Industrial Seminar – HVL & SLL

2015 Mar

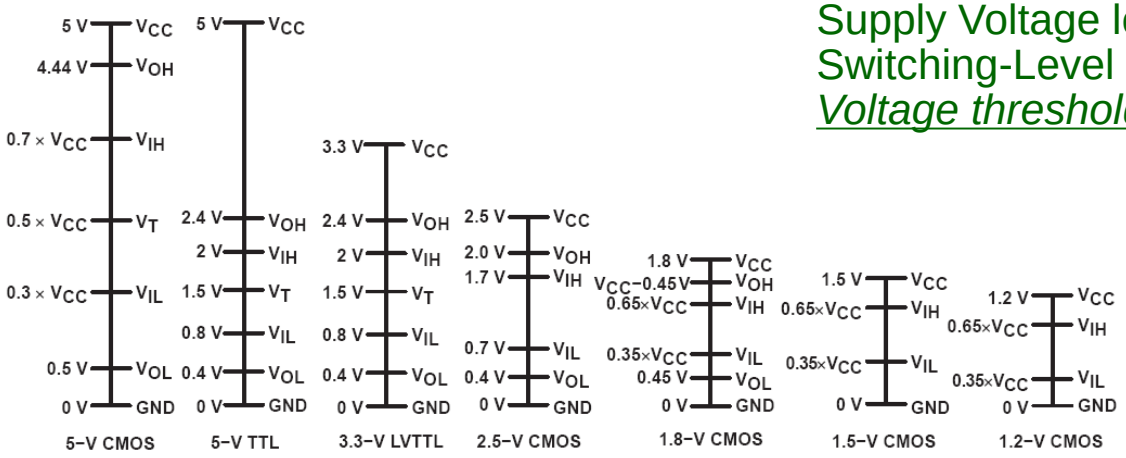
Agenda

- Voltage Level Translator
- ESD Protection Device
- I2C Device
- Load Switch
- RS232 Transceiver
- Relay Driver

Voltage Level Translators

Why need Voltage Level Shifter?

1) Digital Switching Level Standards

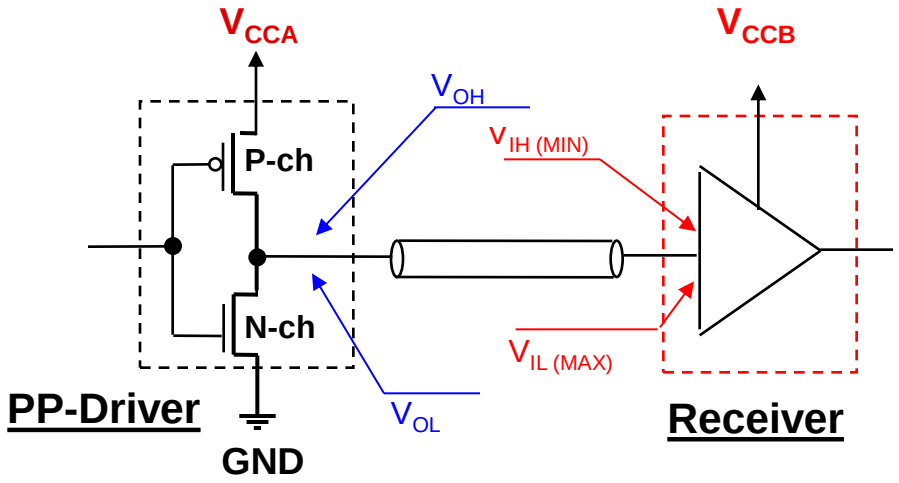


Supply Voltage levels vary across all of these Switching-Level standards for both the *Input-Voltage thresholds* and *Output-Voltage levels*.

Def:

- **V_{OH} = Driver Output Voltage High**
- **V_{OL} = Driver Output Voltage Low**
- **V_{IL} = Receiver Input Voltage Low**
- **V_{IH} = Receiver Input Voltage High**

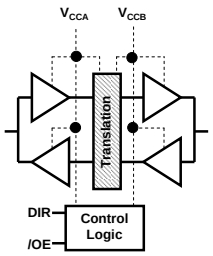
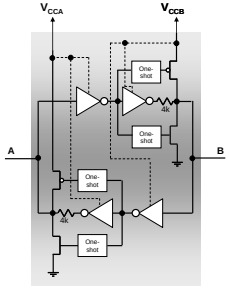
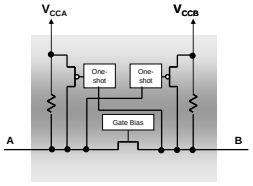
2) Driver Output thresholds must be compatible with Receiver Input thresholds (i.e. Driver Output > Receiver Sensitivity)



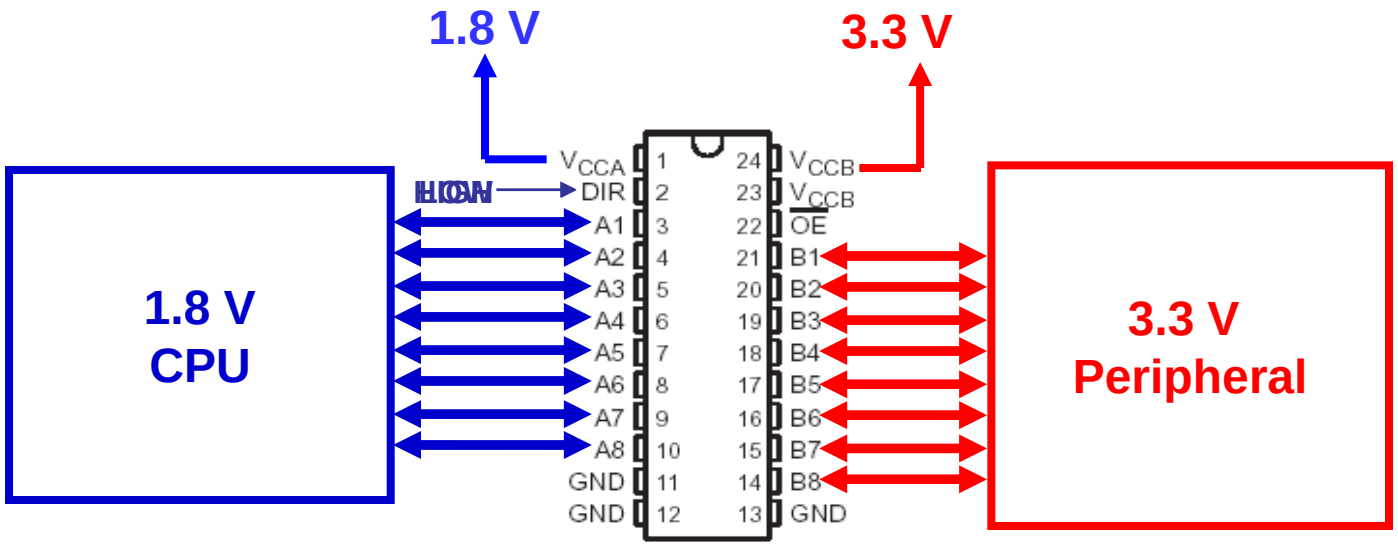
For Two Devices To Have Switching Compatibility:

- **V_{OH} of Driver must be greater than V_{IH} of Receiver ✓**
- **V_{OL} of Driver must be lower than V_{IL} of Receiver ✓**
- **The output voltage from the driver must not exceed the I/O tolerance of the receiver ✓**

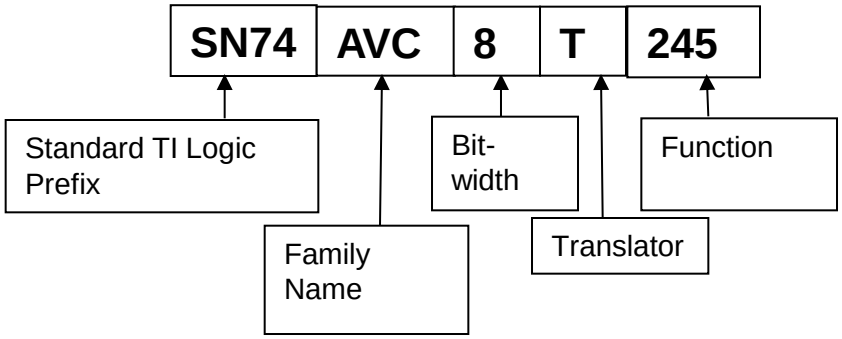
Voltage Translators (Level Shifters)

Type	Advantages	Disadvantages	Bit Options
xT245 	▪ Fast data rate (~300Mbps) ▪ Fully configurable: $V_{CCA} < V_{CCB}$ or $V_{CCB} < V_{CCA}$ ▪ Low Power Consumption ▪ Hi-Z if V_{CCA} or V_{CCB} = 0V ▪ Good DC Current Drive (12mA)	▪ DIR (direction control) required	1, 2, 4, 8, 16, 20, 24, and 32
TXB010x/TXB030x 	▪ Auto-Sensing (no DIR control needed) ▪ Medium data rate (up to 140Mbps) ▪ Low Power Consumption ▪ Hi-Z if V_{CCA} or V_{CCB} = 0V ▪ 15kV HBM ESD protection (B port)	▪ Weak DC drive (few 100uA) ▪ Not good for open drain buses	1, 2, 4, 8
TXS010x/TXB030x 	▪ Auto-Sensing (no DIR control needed) ▪ Good for open-drain buses (I2C) ▪ Low data rate (up to 40Mbps) ▪ Hi-Z if V_{CCA} or V_{CCB} = 0V ▪ 15kV IEC ESD protection (B port)	▪ Higher power consumption compared to ‘245 or weak buffer translators	1, 2, 4, 8

Direction Controlled Translators – AVCxxT / LVCxxT



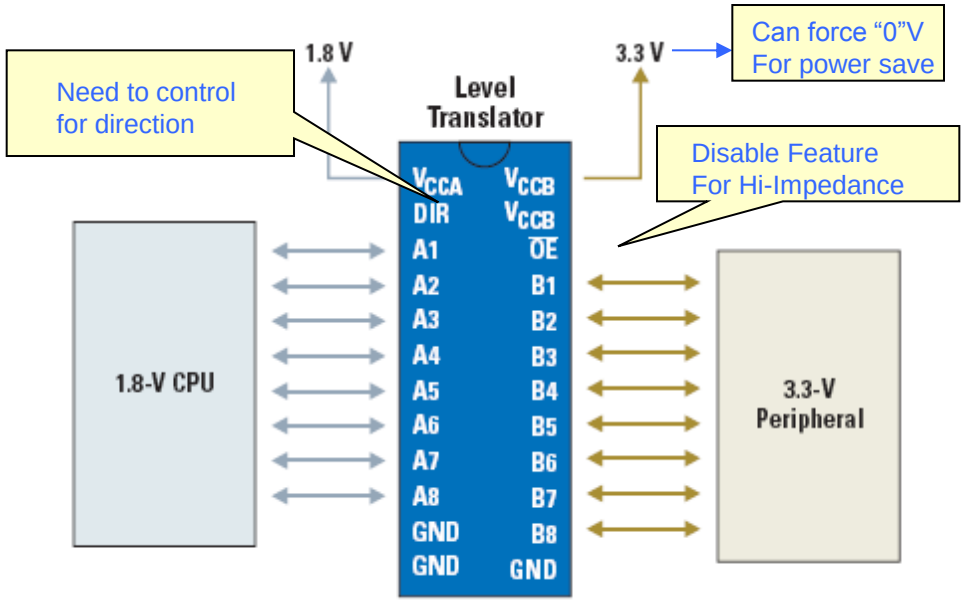
Advantages	Disadvantages
▪ Fast data rate (~300Mbps) ▪ Fully configurable: $V_{CCA} < V_{CCB}$ or $V_{CCB} < V_{CCA}$ ▪ Symmetric Voltage Range for V_{CCA} and V_{CCB} ▪ Low Power Consumption ▪ Hi-Z if V_{CCA} or V_{CCB} = 0V ▪ Good DC Current Drive (12mA)	▪ DIR (direction control) required ▪ Bits are lumped in to banks of one direction

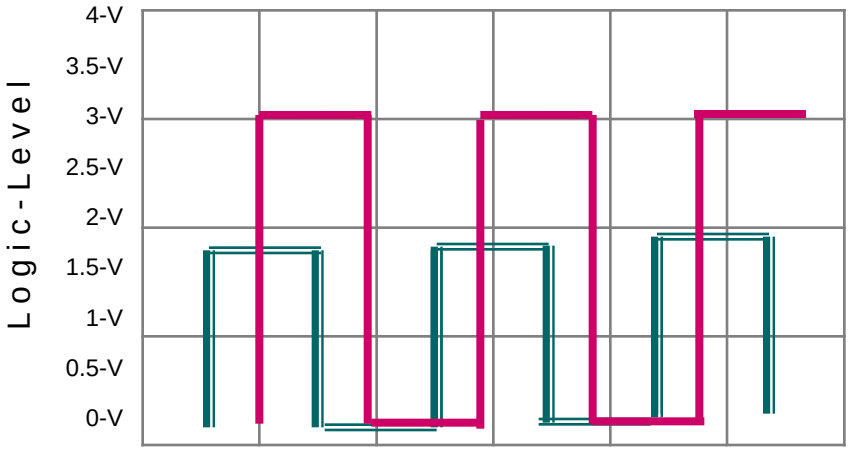


Translator Nomenclature

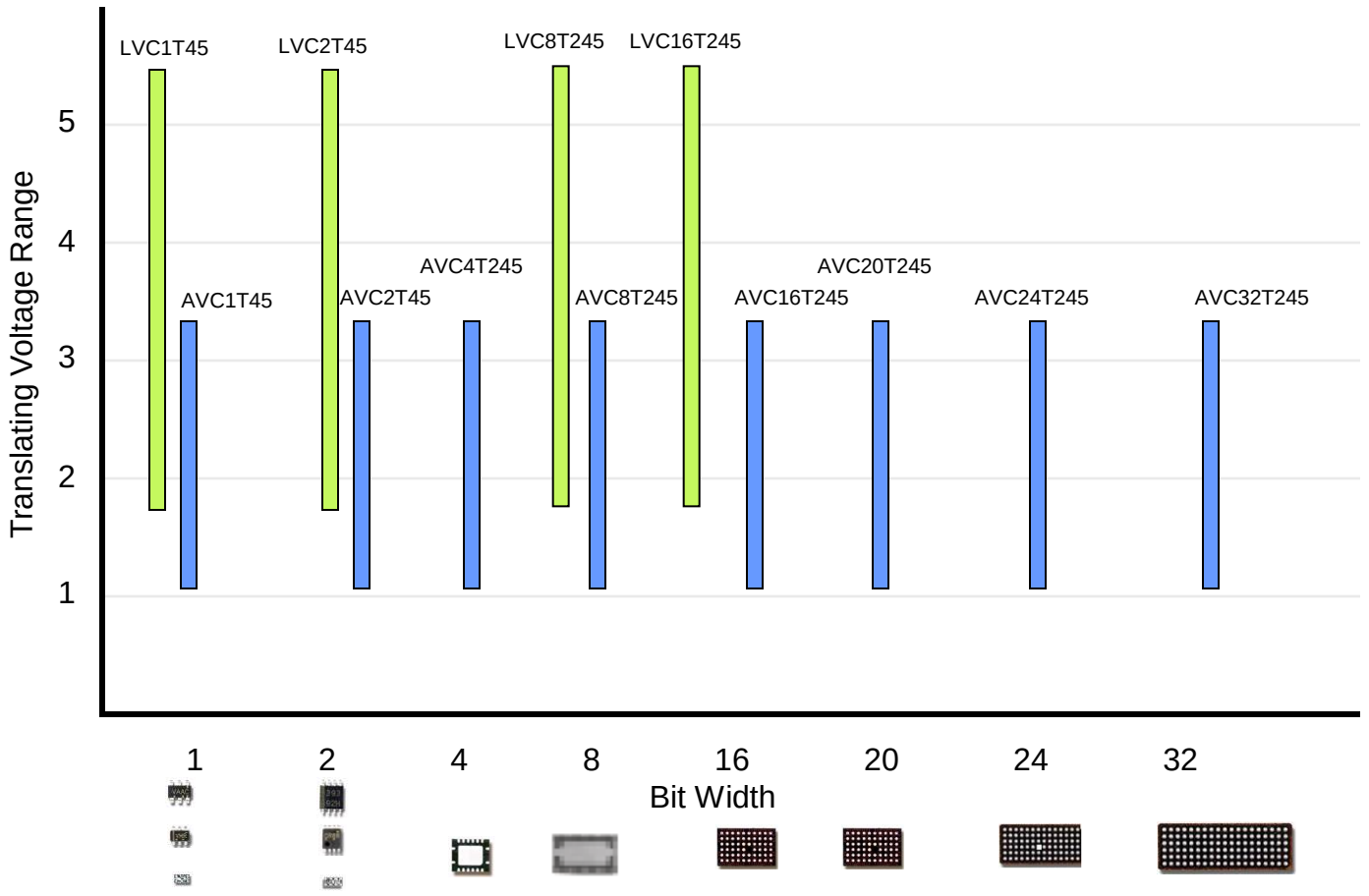
AVC Technology Translator

- Translate the particular logic level to another required logic Voltage Level(e.g:1.8V to/from 3.3V)
- Driving capability to ensure the signal integrity.
- DIR control pin to manage the direction of data transmission.
- /Output enable to reduce power consumption.
- Partial power down (Ioff)



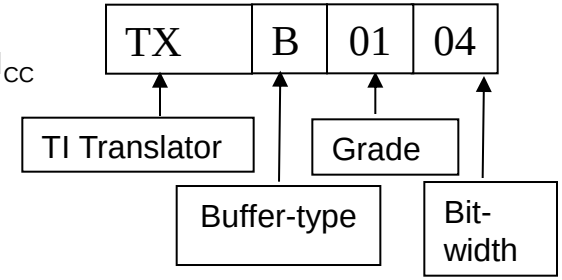


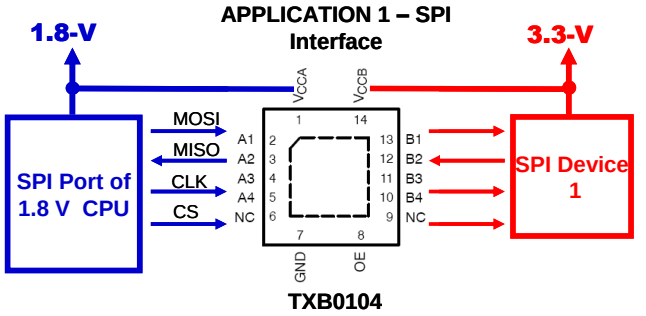
Fully Buffered Voltage Translation

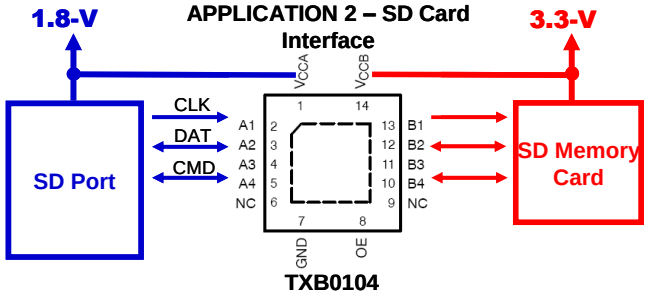


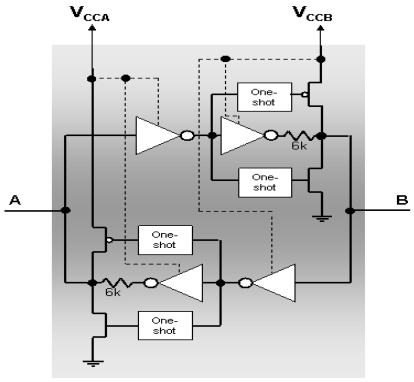
TXB Translator

- Data-Rate
  - V_{CCA} 1.2V <> V_{CCB} 20 Mbps
  - V_{CCA} 1.5V <> V_{CCB} 40 Mbps
  - V_{CCA} 1.8V <> V_{CCB} 60 Mbps
  - V_{CCA} 2.5V <> V_{CCB} 100 Mbps
  - V_{CCA} 3.3V <> V_{CCB} 100 Mbps
- Low Power Consumption 4-µA Max. I_{CC}
- I/Os Push-Pull CMOS
  - $V_{IH} = V_{CCI}$ X 0.65
  - $V_{IL} = V_{CCI}$ X 0.35
  - $V_{OH} = V_{CCI} – 0.4V$,
  - $V_{OL} = 0.4V$
- OE is referenced to V_{CCA} and 5.5V Input Tolerant (CMOS)
- Either V_{CCA} or V_{CCB} Power-Supply can be ramped first
- Driving Load Capacitance up to 70-pF
- External Pull-Up/Down Resistors must be >50kΩ









Device	Pins.	# bits	I/O Level Translator Range	ESD (B-Ports)	Ioff	HI-z	DCK	DCU	SOIC	TSSOP	QFN(RGY)	uQFN	WCSP/BGA
TXB0101	6	1	1.5V, 1.8V, 2.5V, 3.3V, 5V	HBM: ± 15KV	✓	✓	⊙						⊙
TXB0102	8	2	1.5V, 1.8V, 2.5V, 3.3V, 5V	HBM: ± 15KV	✓	✓		⊙					⊙
TXB0104	14/12	4	1.5V, 1.8V, 2.5V, 3.3V, 5V	HBM: ± 15KV	✓	✓			⊙	⊙	⊙	⊙	⊙
TXB0106	16	6	1.5V, 1.8V, 2.5V, 3.3V, 5V	HBM: ± 15KV	✓	✓			⊙		⊙		
TXB0108	20	8	1.5V, 1.8V, 2.5V, 3.3V, 5V	HBM: ± 15KV	✓	✓				⊙	⊙	⊙	

TXS "Switch" Type Translator

- Data-Rate
  20-Mbps to 24-Mbps
- 10K-Ω Integrated R_{PU} on both I/Os
- I/Os Push-Pull/Open Drain
- OE is referenced to V_{CCA} and 5.5V Input Tolerant
- Open Drain/Push Pull Type
- I²C, 1-Wirebus, MMC Card I/F

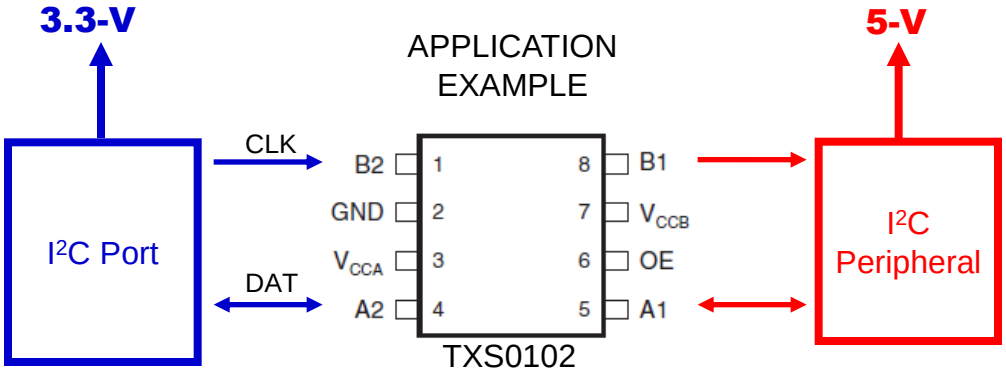
TXS010X E xxx

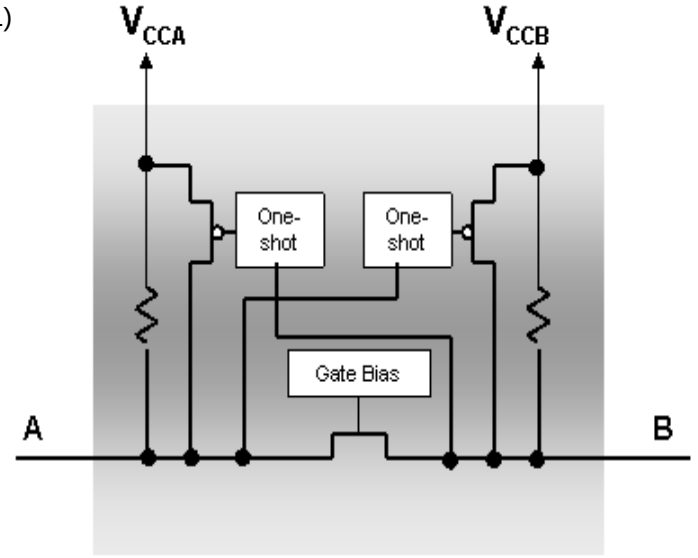
- Air-Gap/Contact ESD
- Number Of Bits

B Port for TXS0104E/0108E
- 15-kV Human-Body Model (A114-B)
- 200-V Machine Model (A115-A)
- 1000-V Charged-Device Model (C101)

IEC 61000-4-2 ESD (B Port)

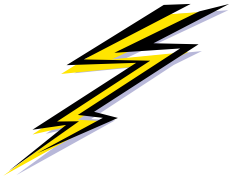
- ±8-kV Contact Discharge
- ±10-kV Air-Gap Discharge



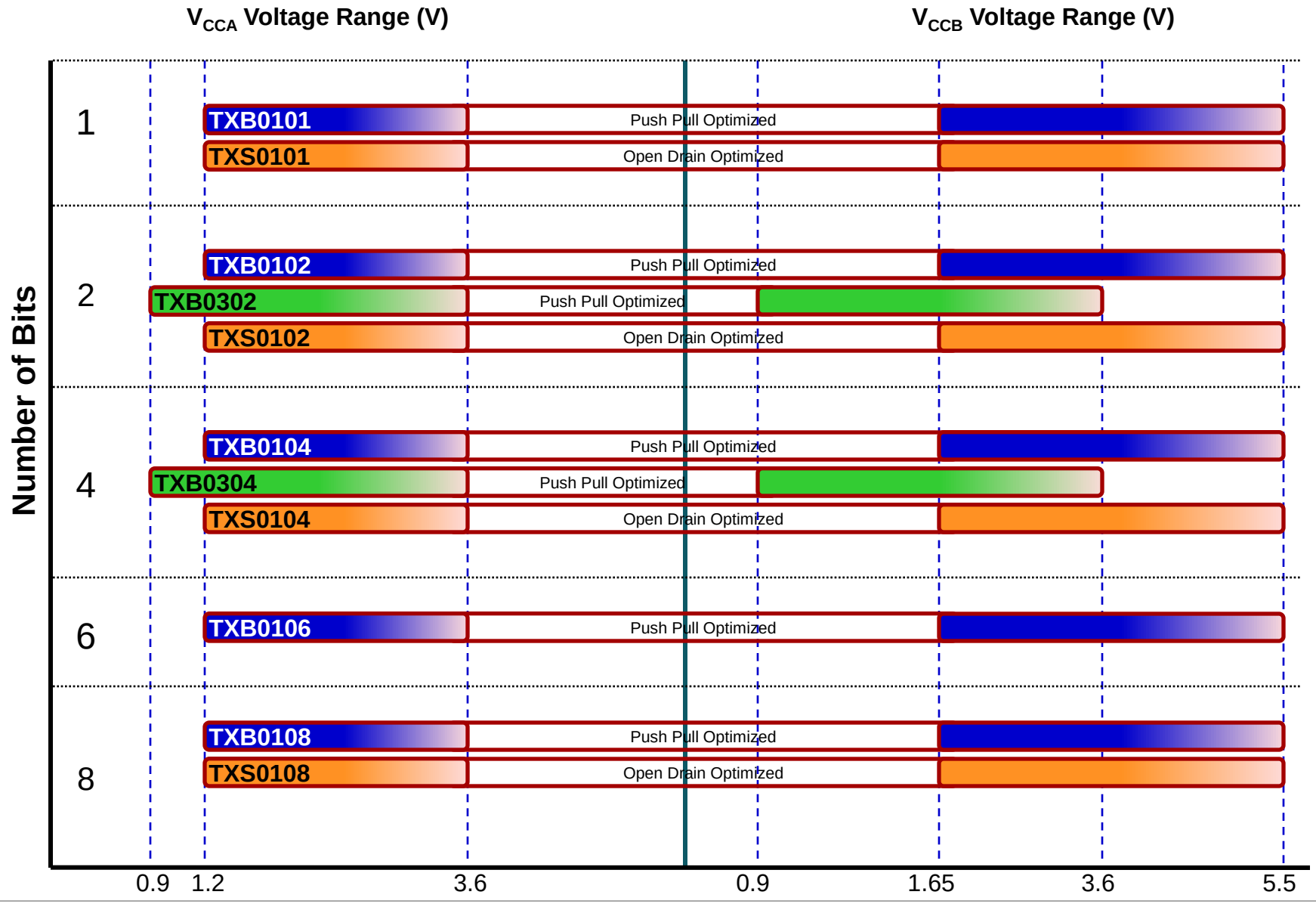


Device	Pins.	# bits	I/O Level Translator Range	ESD (B-Ports)	Air Gap	Ioff & HI-z	DCK	DCU	SOIC	TSSOP	QFN(RGY)	WCSP/BGA
TXS0101	6	1	1.8V, 2.5V, 3.3V, 5V	HBM: ± 8KV		✓	⊙					⊙
TXS0102	8	2	1.8V, 2.5V, 3.3V, 5V	HBM: ± 8KV		✓		⊙				⊙
TXS0104E	14/12	4	1.8V, 2.5V, 3.3V, 5V	HBM: ± 15KV	± 10KV				⊙	⊙	⊙	⊙
TXS0108E	20	8	1.8V, 2.5V, 3.3V, 5V	HBM: ± 15KV	± 15KV					⊙	⊙	

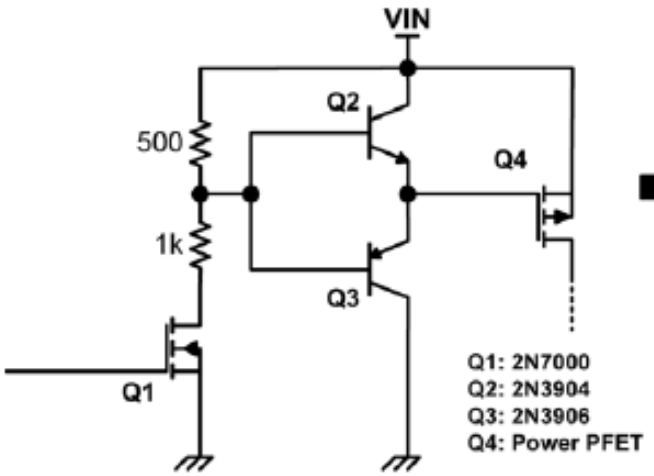
Integrated IEC ESD Protection

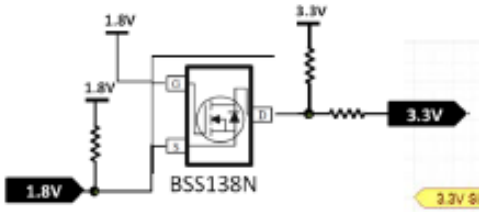


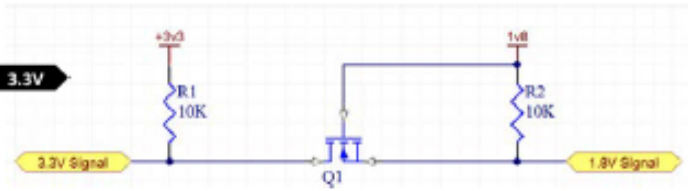
Auto Direction Sensing Translators

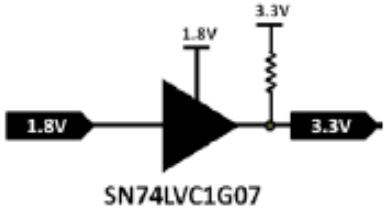


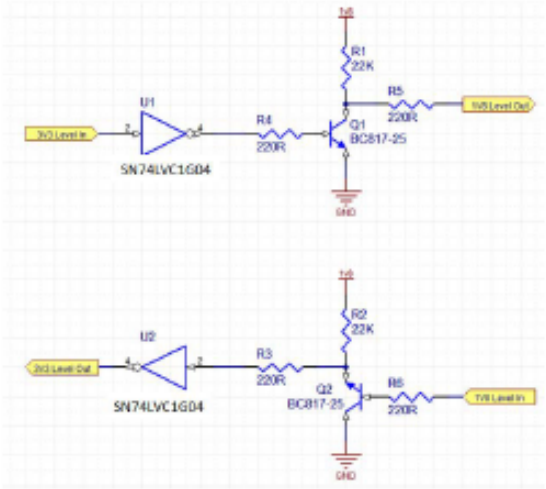
Multi Ways of Level Shifting











Dis-advantages

- High Power Consumption
- Logic Level Accuracy
- No Driving Capability
- More PC Board Space
- Assembly Charge Fee by # devices
- Material Control by # devices

Advantages

- Cost Lower

SN74LVxTxx Family

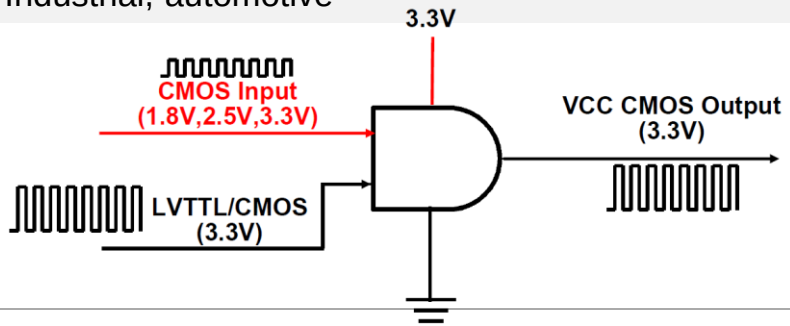
Single Power Supply Translation Logic Family

Features

- Wide voltage range (1.8-5.0V Vcc), flexible, single-supply voltage translator
- Up-Translation Mode
  - 1.2V to 1.8V at 1.8V Vcc
  - 1.8V to 3.3V at 3.3V Vcc
  - 3.3V to 5.0V at 5.0V Vcc
- Down-Translation Mode
  - 2.5/3.3V to 1.8V at 1.8V Vcc
  - 3.3/5.0V to 2.5V at 2.5V Vcc
  - 5.0V to 3.3V at 3.3V Vcc
- Provides standard gate functions and are drop-in replacements
- -40 to 125C T_a operation

Applications

- Computing (Tablet, Smartphones, PC)
- Industrial, automotive



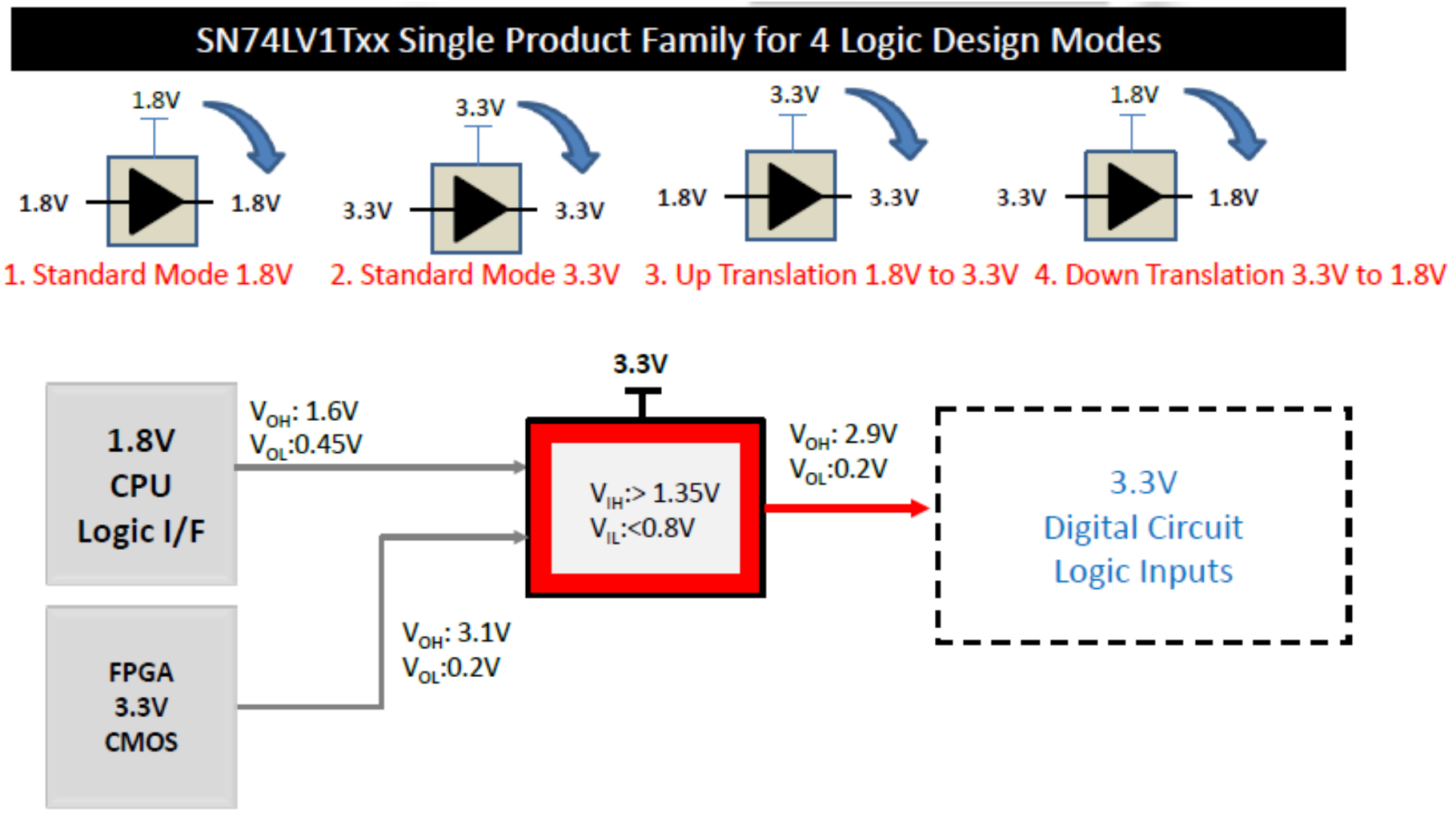
Cross Reference

- Onsemi
  - MC74HC1Gxx
  - NL17SHTxx; NL17SHxx
- NXP
  - XC7SHxx; XC7SETxx
  - 74HCT1Gxx; 74HC1Gxx
- TI (output backward compatible)
  - AUP1G; LVC1G

	Part#	Description	RTM
1	LV1T00	NAND Gate	Now
2	LV1T04	Inverter Buffer	
3	LV1T08	2-Input AND Gate	
4	LV1T02	2-Input NOR Gate	Now
5	LV1T32	2-Input OR Gate	
6	LV1T34	Single Buffer Gate	
7	LV1T125	Buffer w/3-State Output	
8	LV1T126	Buffer w/3-State Output	
9	LV1T86	2-Input XOR Gate	1Q14
10	LV1T14	Schmitt Trigger Inverter Buffer	
11	LV4T125	Quad Buffer w/ 3-state Output	

1-bit Level translator w/ single power supply

SN74LV1Txx Family Coverage



LSF0101/02/08

In Production

1/2/8 - Bit Bidirectional Multi-Voltage Translator for Open-Drain & Push-Pull

Features

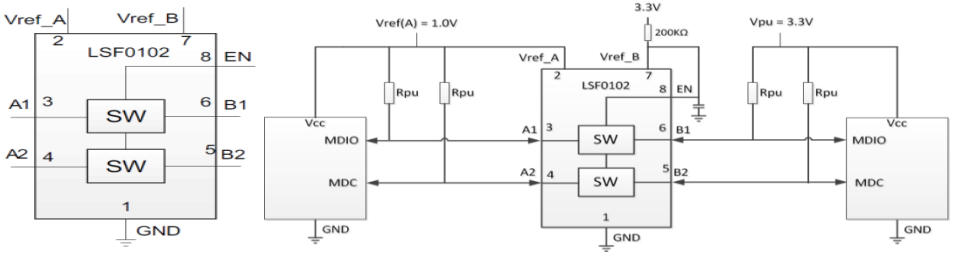
- Allows bidirectional multi-voltage translation w/o direction pin between:
  - 1.0 V ⟷ 1.8/2.5/3.3/5 V
  - 1.2 V ⟷ 1.8/2.5/3.3/5 V
  - 1.8 V ⟷ 2.5/3.3/5 V
  - 2.5 V ⟷ 3.3/5 V
  - 3.3 V ⟷ 5 V
- Supports high speed translation:
  - >100MHz
  - $T_{pd(max)}$ < 1.5ns
- 5V tolerance on I/O port to support TTL
- -40 to 125C Ta operation
- Package Option
  - 1-bit device (DRY)
  - 2-bit device (DCT, DCU, DQE, YZT)
  - 4-bit device (PW, RUT, RGY, YZP)
  - 8-bit device (QFN, PW)

Applications

- Computing (Tablet, Smartphones, PC, SSD)
- Industrial, automotive, and Telecom Infrastructure
- Target Interfaces:
  GPIO, MDIO, SDIO, SVID, UART, SMBus, PMBus, I2C, SPI

Benefits

- Ability to set up multiple channels at different voltage translation levels
- Single chip supports multiple voltage levels
- Seamless translation between higher and lower voltages selected by the user w/o directional control
- Supports high speed data applications for telecom and computing
- 5V Tolerance enabling industrial applications
- Broad industrial temperature range support
- Space savings small form factor packaging



Multiple channels at different I/O levels

Part Name	CH#	RTM	Interface
LSF0101	1	Now	GPIO
LSF0102	2	Now	GPIO, MDIO, SMBus, PMBus, I2C
LSF0108	8	Now	GPIO, MDIO, SDIO, SVID, UART, SMBus, PMBus, I2C, SPI
LSF0204/4D	4	4Q'14	GPIO, MDIO, SDIO, SVID, UART, SMBus, PMBus, I2C, SPI

LSF0204/4D

Sampling
RUT, PW: Now | RGY: Dec '14

4 - Bit Bidirectional Multi-Voltage Translator for Open-Drain & Push-Pull

Features

- Allows bidirectional multi-voltage translation w/o direction pin between:
  - 1.0 V ⟷ 1.8/2.5/3.3/5 V
  - 1.2 V ⟷ 1.8/2.5/3.3/5 V
  - 1.8 V ⟷ 2.5/3.3/5 V
  - 2.5 V ⟷ 3.3/5 V
  - 3.3 V ⟷ 5 V
- Supports high speed translation:
  - >100MHz
  - $T_{pd(max)}$ < 1.5ns
- 5V tolerance on I/O port to support TTL
- -40 to 125C Ta operation
- Package Option
  - 4-bit device (PW, RUT, RGY, YZP)
- Automotive Qualified (PW)

Applications

- Computing (Tablet, Smartphones, PC, SSD)
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- Target Interfaces:
  GPIO, MDIO, SDIO, SVID, UART, SMBus, PMBus, I2C, SPI

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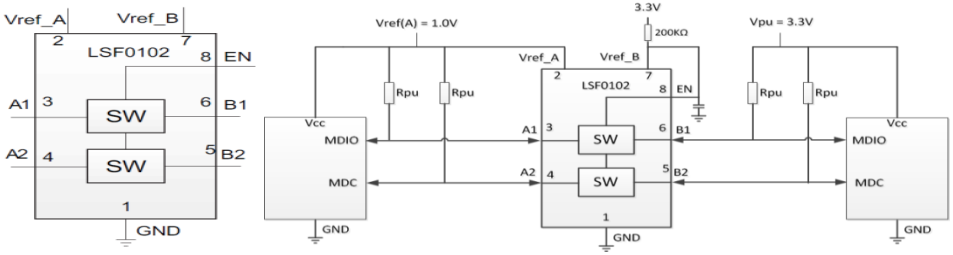

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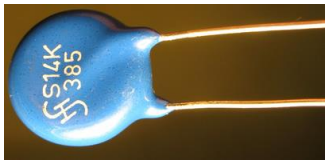
LSF0108	8	Now	GPIO, MDIO, SDIO, SVID, UART, SMBus, PMBus, I2C, SPI
LSF0204/4D	4	4Q'14	GPIO, MDIO, SDIO, SVID, UART, SMBus, PMBus, I2C, SPI

Translation Products by Interface Type

	Voltage Range	Architecture	# of Data Lines	Direction Control Pins	Translation Device
I²C	1.65V-5.5V	Open-Drain	1 Serial Data line (SDA) + 1 Serial Clock line (SCL)	-	TXS0102
				-	TXS0104E
	0.9V-3.6V			-	***TXS0302****
SPI	0.9V-3.6V	Push-Pull	Serial clock (SCLK) + master output slave input (MOSI) + master input slave output (MISO) + slave select (SS) **{4 lines}**	-	TXB0304
	1.2V-5.5V			-	TXB0104
	1.65V-5.5V	Open-Drain/ Push-Pull		-	TXS0104E
BaseBand	1.2V-3.6V	Bluetooth/ WLAN/ SD/ SDIO	Varies	1	TWL1200
	1.1V-3.6V			-	TXS0206
	1.2V-3.6V			1	SN74AVC8T245
Audio Codec	1.2V-3.6V		SDATA_OUT + SYNC + SDATA_IN + RESET + BIT_CLK_IN **{5 lines}**	2	SN74AVC6T622
SD/SDIO Card	1.1V-3.6V	Open-Drain/ Push-Pull	8 Lines	-	TXS0206 \ TXS0206-29
				1	TXS02612
	1.2V-3.6V			3	SN74AVCA406E
SIM Card	1.7V-3.3V ***and*** 2.3-5.5V	Push-pull	2 data lines + 1 clock	-	TXS4555
					TXS02326(A) / TXS02324
				7	*TXS4558*
IC-USB	1.65V-3.6V	Push-pull	2 data lines	-	TXS0202
	1.1V-3.6V			1	SN74AVC2T872
Display	1.2V-5.5V	Push-pull	Multiple	-	TXB0108
	1.65V-5.5V	Open-drain			TXS0108E
	1.2V-3.6V	Push-pull		2	SN74AVC20T245

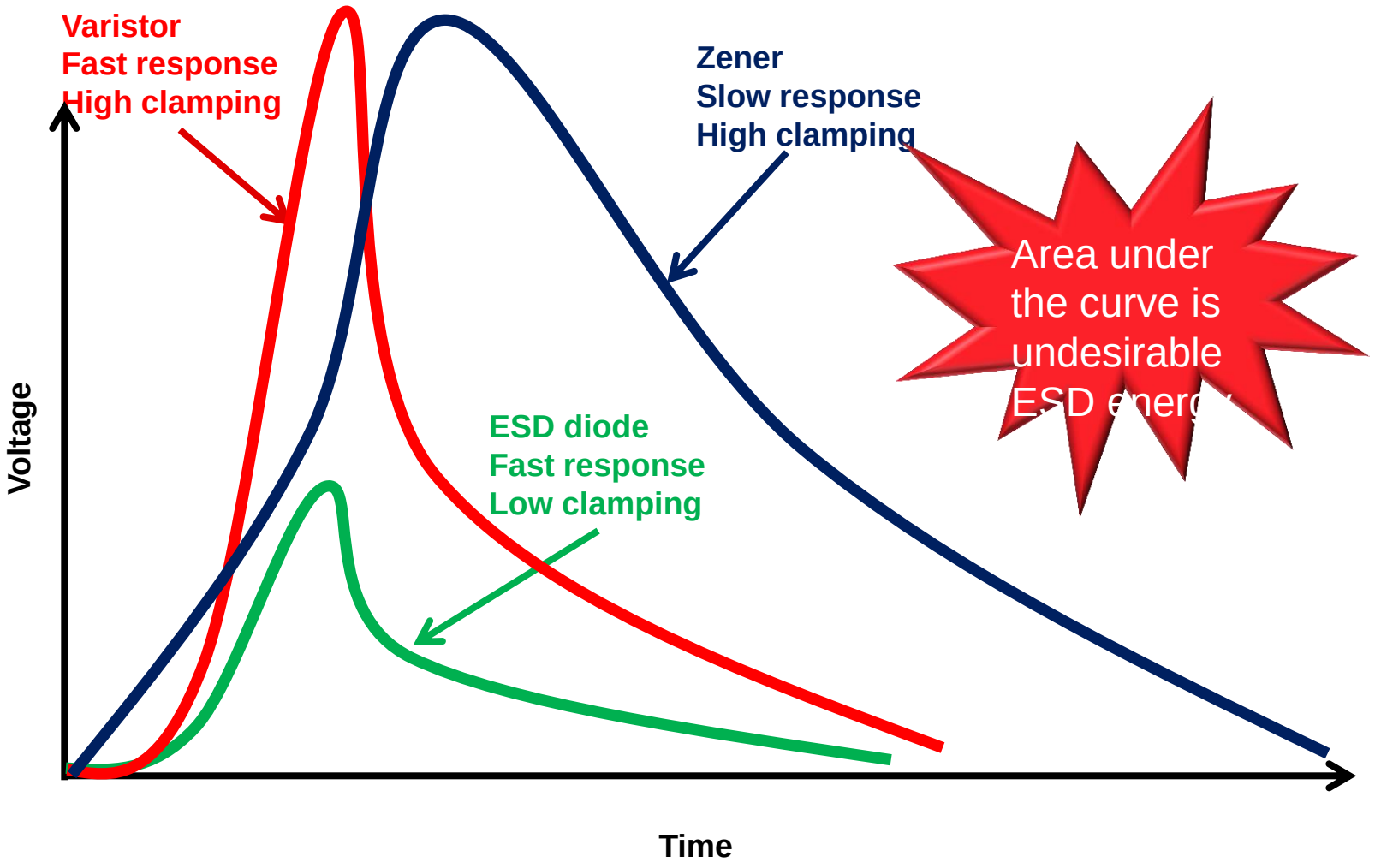
ESD Protection

ESD Protection Device Comparison



	Varistor	Zener	ESD diode
Composition	Ceramic masses	Semiconductor	Semiconductor
General Usage	Line powered Circuitry	Voltage reference	Low voltage ESD protection
Degradation	Degrades with time	Never	Never
ESD rating	Up to ±8kV	Up to ±8kV	Up to ±30kV
Clamping Voltage	50-200 V	50-200 V	10-15 V
Leakage current	1,000-20,000 nA	10–50,000 nA	1-100 nA
Data rate support	> Gigabit/second	< Megabit/second	> Gigabit/second
Dynamic resistance	1-20 Ω	10-30 Ω	< 1 Ω

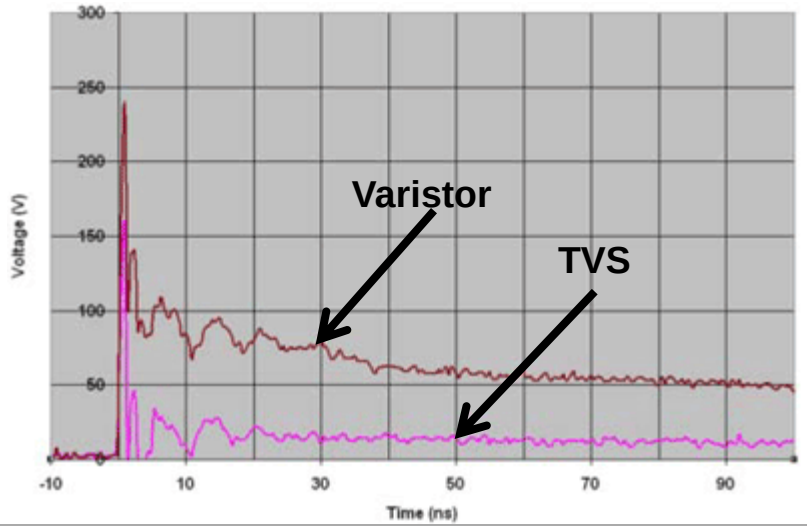
Clamping Voltage Comparison



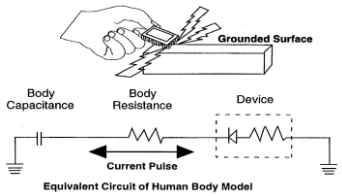
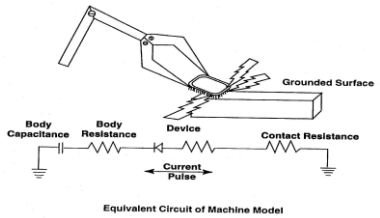
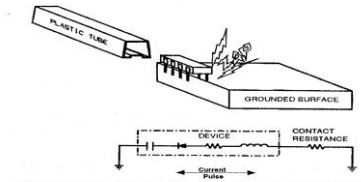
Varistor vs. TVS

	Varistor	TVS
Composition	Ceramic masses	Monolithic semiconductor
General Usage	Line powered Circuitry	Low voltage IOs
Features	Can handle up to 400C	Fast response, low clamping voltage, high reliability
Degradation	Directly proportional to quantity of protection and time; inversely proportional to size	Never
Vclamp @ 50ns (using 8kV Contact Discharge)	50-200V	10-15V
Leakage current	1-20uA	10-100nA
Rdynamic	~10-20 Ohms	<2 Ohms

VCLAMP Varistor vs. TVS using 8kV Contact Discharge



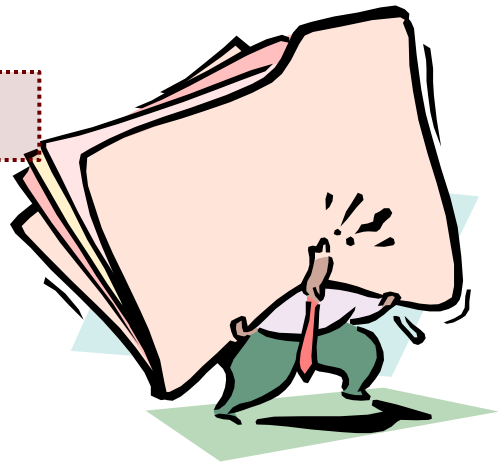
ESD

	**Human body model (HBM)**  Equivalent Circuit of Human Body Model	**Machine model (MM)**  Equivalent Circuit of Machine Model	**Charge device model (CDM)**  Equivalent Circuit of Charged Device Model
Definition	Human body discharging accumulated static	Robotic arm discharging accumulated static	A charged device being grounded
Test Levels (Volts)	500, 1000, 1500 2000, 2500	100, 150, 200	250, 500, 750, 1000
Pulse Width (ns)	~150	~80	~1
Rise Time	2-10 ns	n/a	<400 ps
Typical ESD Failures	Junction Damage, Metal Penetration, Metal Melt, Contact Spiking, Gate Oxide Damage		Gate Oxide Damage, Charge Trapping, Junction Damage

System Level Specifications

IEC 61000-4-xx is a set of about 25 testing specs from the IEC

-2:	ESD Immunity
-3:	Radiated RF EM Field Immunity
-4:	Electrical Fast Transient Immunity
-5:	Surge Immunity
-6:	Conducted RF Immunity
-8 –9 –10:	Magnetic Field Immunity
-11:	Voltage Dips & Variations Immunity
…	many more

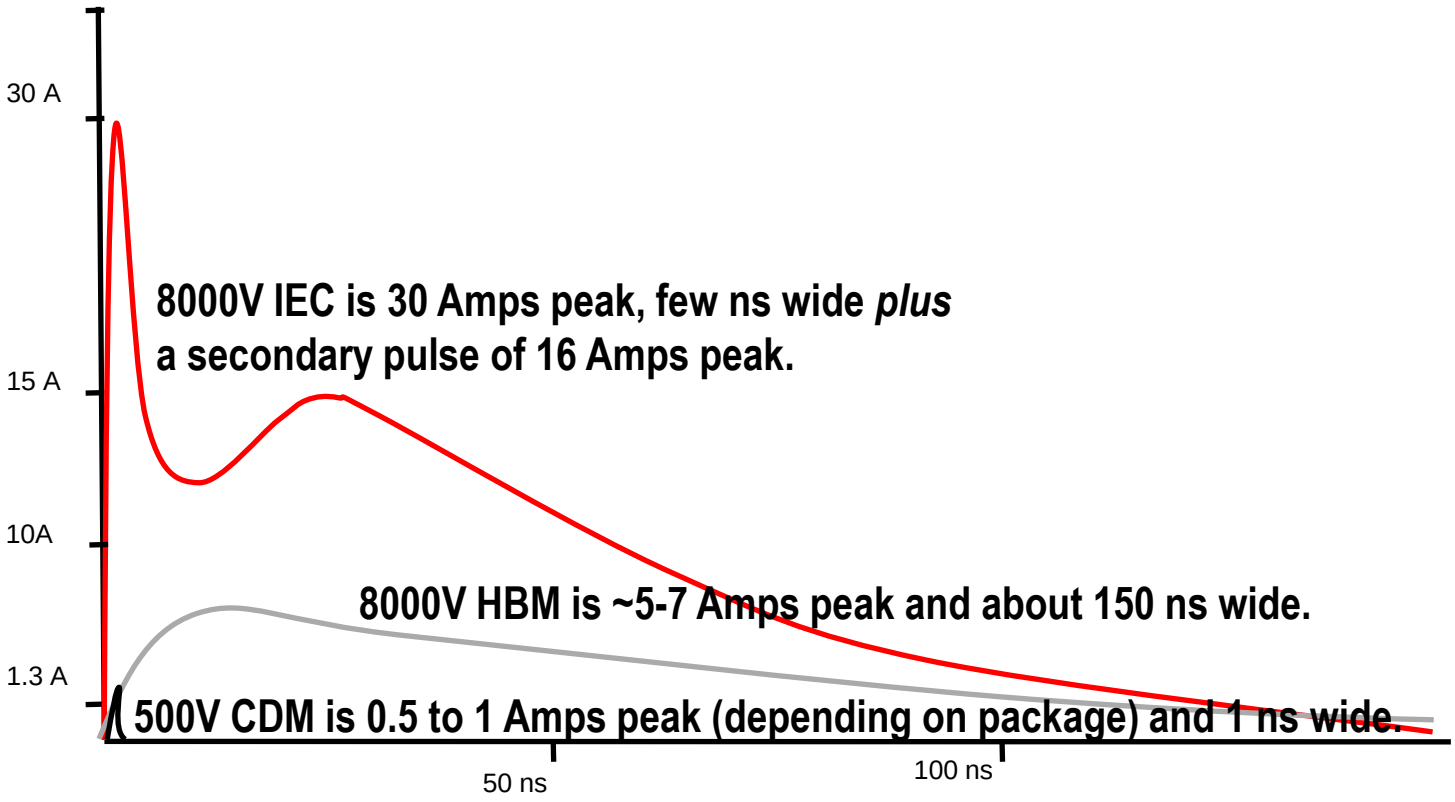


11:14

Comparison of Device Level & System Level ESD Specifications

How does the IEC ESD stress differ from the tests we've been doing?

The stress is like a CDM stress followed by an HBM stress.



ESD protection with ultra-low leakage

Interface	Part #
USB 2.0	TPD4E1U06
µUSB Charging Port	TPD4S014
USB Host	TPD4S214
USB 3.0	TPD6E05U06
VGA	TPD7S019
HDMI	TPD12S016
DisplayPort	TPD4E05U06
Ethernet	TPD4E1U06
Precision Measurement	TPD4E001
RS-485/432	TPD2E007
RS-232/CAN	TPD1E10B09
Keypad	TPD6F002
Memory SDIO	TPD6F003
LCD	TPD4E001
Display	TPD4E1U06
Audio	TPD1E10B09
SIM Card	TPD4E101
Push Button/ Side Keys	TPD1E10B06
SATA Express	TPD1E05U06

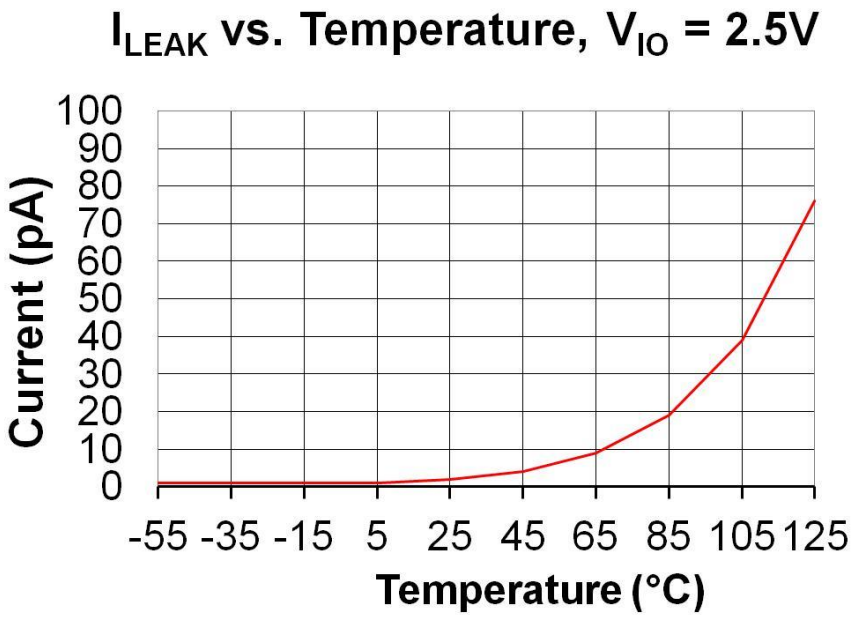
< 5pA @ 25°C

System level ESD protection (IEC61000-4-2)

- Minimum 8kV contact and 15kV air gap ratings
- Complete product selection: single and multi channel

Leakage current is magnitudes lowers than ATE (automatic test equipment) noise floor

Accurate leakage current is measured on test bench and plotted as datasheet waveforms as below

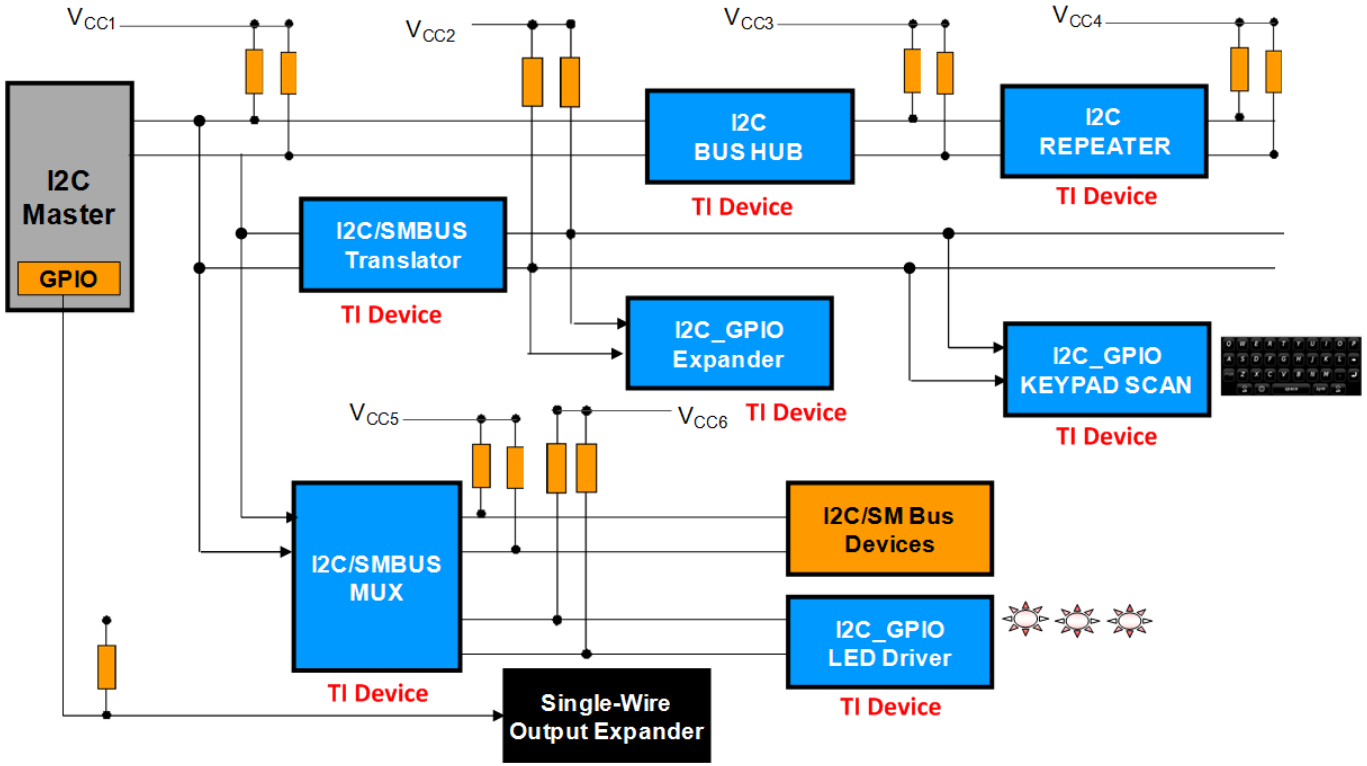


Typical TI ESD protection diode leakage current

I2C Device

I2C Related Products

BLOCK DIAGRAM



I2C Applications

- Industrial
- Consumer
- Telecom
- Networking
- Computing
- MP3/PMP
- Smartphone
- Automotive

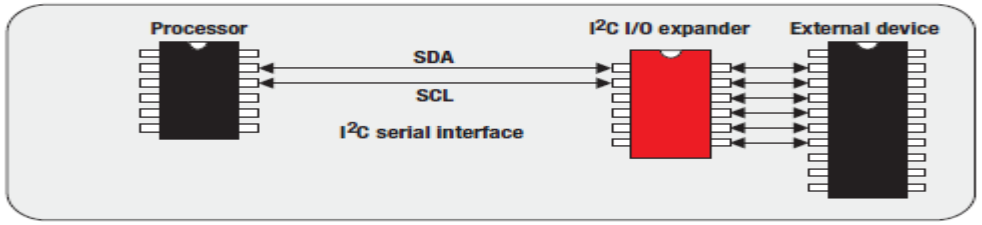
IP VALUE

- **I2C I/O Expander**
  - Best solution for system chips running out of I/O's.
  - Reduce PCB complexity
- **I2C Mux/Switches**
  - Allow expansion, muxing and/or isolation of I2C bus
- I2C Buffers and Translators
  - Increase the number of I2C devices that can be connected to a I2C master.
  - Enables I2C signals over longer traces or a cable
- I2C Keypad controller
  - Manages up tp 80 keys through I2C

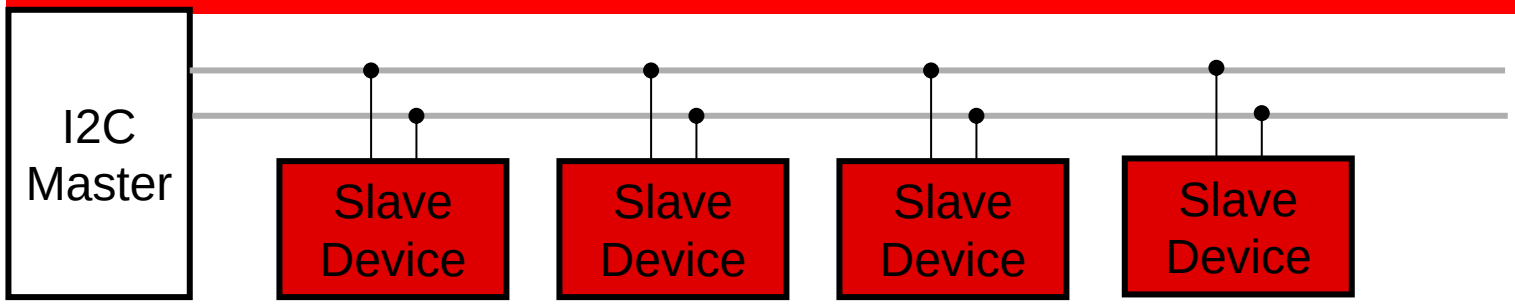
I/O Expander Product Portfolio

Number of I/O Pins	No /RESET Input	/RESET Input	No /RESET Input
SF			TCA8418/E (Keypad Control w/ 18 I/Os); TCA6507 (7–LED Controller)
24		TCA6424A	
18		TCA6418	
16	TCA9555; PCA9555	TCA6416A	TCA9539; PCA9539; TCA9535; PCA9535; PCF8575 (No Config regs); PCF8575C (No Config / Open Drain)
8	TCA9554A; PCA9554A (Addr: 0111 xxx); PCA9554 (Addr: 0100 xxx)	TCA7408; TCA6408A	PCA9557 (Open Drain); PCA9538; PCA6107 (Open Drain); PCA9534 (Addr: 0100 xxx); PCA9534A (Addr: 0111 xxx)
4	PCA9536		Unless Otherwise indicated: All I/Os are Push-Pull Type

System with I²C I/O expanders



I2C Bus – Multiplexers & Switches



Benefits With I2C_Multiplexers

▶Solve Address Conflicts

I2C Master would connect to Multiple Slave I2C Devices, They may be same address and it may wrongly program into identical devices.

▶Capacitive Load Sharing

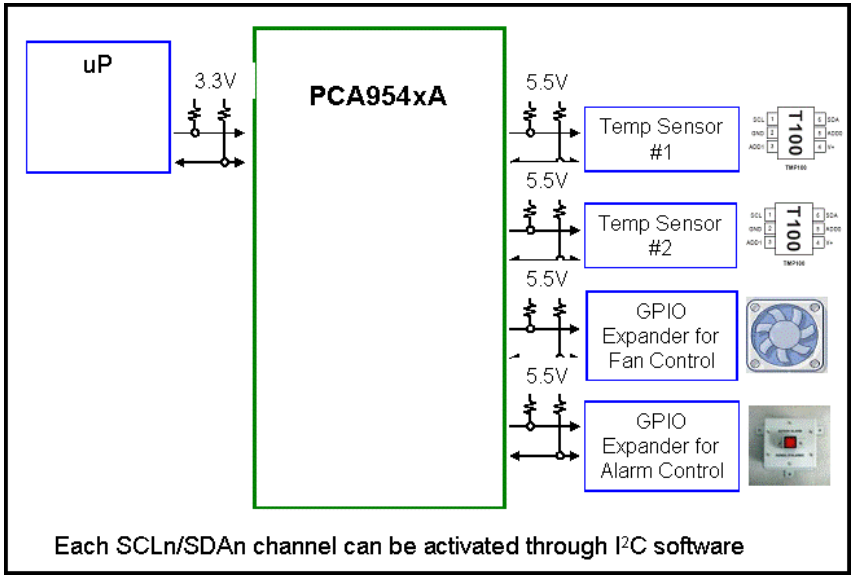
-Reduce Capacitive bus loading by isolation the un-needed sub device

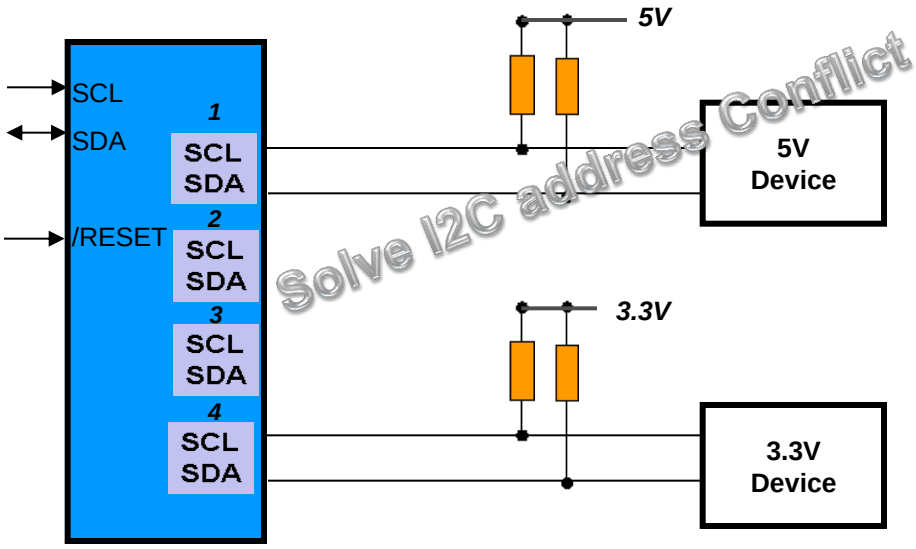
▶Voltage Level Shifting

-The slave device may be operated at different VCC Level and I2C Bus Level is affected.

- All MUX Devices are 5V I/O Tolerant and you can pull up to desired the maximum voltage Level for I2C Bus

I2C 1 to X Multiplexdr Applications



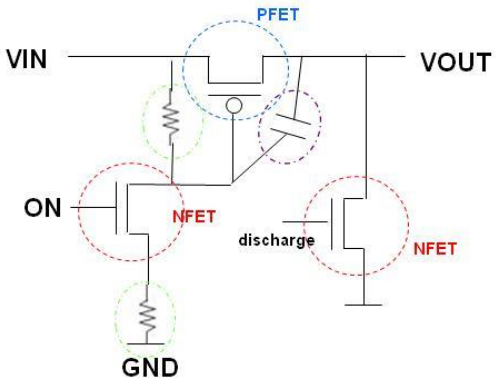


Device	In/ Out #	Active #CH	Pin	I2C Address	Vcc (V)	I²C Level Shift Range				#I NT Inputs	#Int Outputs	/Reset	5V I/O Tolerant
						1.8V	2.5V	3.3V	5V				
PCA9543A	1:2	2	14	1110 0xx	2.3 to 5.5	✓	✓	✓	✓	2	1	✓	✓
PCA9544A	1:4	1	20	1110 xxx	2.3 to 5.5	✓	✓	✓	✓	4	1		✓
PCA9545A	1:4	4	20	1110 0xx	2.3 to 5.5	✓	✓	✓	✓	4	1	✓	✓
PCA9546A	1:4	4	16	1110 xxx	2.3 to 5.5	✓	✓	✓	✓	0	0	✓	✓
TCA9548A	1:8	8	24	1110 xxx	2.3 to 5.5	✓	✓	✓	✓	0	0	✓	✓

Load Switch

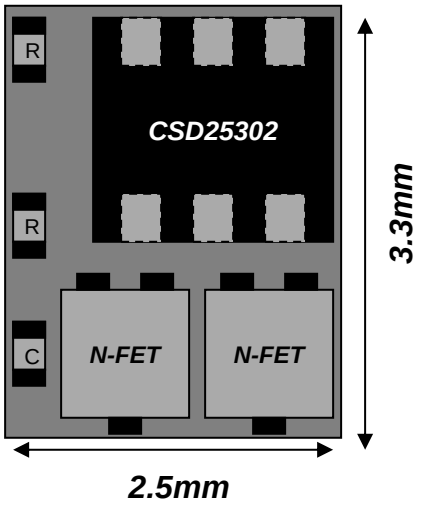
The Integration / Size Advantage

Discrete Circuit



Multiple FET devices, resistors, capacitors

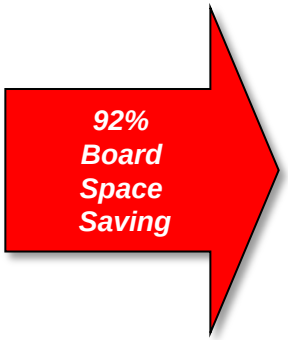
Conventional Solution

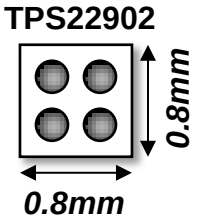


8.25mm²

Need Design time and expertise
Slew-Rate control will need R & C

TPS22902 Load Switch





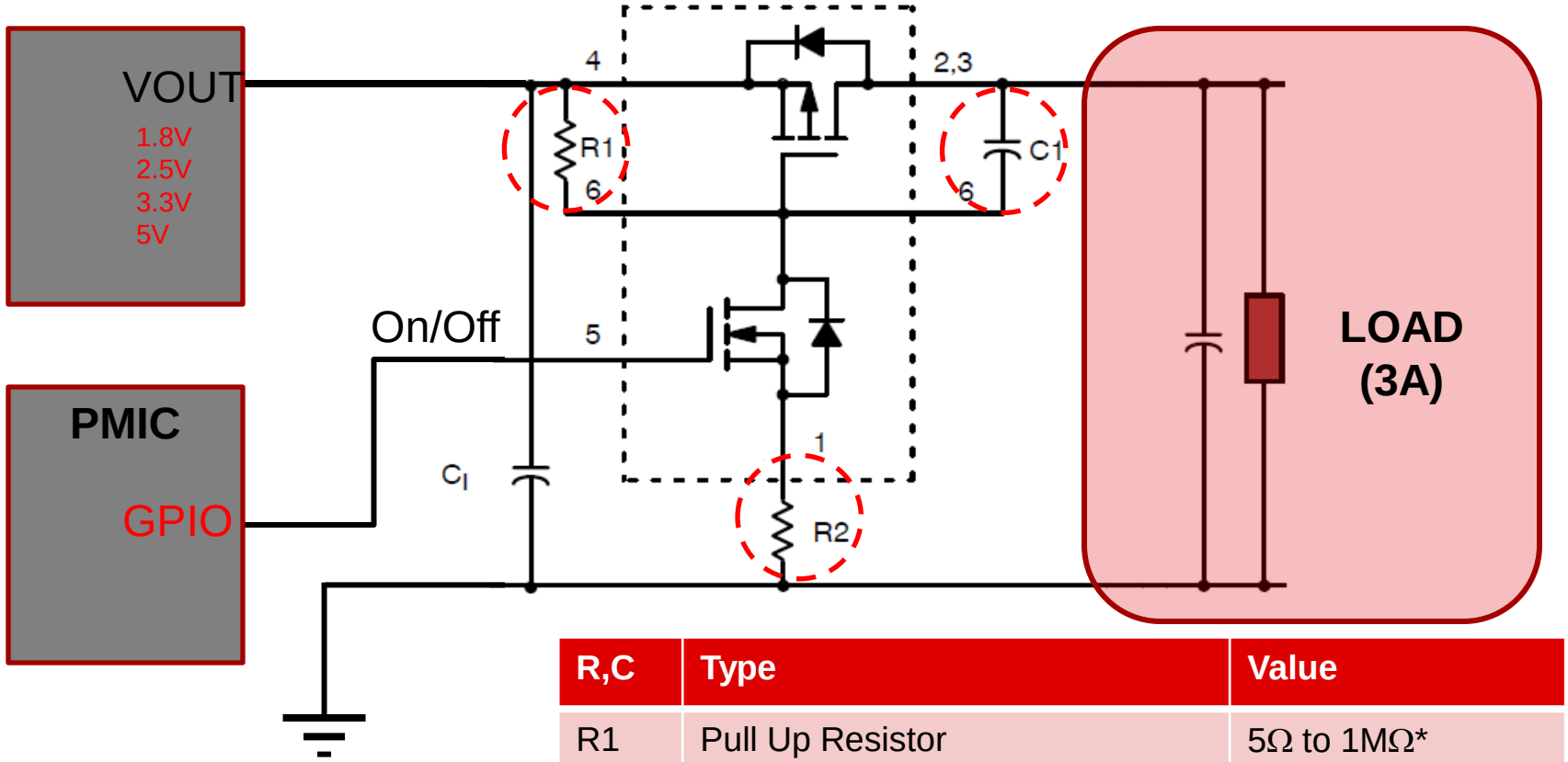
0.64mm²

Controlled Slew-Rate
Reduced Design time
Additional features
92% Smaller Size

Power switching benefits

Problem	Solution	Value
Powering up sub-systems in an orderly fashion without a dedicated PMIC	Create simple control of sub-system power up	Power sequencing
Stringent requirements on supplies due to inrush current	Provide controllable / configurable supply ramp	Slew rate control
Wasted power in unused sub-systems	Disable power to unused sub-systems	Reduced energy
Safety and reliability concerns due to harsh conditions	Integrate fault protection and isolation features	Fault protection and isolation
Conventional solution size for power switching is too big	Integrate features into single device	Space savings

Application Example: Inrush Current Control

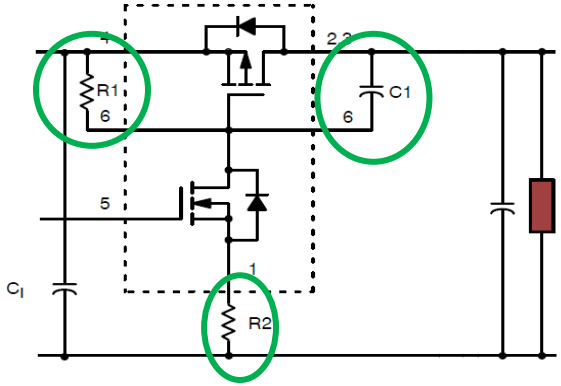


ON/OFF	P-Channel
High	Connected
Low	Dis-Connected

R,C	Type	Value
R1	Pull Up Resistor	5Ω to 1MΩ*
R2	Slew Rate Control Use	0 to 100kΩ
C1	Slew Rate Control Use	0 to 10nF

*** Keep R1> 10*R2; Higher value of R1 minimizes IQ; R2 & C1 required when setting slew rate**

In-rush Current Protection & Power Sequencing



C1 (1)	Rise Time (µs) (2)(3)							
	R1=10kΩ, R2=1kΩ				R1=5.1kΩ, R2=510Ω			
	VIN = 7V	VIN = 5V	VIN = 3.3V	VIN = 1.2V	VIN = 7V	VIN = 5V	VIN = 3.3V	VIN = 1.2V
220pF	.253	.316	.416	.810	.129	.161	.212	.413
1000pF	1.15	1.44	1.89	3.68	.586	.732	.963	1.88
4700pF	5.4	6.75	8.88	17.3	2.76	3.44	4.53	8.83
0.18uF	207	258	340	663	106	132	173	338
0.27uF	310	388	510	994	158	198	260	507
0.33uF	379	474	623	1220	194	242	318	620
1uF	1150	1440	1890	3680	586	732	963	1880

(1) Typical ceramic capacitor values
(2) CLoad=10uF. Output rise time is independent of CLoad when CLoad >> C1
(3) Rise Time is 250ns for R2=0Ω and C1=CLoad=0F

RS232 Transceiver

Data Communication Transceivers

RS-232 Transceiver

Low Voltage RS-232 Transceiver

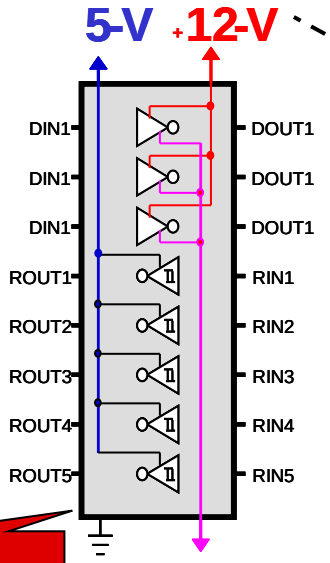
RS-422/423 Transceiver

RS-485 Transceiver

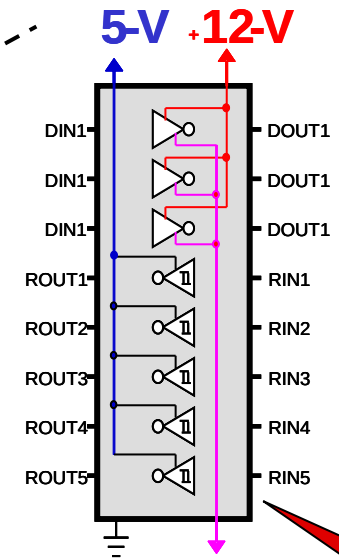
Single Chip Peripheral Port	
SN75196	5Tx/3Rx
GD75323	5Tx/3Rx
SN75LP196	5Tx/3Rx

Multiple Power Rails RS-232 Transceiver

UART



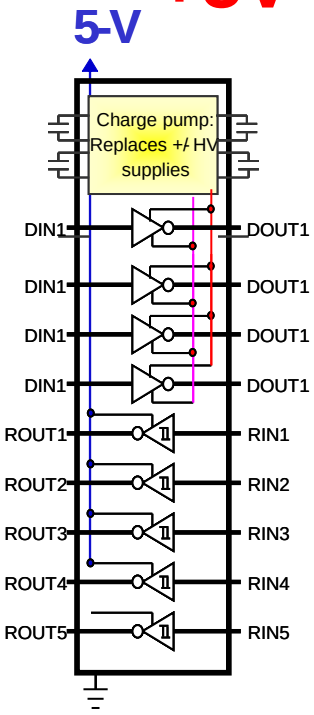
RS-232 Analog Signals Bus



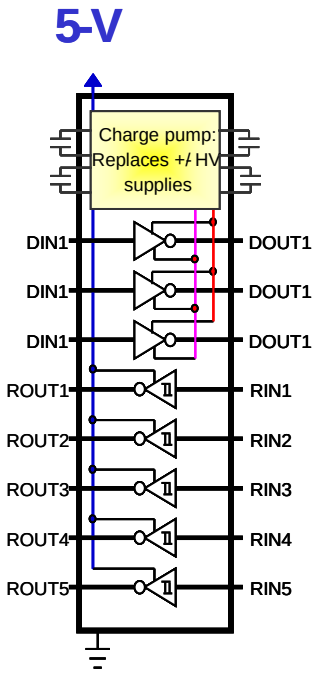
SN75185/SN75C185
SN75LP1185/SN75LPE185
GD75232

SN75196
GD75323
SN75LP196

+5V Single Supply RS-232 Transceivers

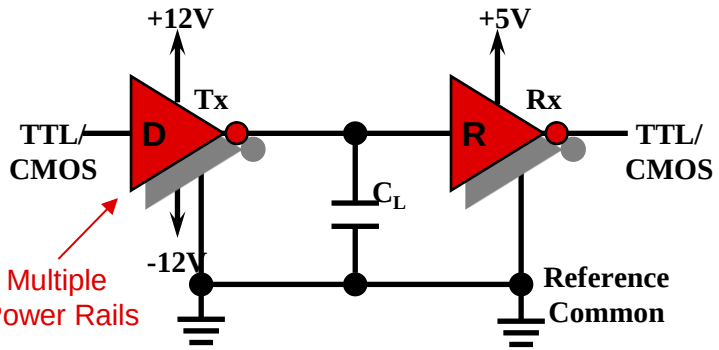


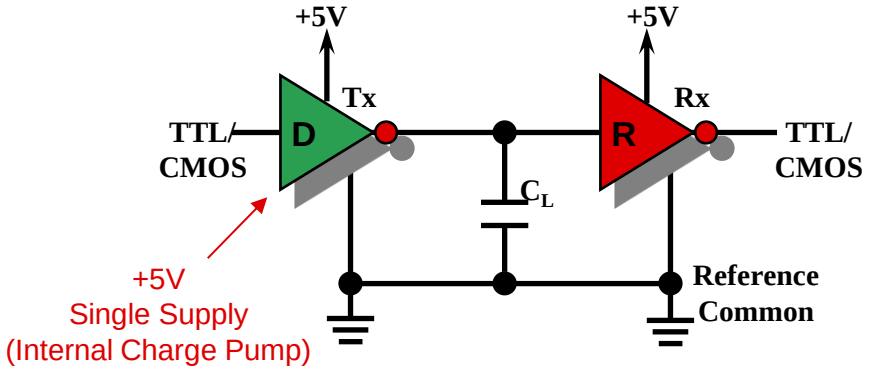
SN75LBC241
(MAX241 Compatible)



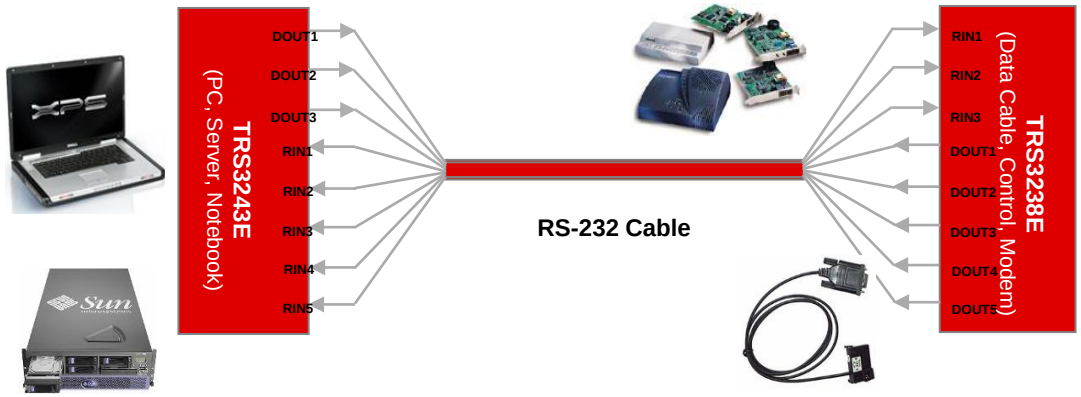
SN75LBC187
(MAX241 Compatible)

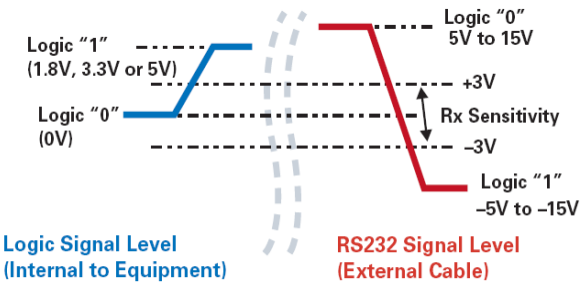
Device	Power Supply (V)	No. Tx	No. Rx	Shutdown
TRS232 TRS232E	+ 5V	2	2	No
TRS202 TRS202E	+ 5V	2	2	No
TRS207	+ 5V	5	3	No
TRS208	+ 5V	4	4	No
TRS222	+ 5V	2	2	Yes
TRS211	+ 5V	4	5	Yes
TRS213	+ 5V	4	45	Yes





Low Voltage (3.3V/5V) Transceiver





RS-232 signal level compaired against logic signal level.

TRS3238E (5Dr, 3Rx) Complements TRS3243E (3Dr, 5Rx) in PC Peripheral Applications

Continued

DEVICES	PINS	Tx	Rx	ESD (KV)		Vcc		Data_Rate (kbps)	No. Cap	Cap Value	Power Down
				HBM	Air-GAP	Min.	Max.				
TRS3221	16	1	1	15	-	3	5.5	250	4	0.1-µF	✓
TRS3221E	16	1	1	15	15	3	5.5	250	4	0.1-µF	✓
TRSF3221	16	1	1	15	-	3	5.5	1000	4	0.1-µF	✓
TRSF3221E	16	1	1	15	15	3	5.5	1000	4	0.1-µF	✓
TRS3222	20	2	2	15	-	3	5.5	250	4	0.1-µF	✓
TRS3222E	20	2	2	15	15	3	5.5	250	4	0.1-µF	✓
TRSF3222	20	2	2	15	-	3	5.5	1000	4	0.1-µF	✓
TRSF3222E	20	2	2	15	15	3	5.5	1000	4	0.1-µF	✓
TRS3223	20	2	2	15	-	3	5.5	250	4	0.1-µF	✓
TRS3223E	20	2	2	15	15	3	5.5	250	4	0.1-µF	✓
TRSF3223	20	2	2	15	-	3	5.5				
TRSF3223E	20	2	2	15	15	3	5.5	1000	4	0.1-µF	✓

Low Voltage (3.3V/5V) Transceiver

DEVICES	PINS	Tx	Rx	ESD (KV)		Vcc		Data_Rate (kbps)	No. Cap	Cap Value	Power Down
				HBM	Air-GAP	Min.	Max.				
TRS3232	16	2	2	15	-	3	5.5	250	4	0.1-µF	×
TRS3232E	16	2	2	15	15	3	5.5	250	4	0.1-µF	×
TRSF3232	16	2	2	15	-	3	5.5	1000	4	0.1-µF	×
TRSF3232E	16	2	2	15	15	3	5.5	1000	4	0.1-µF	×
TRS3238	28	5	3	15	-	3	5.5	250	4	0.1-µF	✓
TRS3238E	28	5	3	15	15	3	5.5	250	4	0.1-µF	✓
TRSF3238E	28	5	3	15	15	3	5.5	1000	4	0.1-µF	✓
TRS3227	16	1	1	15	-	3	5.5	1000	4	0.1-µF	×
TRS3227E	16	1	1	15	15	3	5.5	1000	4	0.1-µF	×
TRS3237E	28	5	3	15	15	3	5.5	1000	4	0.1-µF	✓
TRS3243	28	3	5	15	-	3	5.5	250	4	0.1-µF	✓
TRS3243E	28	3	5	15	15	3	5.5	250	4	0.1-µF	✓
TRSF3243	28	3	5	15	-	3	5.5	250	4	0.1-µF	✓
TRS3318	28	2	2	15	-	2.5	3.3	460	4	0.1-µF	×
TRS3318E	28	2	2	15	15	2.5	3.3	460	4	0.1-µF	×
TRS3253E*	32	3	5	8	8	1.65 - Vcc	3 ~ 5.5V	1000	4	0.1-µF	✓
TRS3386E*	20	3	2	15	15	1.65 - Vcc	3 ~ 5.5V	250	4	0.1-µF	✓

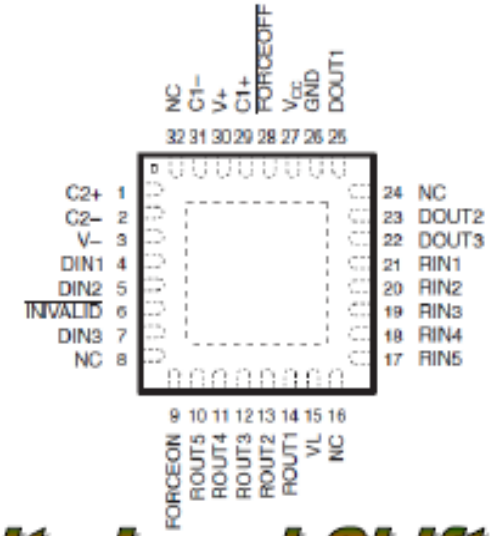
* Separate Vcc rail for Logic side

TRS3253E (1Mbps, 3Tx/5Rx)

SPLIT SUPPLY PIN FOR LOGIC SIDE

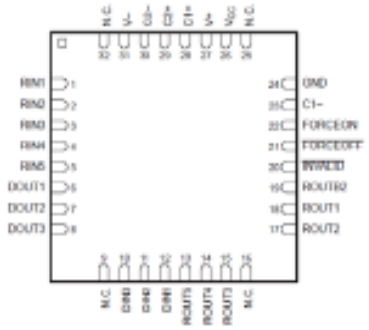
Features

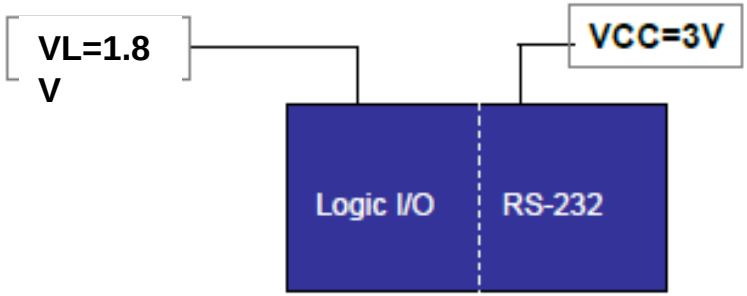
- ✓ VL Pin for Compatibility With Mixed-Voltage Systems Down to 1.8 V on Logic Side
- ✓ Enhanced ESD Protection on RIN Inputs and DOUT Outputs
  - ±8 kV IEC 61000-4-2 Air-Gap Discharge
  - ±8 kV IEC 61000-4-2 Contact Discharge
  - ±15 kV Human-Body Model
- ✓ Low 300-μA Supply Current
- ✓ Specified 1000-kbps Data Rate
- ✓ Auto Powerdown Plus Feature



Save 7-bits Level Shifter

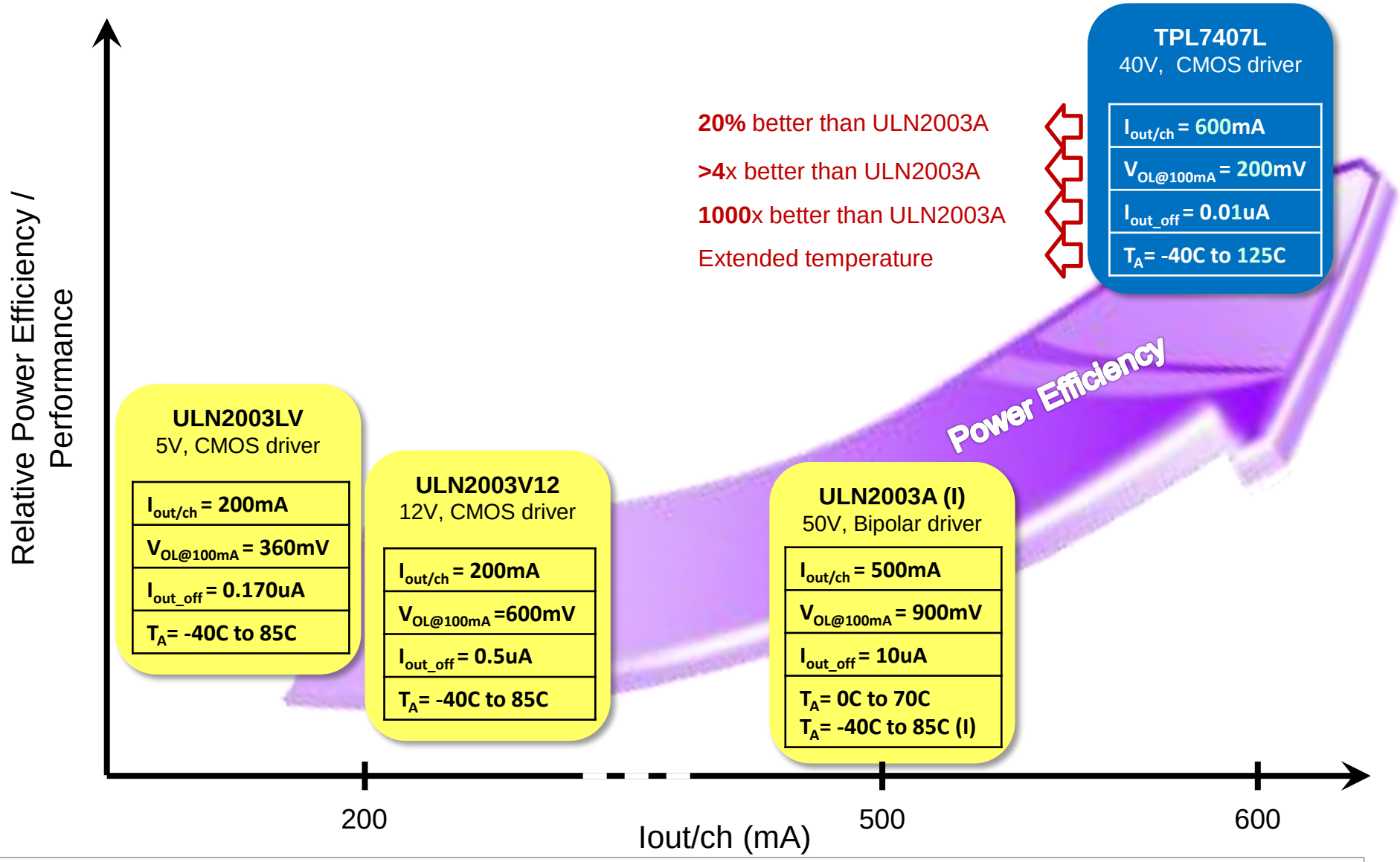
Single Power 3V TRS/F3243E → Split Supply TRS3253E





Relay Driver

Product positioning of 7-channel relay drivers



ULN2003A

High-Voltage, High-Current Darlington Transistor Arrays / Relay driver

In production

Features

- 7 drivers per package
- High-voltage outputs: 50V
- 500mA-rated collector current (Single Output)
- Inputs compatible with various types of logic (CMOS, TTL)
- VOL@100mA = 900mV
- Output clamp diodes
- Temperature range:
  - 0 to 70C
  - -40 to 85C (I, Q)
- Package: SOIC, TSSOP, PDIP, 16SO

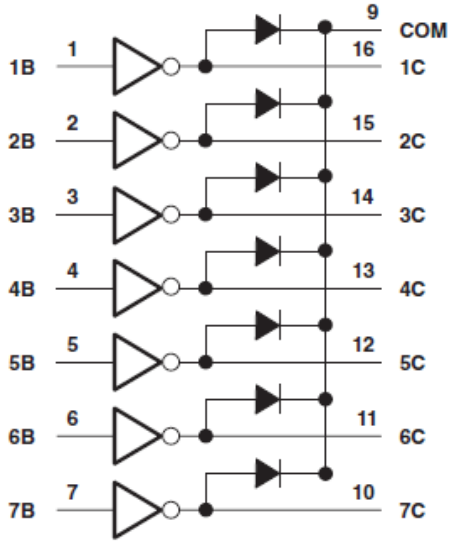
Benefits

- Support high current and voltage loads
- No external diode needed for inductive loads
- Support channel grouping for higher current loads

Applications

- Relays and similar inductive drivers in telecom, consumer and industrial applications
- Uni-polar stepper motor driver
- Lamp and LED displays
- Logic level shifter
- Logic driver
- Constant current generator

LOGIC DIAGRAM



TPL7407L

40V max output voltage, 7-channel, low side driver

Features

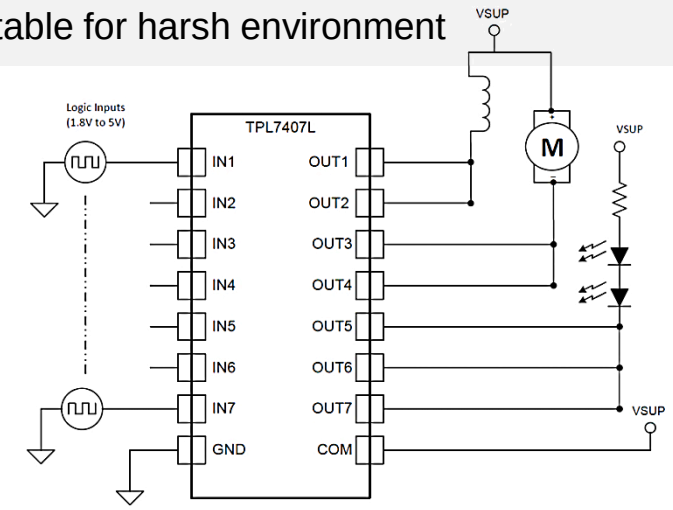
- Rated drain current: **600mA / per channel**
- Excellent power efficiency: **V_{OL}=200mV @ 100mA**
- CMOS pin-pin replacement of 7ch Darlington array
- Very Low Output leakage: <**10nA / channel**
- Full drive @ **1.8/3.3/5V**
- Internal free-wheeling diodes
- T_A:-**40 to 125C**
- Package: 16 TSSOP (PW), 16 SOIC (D)

Applications

- Inductive load drivers:
  - Relays
  - Stepper, unipolar and DC motor drive
- LED drive
- Targeted markets: **White goods and energy efficient appliances**, **industrial** and **telecom**

Benefits

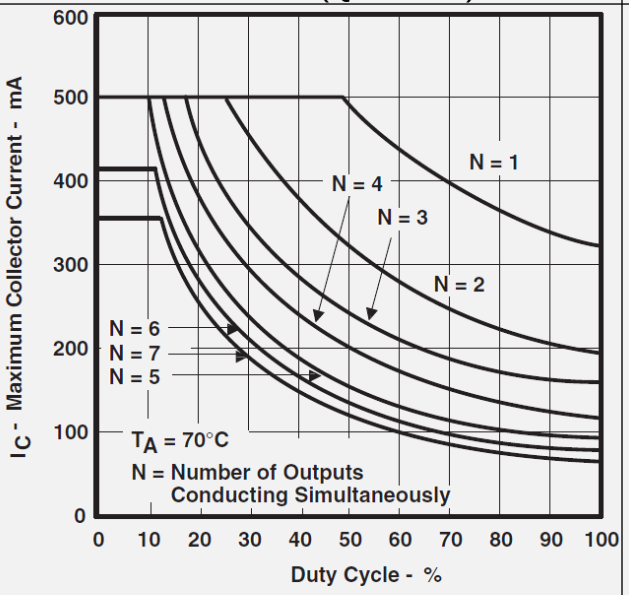
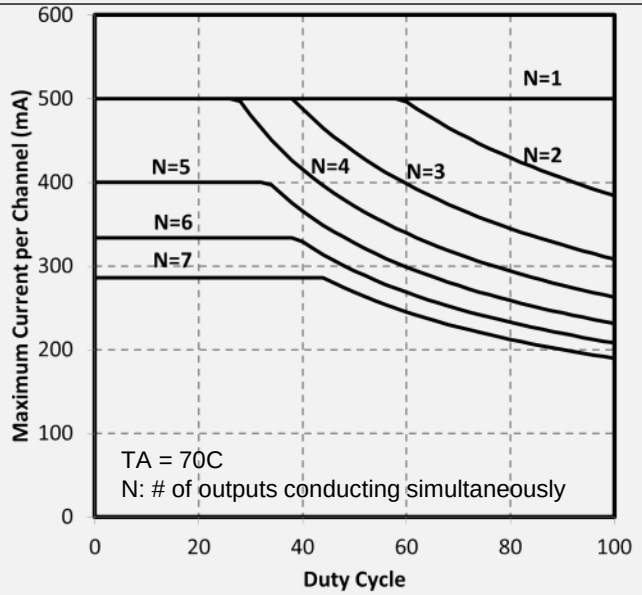
- **Higher power driving capability**
- **Reduce # of relay drivers used for high power applications**
  4x less power dissipation @ typical relay usage
- **Easy replacement** of ULN2003A
- Lower standby current facilitates energy conscious designs
- Simple control using GPIOs of microcontroller
- Inductive kickback protection
- Suitable for harsh environment



TPL7407L Multi-Purpose Sink Driver Application

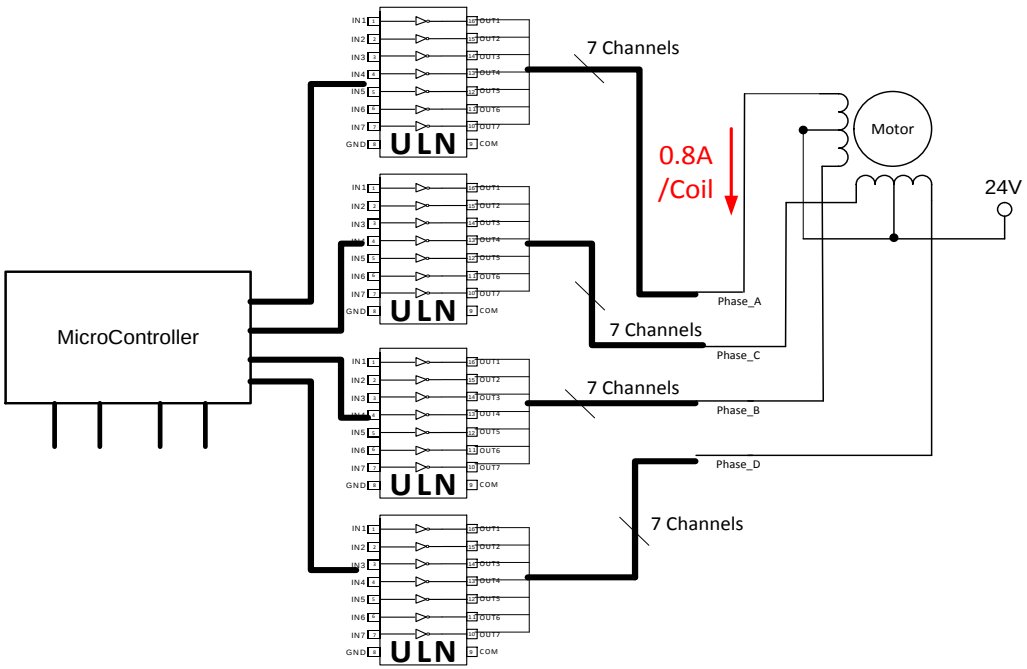
Potential **Q100** qualification

TPL7407L vs ULN2003A

	ULN2003A TI, Toshiba, ON, STM, Rohm, UTC, KEC	TPL7407L TI
Technology	**BIPOLAR**	**CMOS** • 4x less power dissipation @ typical relay usage • Full drive ability at any input logic >1.6V • FET benefit (No thermal runaway and secondary breakdown)
Max Output voltage	50V	40V
V_{OL}	V_{OL} @100mA > 0.9V (typ) V_{OL} @200mA > 1V (typ)	V_{OL}@100mA = 0.2V (typ) V_{OL}@200mA = 0.42V (typ)
Leakage	10uA / ch (typ)	0.01uA / ch (typ)
Ambient Temperature	0 to 70C (Standard) -40 to 85C (I version) -40 to 125C (Q version)	-40C to 125C
Max output current		 TPL7407L enables **BOM cost savings** (see next slide)!

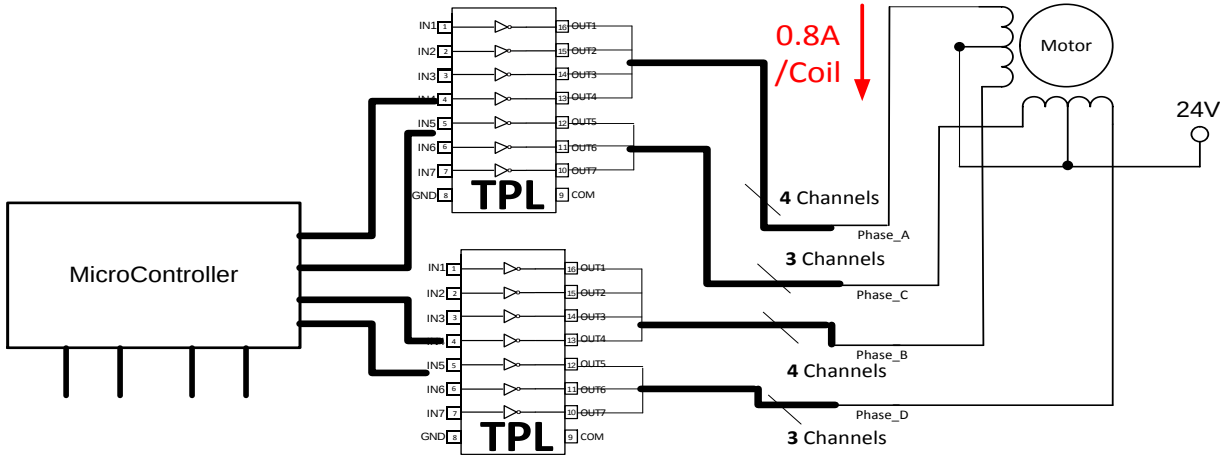
TPL7407L vs ULN2003A: Stepper Motor Example

4x ULN2003A



VS.

2x TPL7407L



Obvious BOM/cost saving!

At 70°C and 50% duty cycle:

- ULN can drive 800mA with 5 channels minimum
- **TPL** can drive >800mA with 3 channels minimum

Low V_{OL} enables TPL to drive more current per channel → Reducing total channels needed

ULN2003V12, Low Power Sink Driver

Features

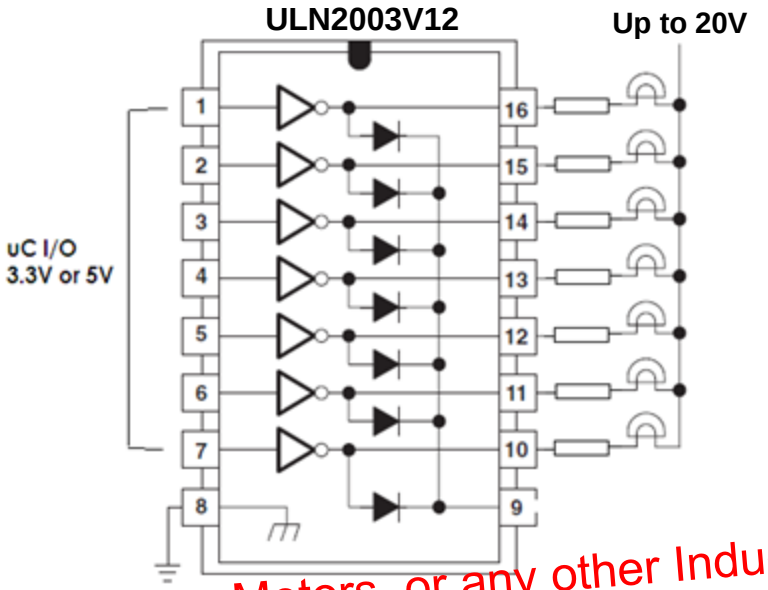
- 7-Ch High Current Sink Drivers
  - Supports 5-12V standard relays
  - DC Pull up voltages up to 20V
- Compatible to 3.3V and 5.0V micro-controllers
- Very Low Input leakage (<20uA) and Stand-by (< 0.2uA) currents
- Low output VOL of 0.6V (Typical) with
  - 100mA max per channel @ 3.3V input
  - 140mA max per channel @ 5.0V input
- Internal Free-wheeling diodes for inductive kickback protection
- Input pull-down resistor allows tri-state input driver
- In-built ESD protection
- 16-TSSOP(PW)/SOIC(D)/PDIP(N) packages

Applications

- Relay/Inductive Loads
- Uni-polar Stepper Motor Drives
- Lamp and LED Displays
- Inverting Level Shifter
- Constant Current Source

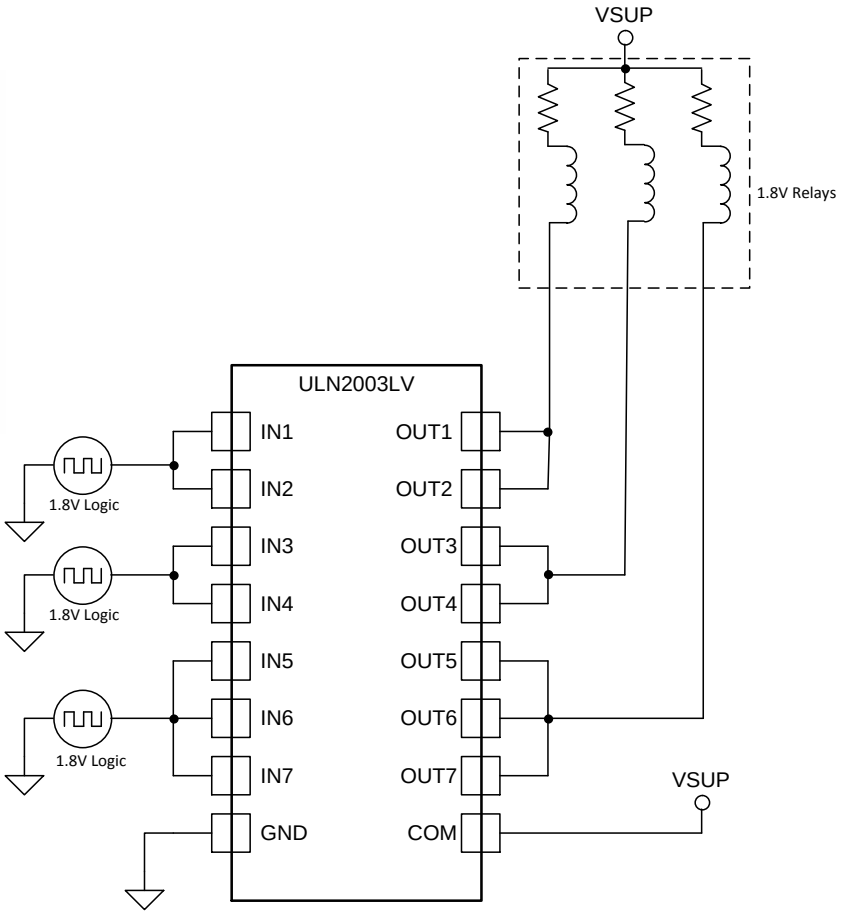
Benefits

- Drop-in replacement for ULN2003x in 3V & 5V Apps
- VOL limits compatible to most 5-12V Relays
- Higher power efficiency: <20uA DC input
- Supports mixing of 3V & 5V input logic levels
- Supports Channel grouping for higher current loads



Relays, Motors, or any other Inductive Loadings

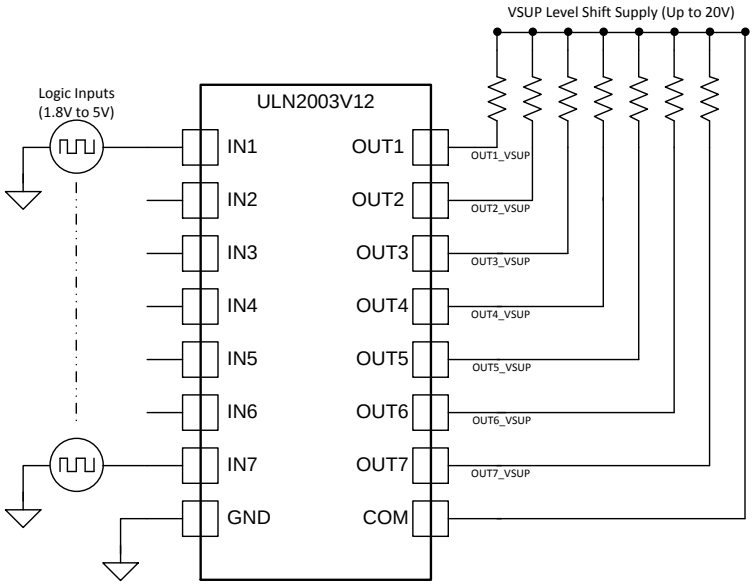
ULN2003LV, Driving 1.8V or 3V Relays



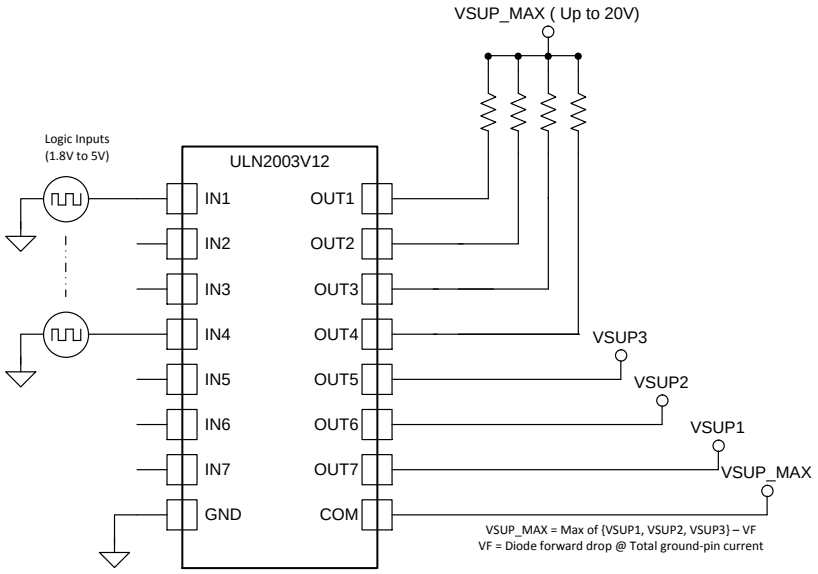
Telecom

ULN2003LV Driving 1.8V or 3V Relays

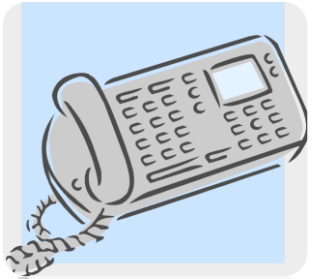
ULN2003V12, High Voltage Level Shifter



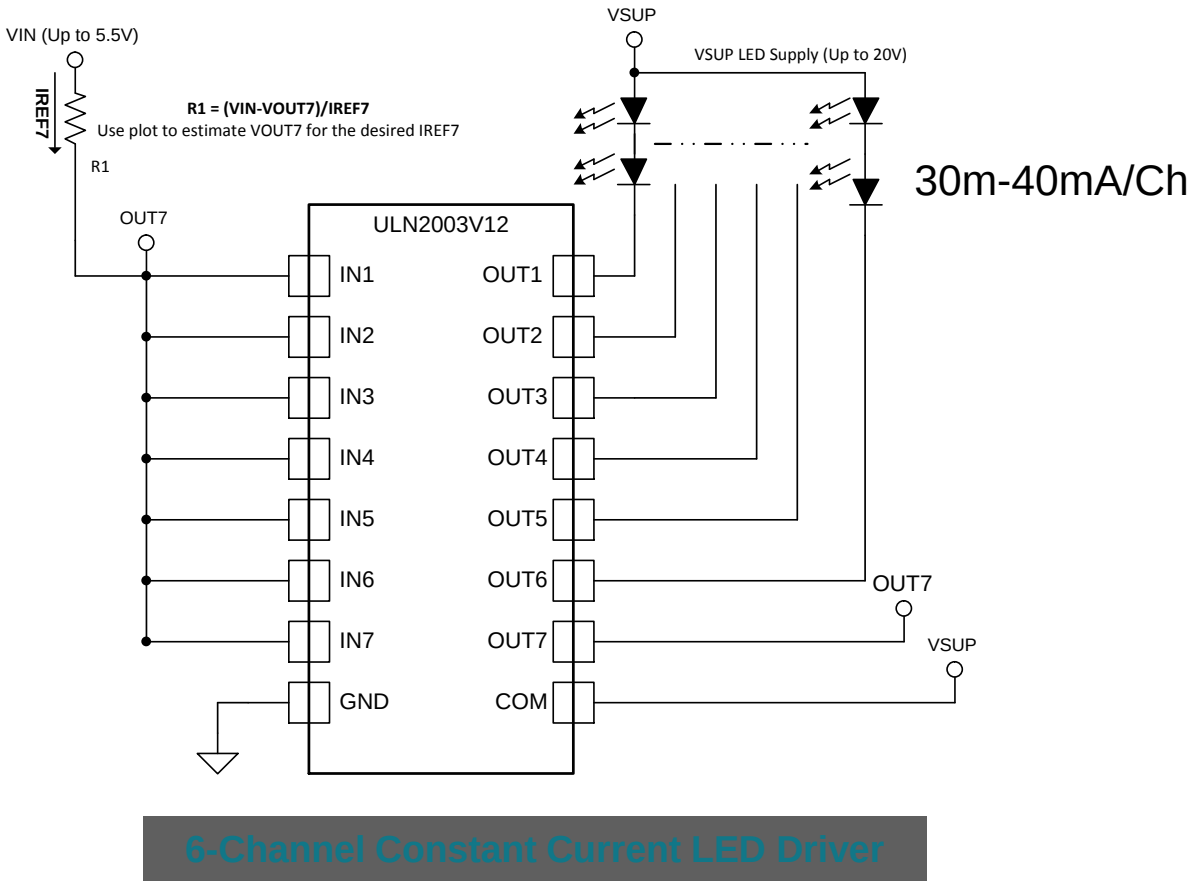
Inverting Logic Level Shifter



Level Shifter with Max Supply Select



ULN2003V12, LED Driver



Thanks

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