Radiation Tolerant CAN Transceiver for Space

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Background

CAN bus is proposed to replace the discrete telemetry (ECSS-E-ST-50-14), PPS and on/off commands

CAN space standard (ECSS-E-ST-50-15C)

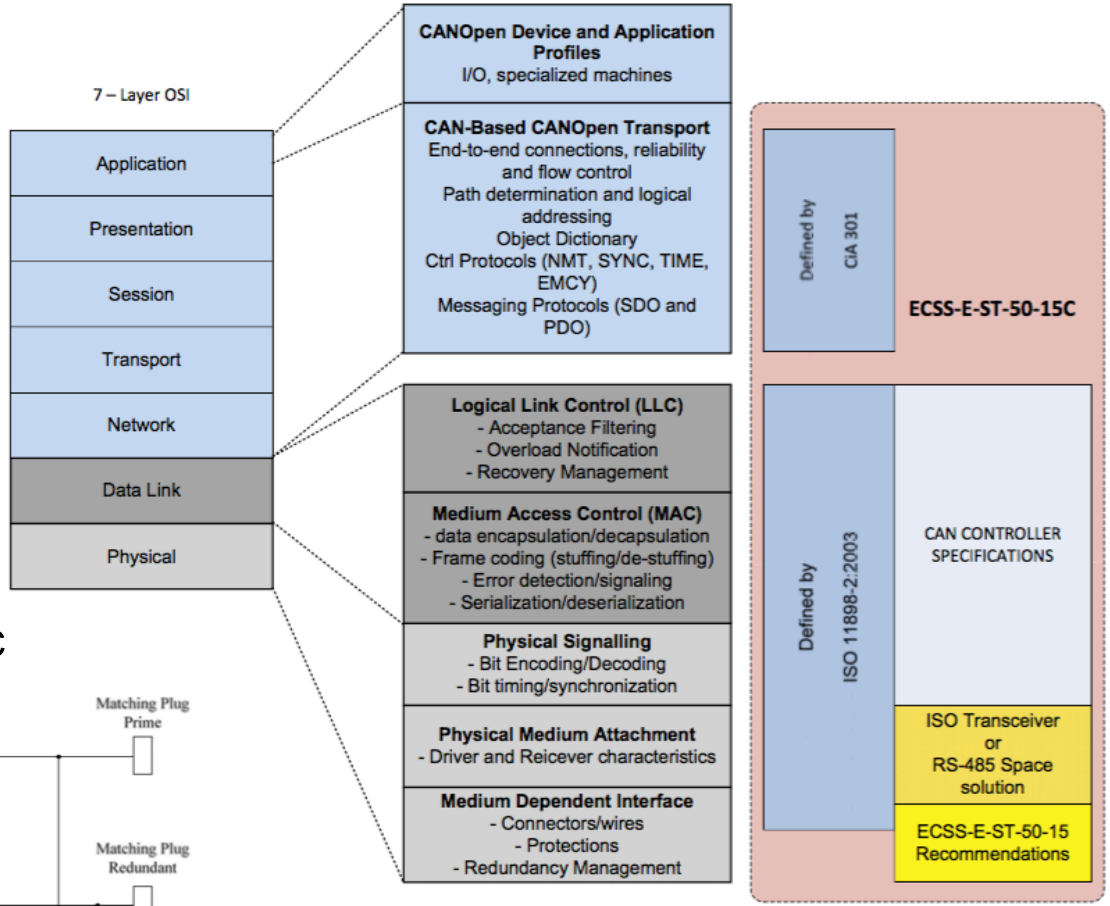
- Protocol
- Time distribution
- Redundancy
- Physical Layer

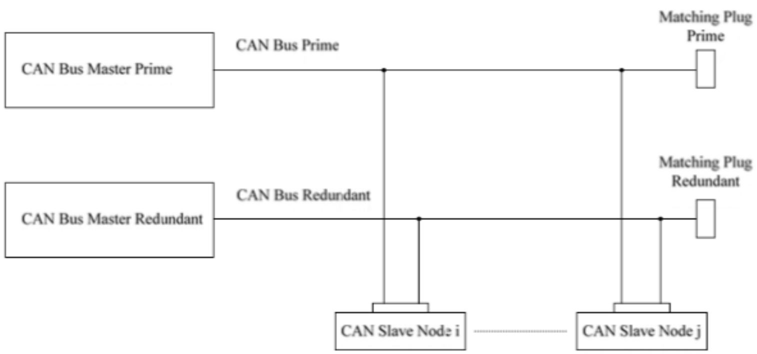
Limited number of nodes (<30)

- Separate transceiver and application IC

Large number of nodes (>100)

- Integrated transceiver and application IC





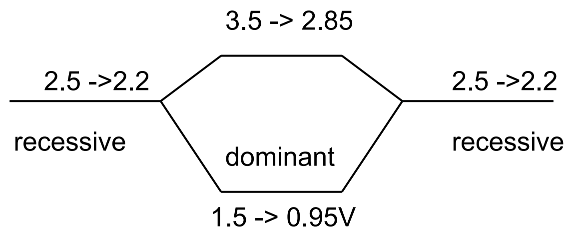
Space engineering

CANBus extension protocol

Issues

Integration of the CAN Transceiver and Application on a single IC causes issues

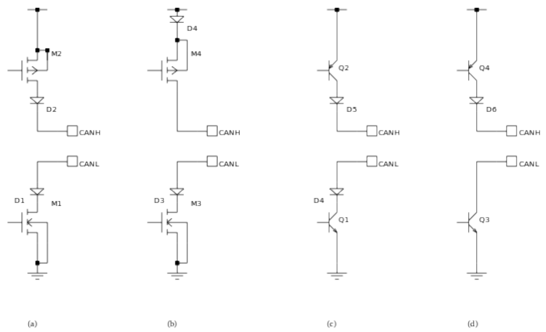
- Application supply voltage and technology is limited to 3.3V supply
- CAN dominant state differential voltage is >1.5V
- CAN port voltage tolerance from -3V to 16V
- CAN bus common mode range is -2V to 7V



Not all IC technologies combine

- Radiation tolerance
- High current density diodes
- High voltage transistors

Require a different approach



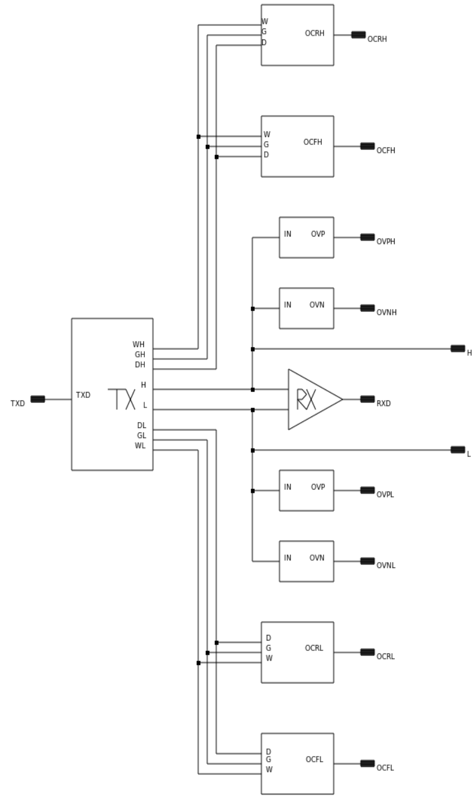
Conventional CAN driver output stages that prevent reverse bias leakage

Architecture

The CAN driver requires protection against
- over-current in the forward and reverse direction
- over-voltage for the CAN H and L ports.

The CAN transceiver consists
- receiver circuit
- driver circuit
- CAN H port forward over-current detection circuit
- CAN H port reverse over-current detection circuit
- CAN L port forward over-current detection circuit
- CAN L port reverse over-current detection circuit
- CAN H port over-voltage detection circuit
- CAN L port over-voltage detection circuit

The detection circuits can determine the state of the CAN bus
- open or short on the CAN H bus
- open or short on the CAN L bus



CAN Transceiver Architecture

Implementation - Transmitter

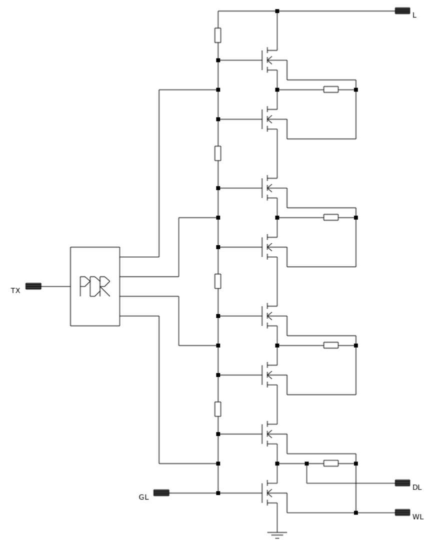
The high-voltage tolerance is realised by stacking the MOS transistors.

- In the recessive state the resistive voltage dividers ensure that the correct voltage drop occurs across the terminals of the MOS transistor
- In the dominant state the Pre-Driver (PDR) ensure that all the gates are pulled high for maximum conduction.

The reverse leakage is prevented by joining the wells between two MOS transistors

Over current protection should be realised by measuring the current through the first MOS transistor for the forward and reverse direction

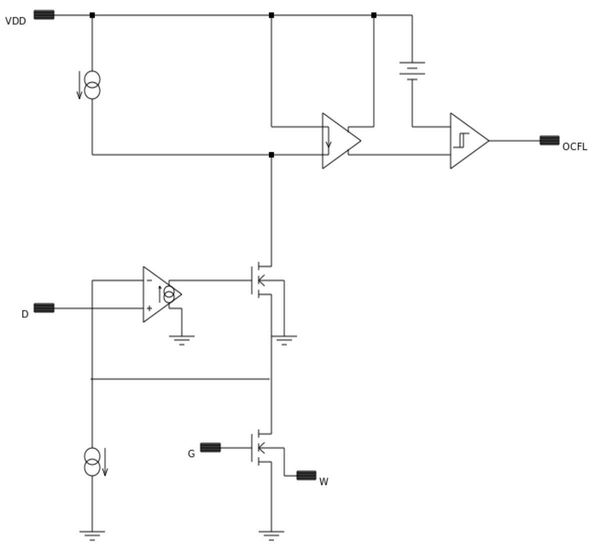
Over voltage protection should ensure that the driver stays in recessive state if the port voltage is larger than 16V



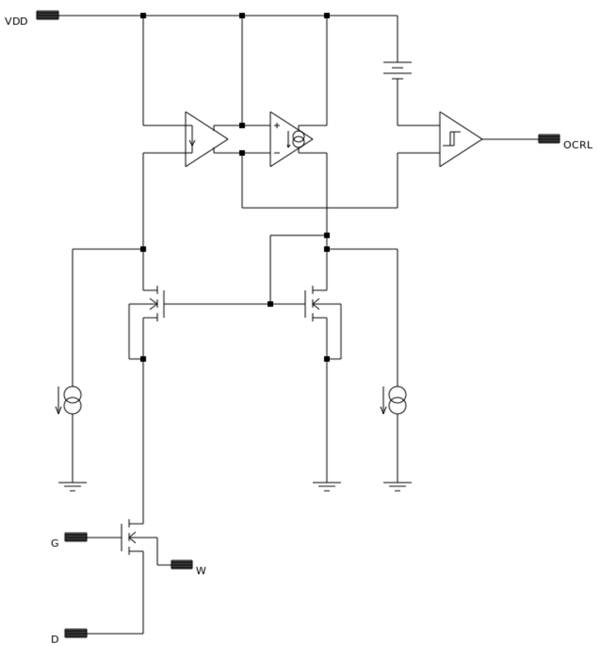
CAN L Port Driver Circuit

Implementation - Detector

CAN L port forward over-current detection



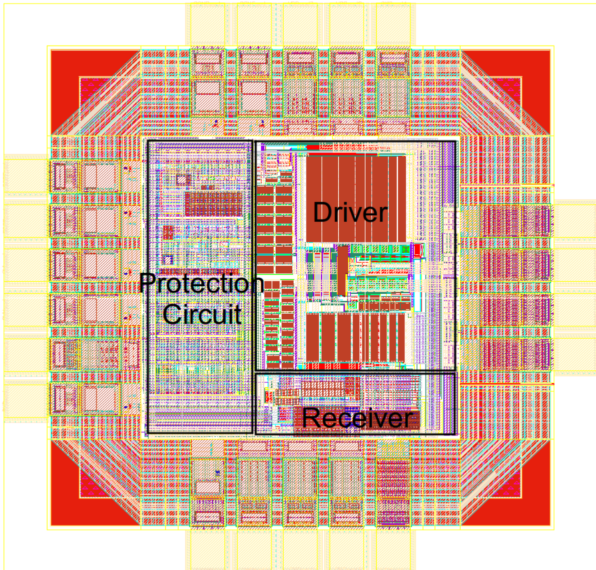
CAN L port reverse over-current detection

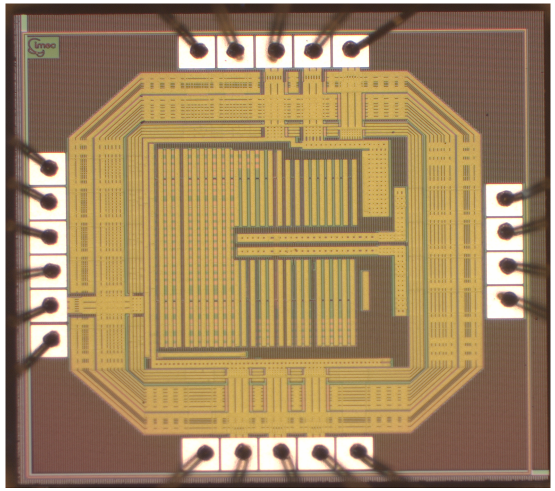


Fabrication

CAN transceiver has been manufactured in the DARE180U technology

Die packaged in a SOIC 20 pin package





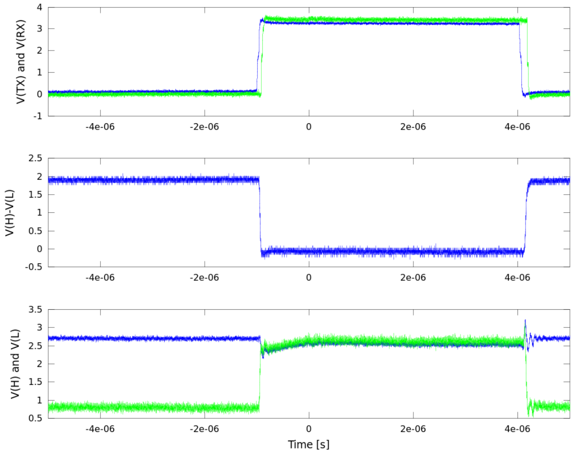
Electrical Measurements

Receiver

Description	Symbol	Unit	Min	Typ	Max
RX Threshold: D->R	$V_{diff,TH,RD}$	V	557	684	782
RX Threshold: R->D	$V_{diff,TH,DR}$	V	630	750	843
RX Hysteresis	V_{HYS}	mV	48	66	88

Transmitter

Description	Symbol	Unit	Min	Typ	Max
CANH Dominant	$V_{CANH,D}$	V	2.340	2.668	3.012
CAN L Dominant	$V_{CANL,R}$	V	0.587	0.693	0.879
CANH Recessive	$V_{CANH,D}$	V	1.991	2.196	2.404
CANL Recessive	$V_{CANL,R}$	V	1.989	2.195	2.403
Dominant Differential	$V_{diff,D}$	V	1.538	1.973	2.379
Recessive Differential	$V_{diff,R}$	V	0.001	0.001	0.001



Transceiver in loopback configuration

- TX and RX signals
- CAN differential signal
- CAN H and L signals

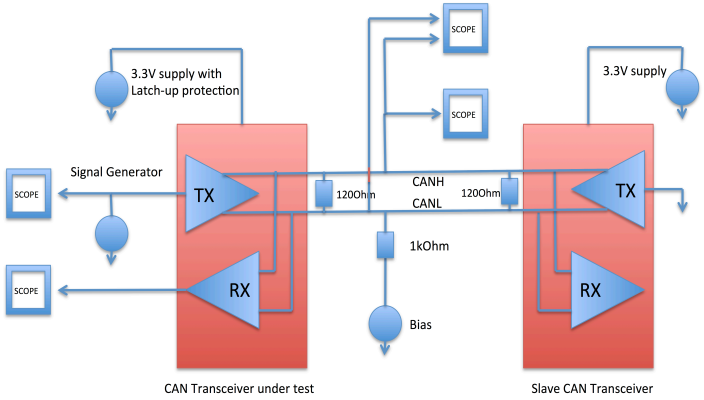
Electrical Measurements

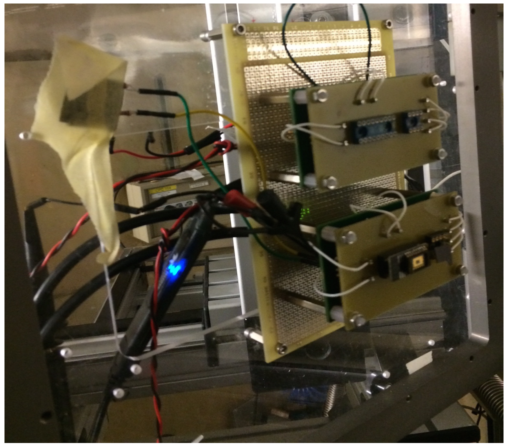
Transceiver

Description	Symbol	Unit	Min	Typ	Max
Current Recessive	I_R	mA	2	3	4
Current Dominant	I_D	mA	29	37	45
Input resistance	R_{in}	kΩ		22	
Input resistance matching	M_{in}	%			1
Differential input resistance	R_{diff}	Ω		22	
Input capacitance CANH	$C_{in.CANH}$	pF		3.5	
Input capacitance CANL	$C_{in.CANL}$	pF		3.5	
Differential input capacitance	C_{diff}	pF		3.8	
Propagation Delay CMOS -> CAN: R -> D	$t_{TX,RD}$	ns	70	90	115
Propagation Delay CMOS -> CAN: D -> R	$t_{TX,DR}$	ns	30	35	40
Propagation Delay CAN -> CMOS: R -> D	$t_{RX,RD}$	ns	20	25	30
Propagation Delay CAN -> CMOS: D -> R	$t_{RX,DR}$	ns	25	30	45
Propagation Delay Loop R -> D	$t_{LOOP,RD}$	ns	100	120	140
Propagation Delay Loop D -> R	$t_{LOOP,dR}$	ns	60	65	75

Radiation Measurements

CAN Transceiver in loopback configuration





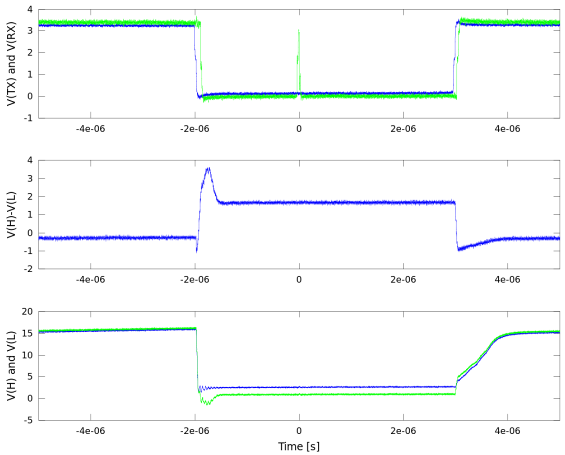
LET [MeVcm^2/mg]	RX+TX cross-section [cm^2]
6.4	4.5×10^{-7}
24.0	1.5×10^{-5}
49.0	2.8×10^{-5}
72.1	3.3×10^{-5}

CAN Transceiver Cross-section

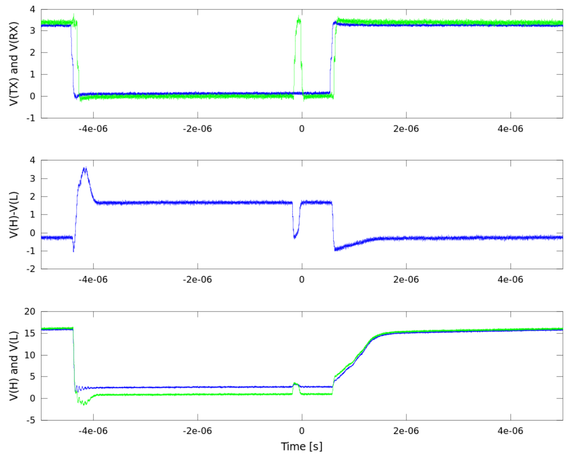
Radiation Measurements

CAN Transceiver in loopback configuration with common-mode bias

Ions	Angle [deg]	LET [MeVcm^2/mg]	Fluence [cm^{-2}]	Temp. [C]	Bias [V]
Xe-136	0	61.02	1 x10^7	25	2.0
Xe-136	0	61.02	5 x10^6	25	5.5
Xe-136	0	61.02	5 x10^6	25	7
Xe-136	0	61.02	5 x10^6	25	10
Xe-136	0	61.02	1 x10^7	25	16.0
Xe-136	0	61.02	1 x10^7	25	22.5



SET recorded in RX circuit



SET recorded in TX circuit

TX and RX signals

CAN Differential bus signal

CAN H and L bus signals

Conclusion

CAN Transceiver has been realised

- compliant to CAN standard
- radiation Tolerant

Possibly world first CAN transceiver realisation in low-voltage 3.3V digital CMOS process
Two patents have been filed that cover the CAN transistor architecture and driver

CAN transceiver implementation does not include

- ESD protection
- Improved RX section to reduce SET cross-section

Voltage tolerance of 3.3V DARE180U CMOS technology extended to 16V

Thank you

Any Questions?