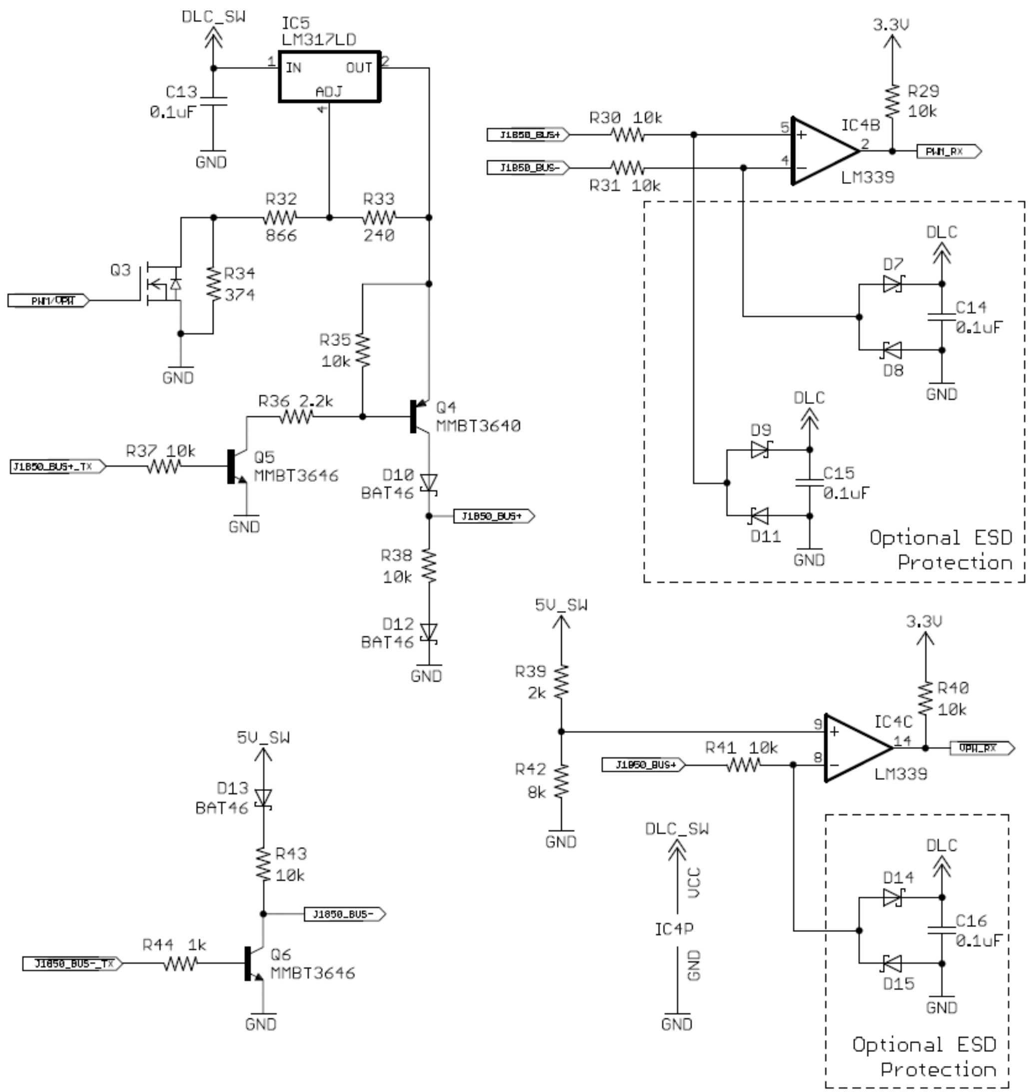
Transceiver Design

- **Considerations:**
  - Functionality
  - Reliability
  - Cost
  - Performance
  - Part count
  - Available resources

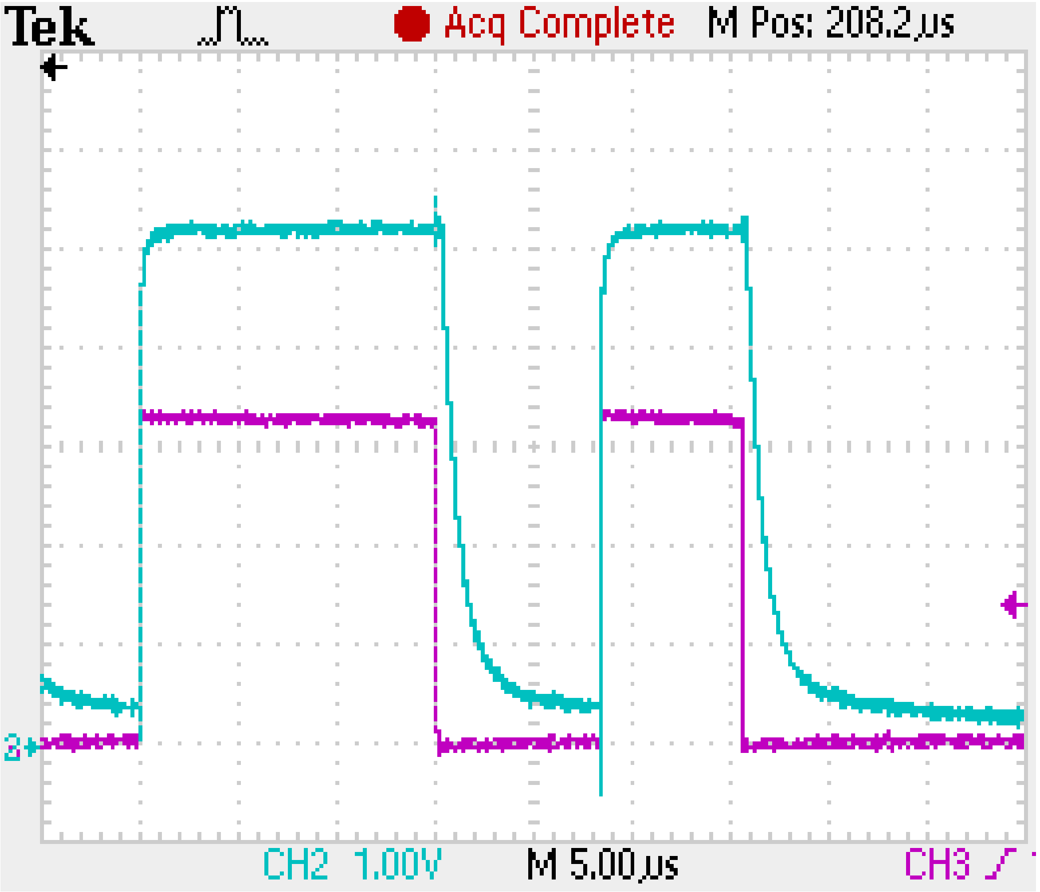
Transceiver Design

- **Advantages of Discrete Design**
  - Cost ($0.75 vs $3)
  - Availability
- **HS CAN still requires an IC (e.g., MCP2561-62)**

J1850 Transceiver

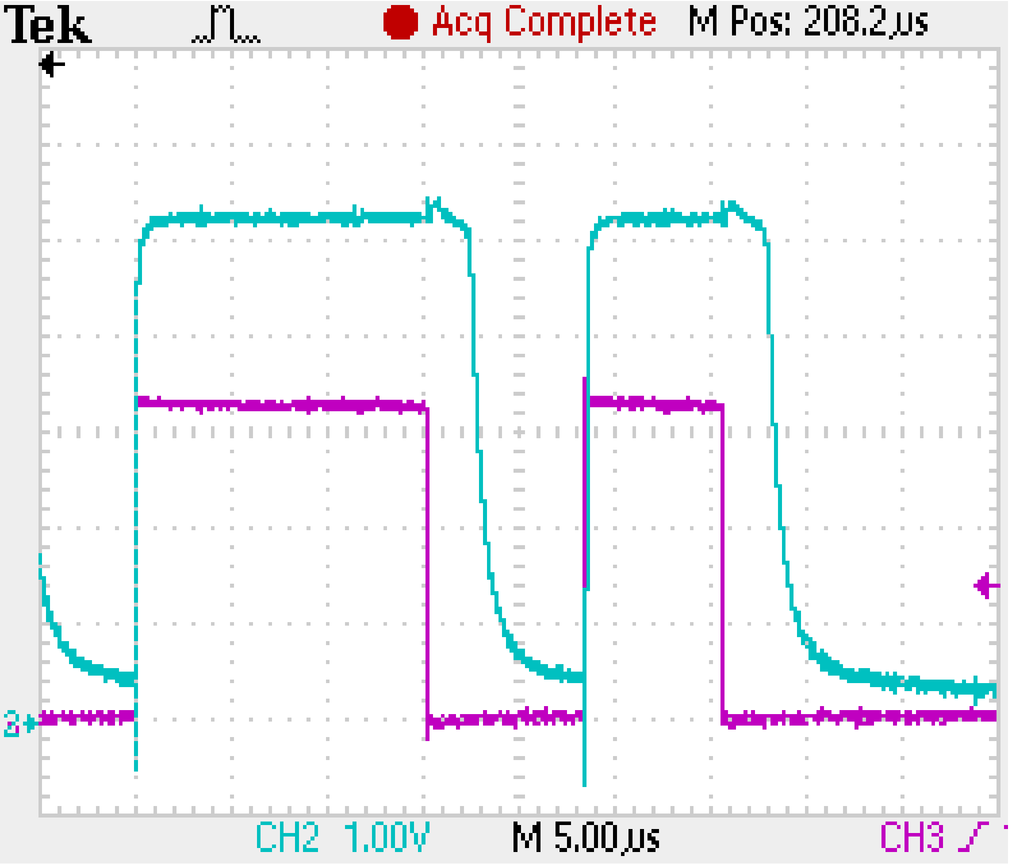


J1850 Transceiver



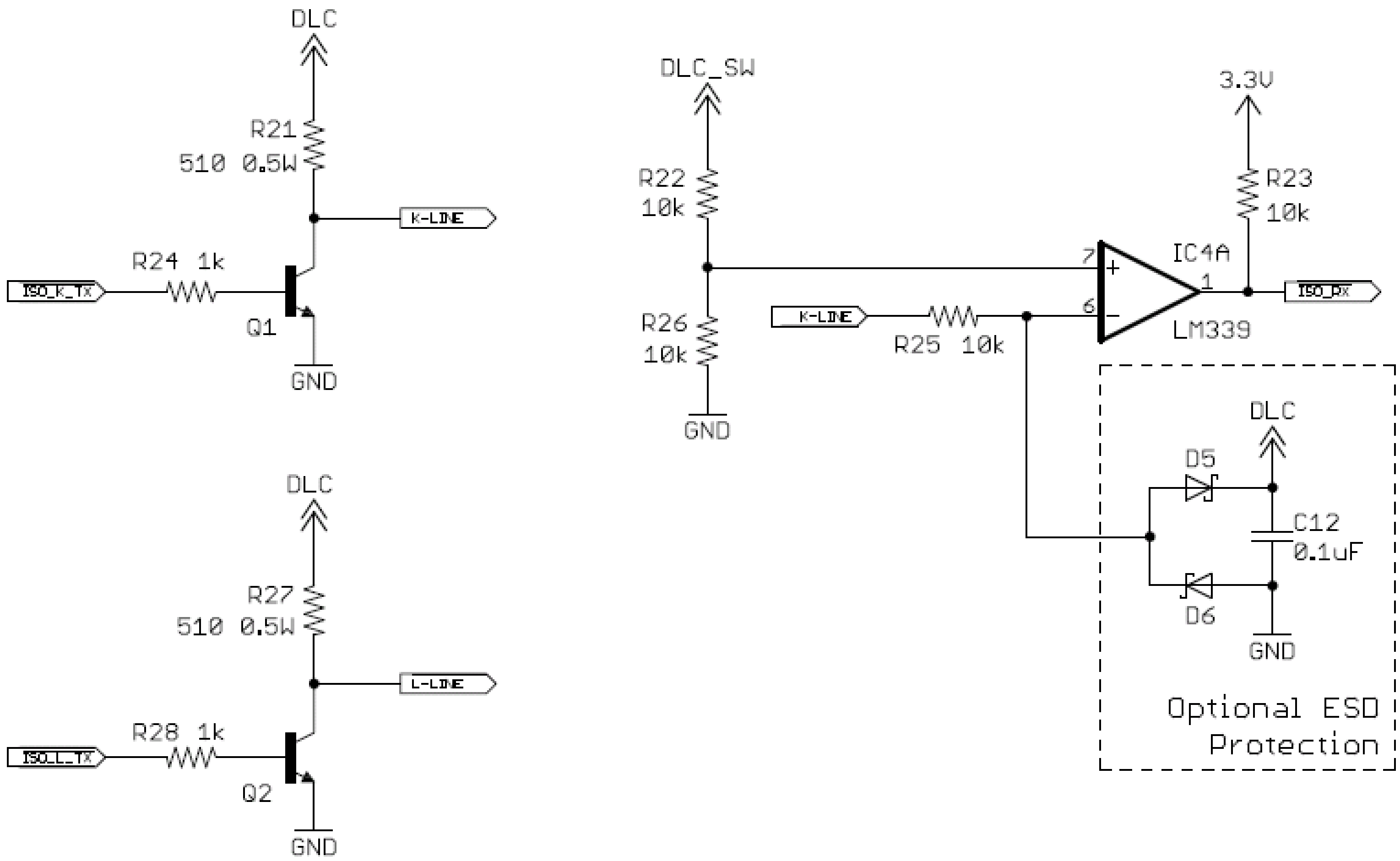
2N3646, 2N3640
Switch-off time (max): 2 uS

J1850 Transceiver



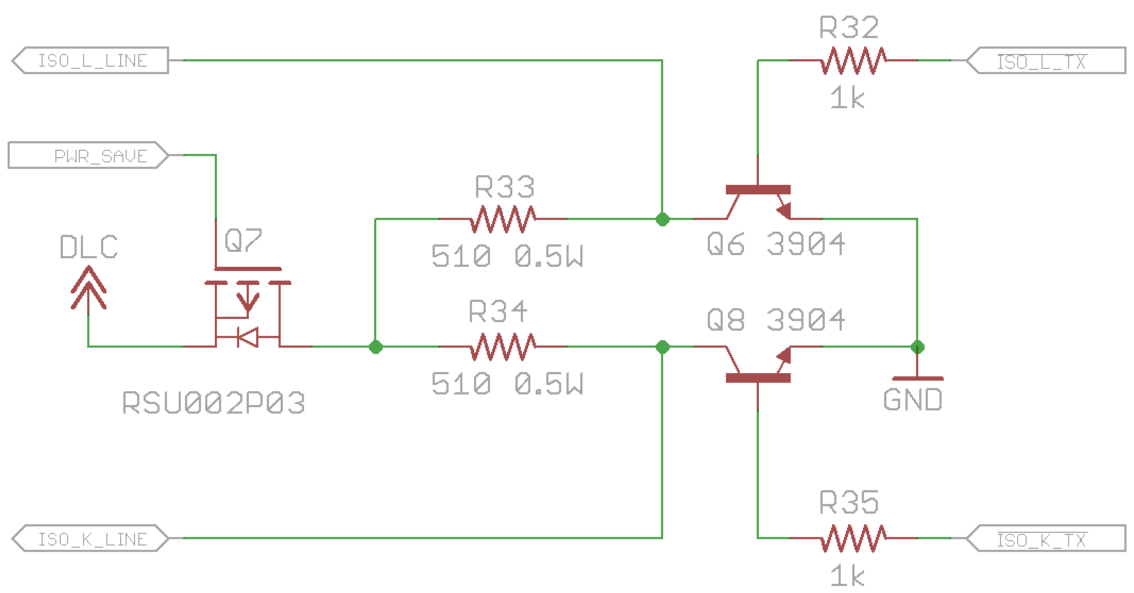
2N3904, 2N3906
Switch-off time (max): 4 uS

ISO/KWP Transceiver



ISO/KWP Transceiver

Disconnect ISO transmitter pull-ups in sleep



Common Pitfalls

- **Using slow transistors for J1850**
- **Not switching off ISO transmitter in sleep**
- **Not switching off or putting CAN transceiver to sleep**
- **Powering comparators from 3V instead of V_{DLC}**

Lab 3:
OBD Development & Testing

Lab 3 Objectives

- Create and configure a virtual ECU
- Create fault sets
- Create custom PIDs

Lab 3 Summary

- **OBD simulator is an essential tool for development/testing**
- **It is important to simulate and test marginal cases**

Avoiding Interference

Avoiding Interference

- **Symptoms**
- **Causes**
- **Solutions**

Avoiding Interference

- **Symptoms**
  - Tripping dashboard lights
  - Setting off trouble codes
  - Stalling engine
  - Disabling functions: clock, power windows, etc

Avoiding Interference

- **Causes**
  - Hardware design flaws (e.g., hard-wired pullups on ISO transmitter)
  - Transmitting on the wrong protocol or baud rate
  - Flooding the bus with messages
  - Long responses on J1850 PWM

Avoiding Interference

- **Solutions**
  - KOEO is the best time to run protocol detection
  - “Listen before transmit”
  - Remember last protocol between power cycles
  - Pace data requests
  - Check RPM=0 before requesting VIN, CALID, etc

Summary

Today we covered:

- OBD and its applications
- Accessing and interpreting OBD data
- Power supply and transceiver design
- Using an OBD simulator
- Ways to avoid creating interference on the OBD bus

Additional Resources

- **SAE Standards (sae.org)**
  - J1979, J1850, J2012, J1939
- **ISO Standards (iso.org)**
  - ISO 9141, ISO 14230, ISO 15765
- **http://www.obdsol.com/articles/**

Dev Tools For This Class

- STN11xx OBD development board
- ECUsim 2000

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