Designing with NXP Interface Devices

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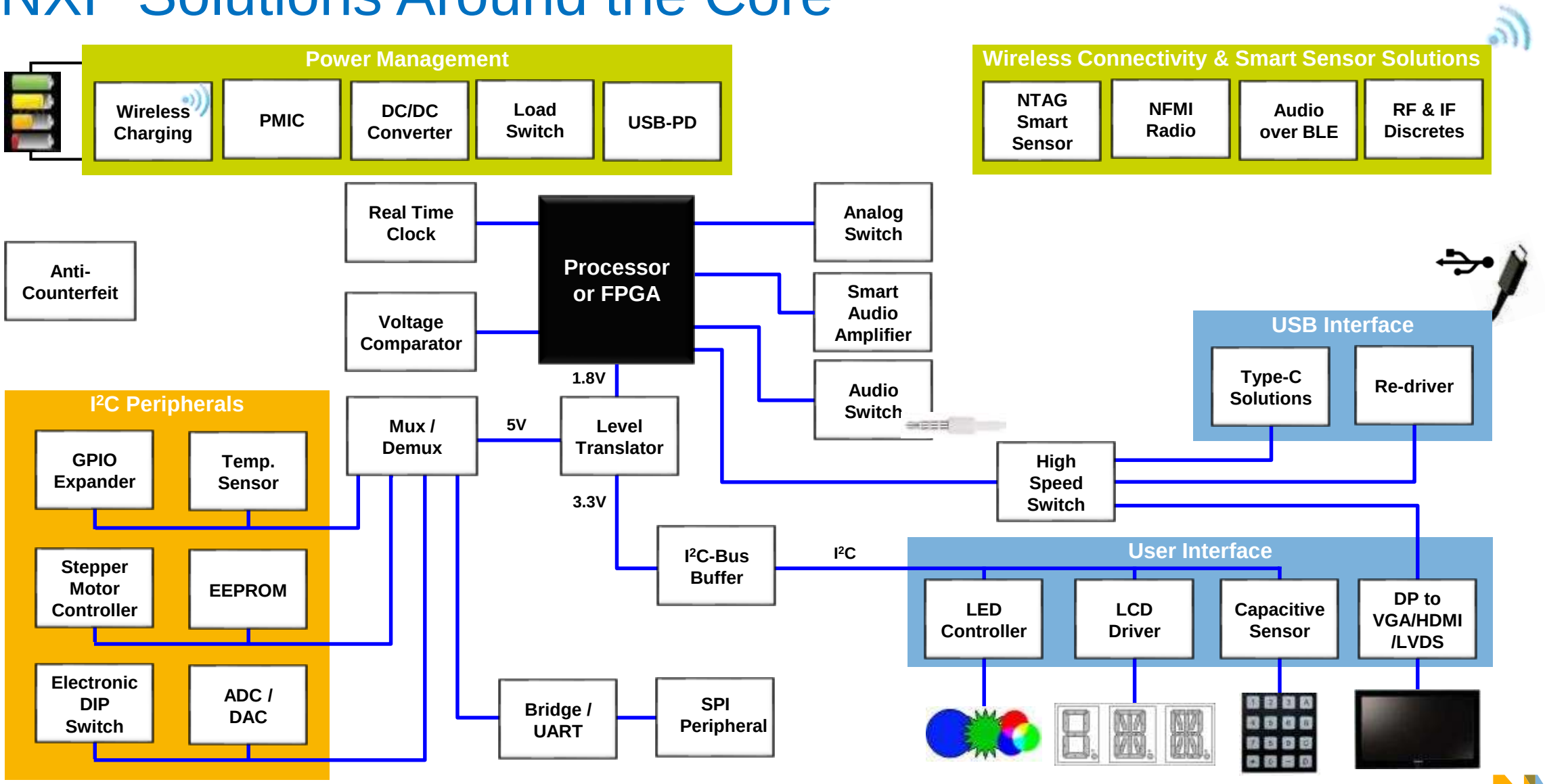
SECURE CONNECTIONS
FOR A SMARTER WORLD

Agenda

- Introduction to Interface Solutions
- Signal Switches
- Voltage-Level Translators
- GPIO Expanders
- LED Controllers

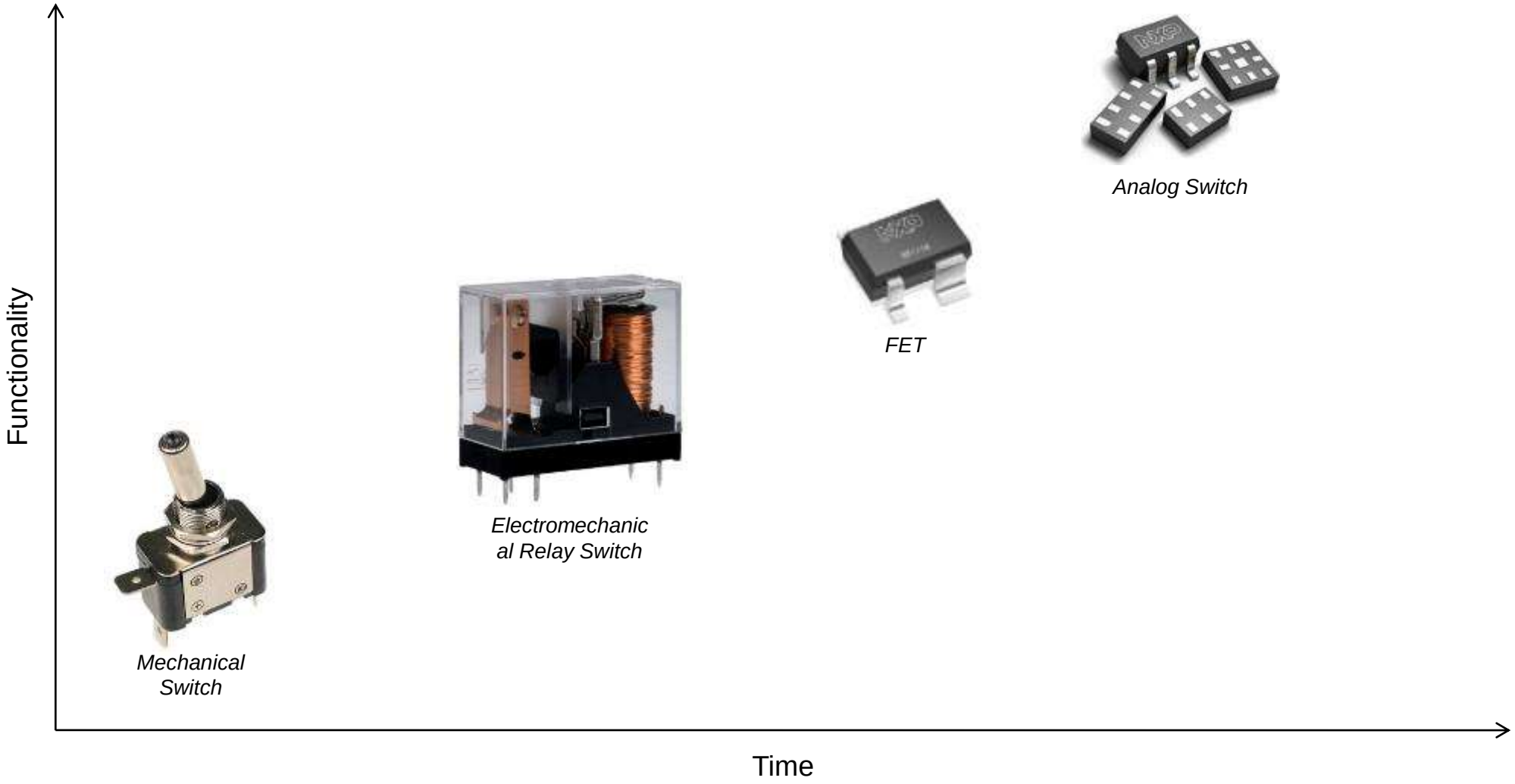
Introduction to Interface Solutions

NXP Solutions Around the Core



Signal Switches

The Evolution of Switches



Selecting a Switch – Critical Parameters

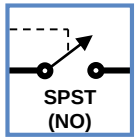
- Switch Configuration
  - SPST, SPDT, DPDT, etc.
  - Pick the configuration and number of controls pins for the application.
- Supply Voltage (V_{DD})
  - Bias voltage required to power the switch.
  - Lower V_{DD} means less head room to pass a signal.
  - Some applications like audio, may require negative voltage capability to maintain signal integrity.
- Switch Voltage (V_{SW})
  - Maximum voltage that can be applied at an input pin with respect to GND.
- Input Voltage Range (V_I)
  - The maximum voltage that can be applied at the control pin to GND.
- Bandwidth (f_{-3dB})
  - Frequency at which the signal is attenuated by -3dB from its DC level.
  - It represents the upper cutoff frequency of the switch.
  - The higher the bandwidth, the higher the data rate it can support.
- Enable & Disable Time (t_{en} / t_{dis})
  - Time it takes for the switch to change state (enabled or disabled) from the time the select pin has been triggered (asserted or de-asserted).
- ON Resistance (R_{ON} or R_{DS-ON})
  - Input-to-output resistance when the switch is closed.
  - The lower the R_{ON}, the less the signal passing through the switch will be attenuated.
  - R_{ON} will vary with voltage, temperature, and load current. A measure of this variation is $R_{ON(flat)}$. Selecting a low $R_{ON(flat)}$ means the device will minimize signal distortion.
- ON State Capacitance ($C_{S(ON)}$)
  - Equivalent capacitance of the switch when closed.
  - This capacitive loading of the line will affect overall bandwidth and drive current.
- Control Pin Threshold Levels (TTL versus CMOS)
  - Switches can be triggered at different threshold levels.
  - TTL trigger low and high levels are typically at 0.7V and 1.4V respectively. CMOS trigger low and high levels are at 30% and 70% of the supply voltage.
- Package Size
  - Based on layout constraints and application.

Switch Design Tradeoffs

It’s all about the size of the FET…..

– Lower R_{DSon} = bigger FET	➔ Higher capacitance = lower bandwidth
– Higher R_{DSon} = smaller FET	➔ Lower capacitance = higher bandwidth
– Higher current = bigger FET	➔ Higher capacitance = slower turn-on

Analog Switch Configurations and Nomenclatures



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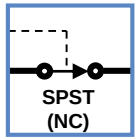

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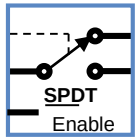

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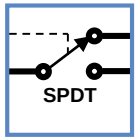

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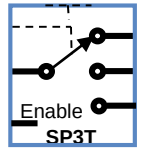

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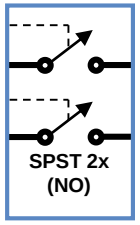

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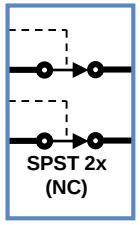

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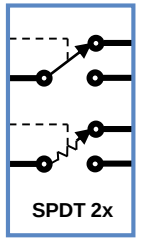

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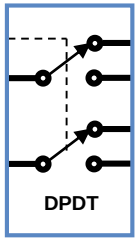
2267



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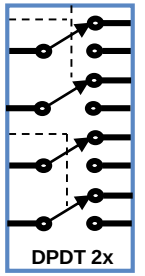
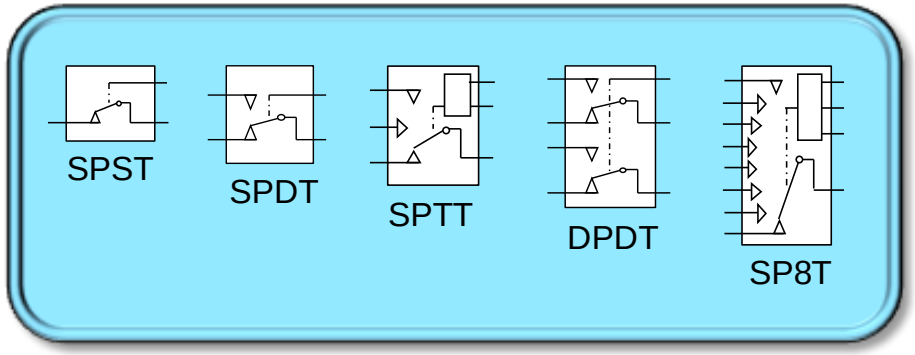


2467
2567
3899

NX3L Analog Switch Portfolio

Config	Device type	R_{ON} (Ω)	f_{-3dB} (MHz)	THD (%)	X-talk (dB)
1x SPST	NX3L1G66	0.75	60	0.024	-90
	NX3VT384	0.45	25	0.01	-90
2x SPST	NX3L2G66	0.75	60	0.024	-90
	NX3VT384	0.45	25	0.01	-90
1x SPDT	**NX3L1G3157GW-Q100**	0.75	60	0.024	-90
	NX3L1T3157	0.75	60	0.024	-90
	NX3L1G53	0.75	60	0.024	-90
	NX3L1T53	0.75	60	0.024	-90
2x SPDT	NX3L4684	0.8	60	0.01	-90
		0.5	25		
	NX3L2267GU-Q100	0.75	60	0.024	-90
2x DPDT or 4PDT	NX3L2467	0.75	60	0.02	-90
	NX3DV2567HR-Q100	9.5	330	-	-60
	NX3DV3899	4.5	200	0.01	-90
1x SPTT	NX3L4357	0.75	30	0.02	-90
1x SP8T	**NX3L4051HR-Q100** **NX3L4051PW-Q100**	0.75	15	0.02	-90
3x SPDT	**NX3L4053HR-Q100** **NX3L4053PW-Q100**	0.8	60	0.02	-90

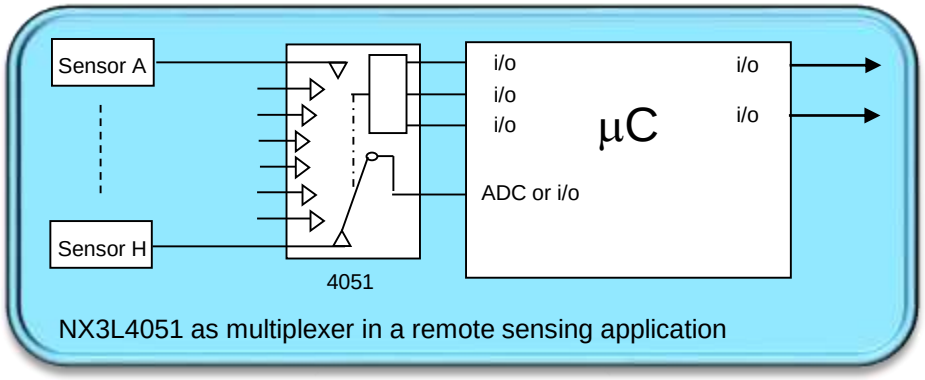
Devices listed in Blue are AEC-Q100 Qualified



Suffix	GW	GT	PW	BQ	GU
					
	SOT363	SOT833	SOT403	SOT763	SOT1161
	6-pin	8-pin	16-pin	16-pin	16-pin
Width (mm)	2.10	1.00	6.40	2.50	1.80
Length (mm)	2.00	1.95	5.00	3.50	2.60
Pitch (mm)	0.65	0.50	0.65	0.50	0.40

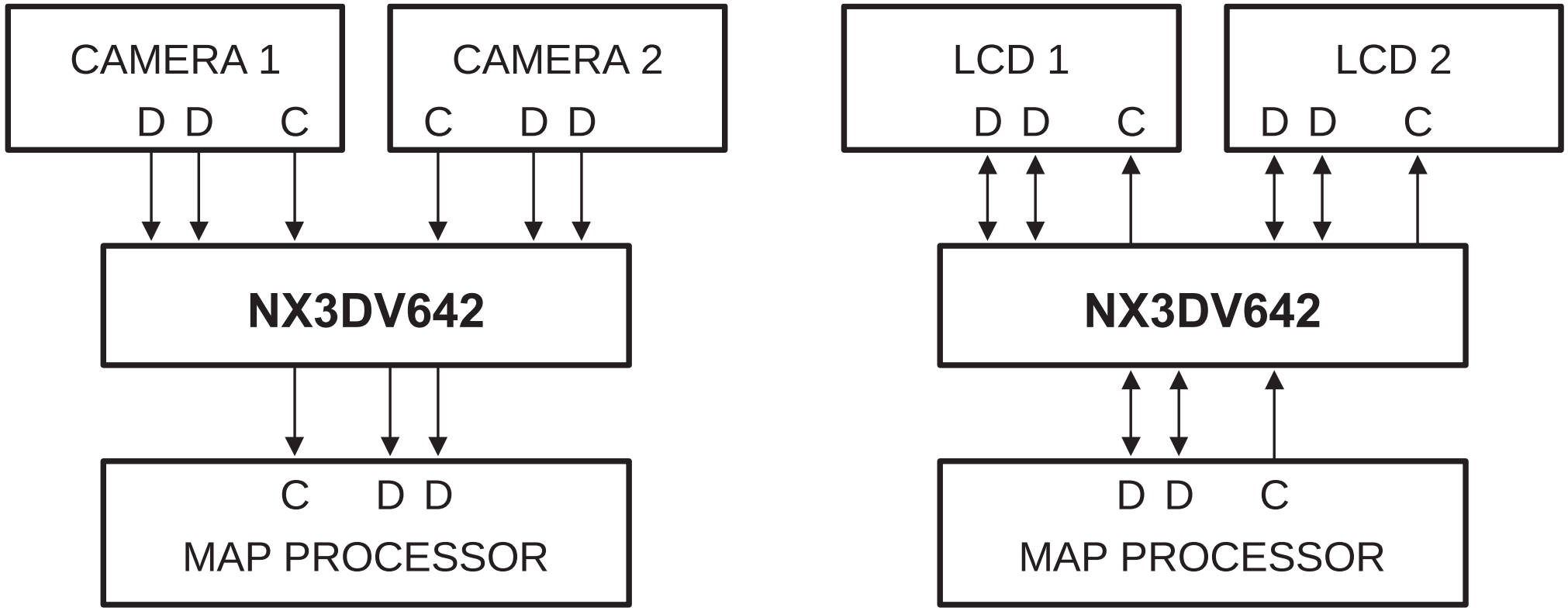
Analog Sensing Application Example with NX3L4051

- Multiple analog sensors are used in chassis & safety functions
  - Climate control (temperature)
  - Collision prevention (proximity)
  - Passenger detection (pressure)
  - Steering (angle)
  - Windshield wipers (humidity)
- Analog multiplexers are used to
  - Reduce number of microcontrollers (ADC) required
  - Enable use of lower cost (lower pin count) microcontrollers
- Feature Low leakage (IS(ON) < 50 nA @ 85°C)
  - Reduces the inaccuracy introduced by multiplexing

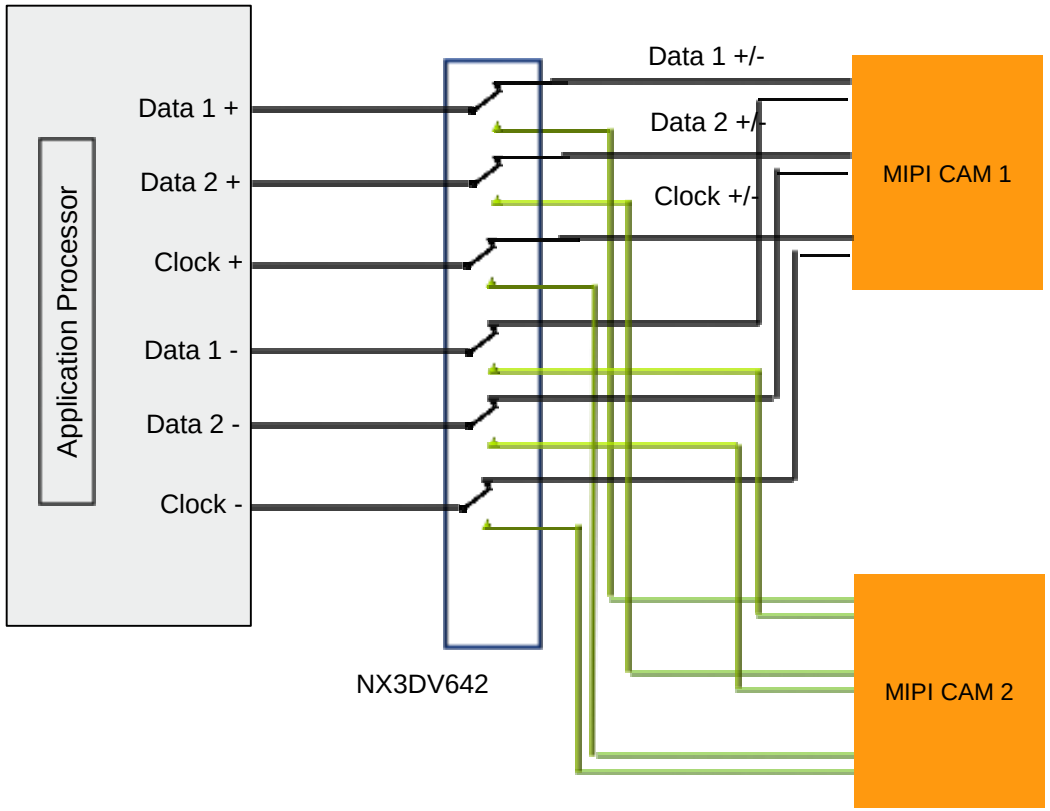


NX3L4051 as multiplexer in a remote sensing application

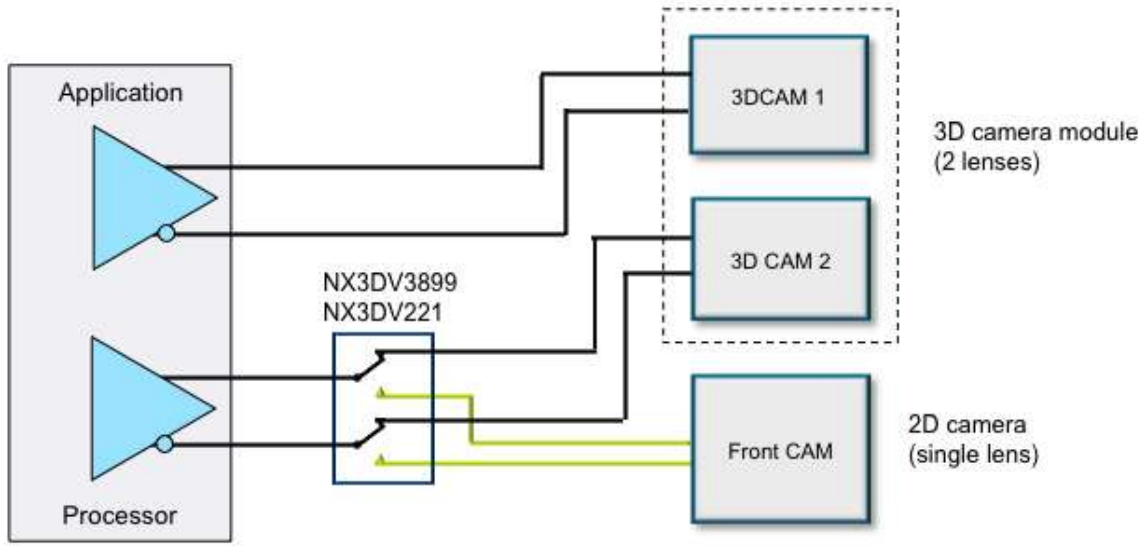
MIPI Application Example – Dual Signal Switching



MIPI Camera – Dual Camera & 3D Camera Applications



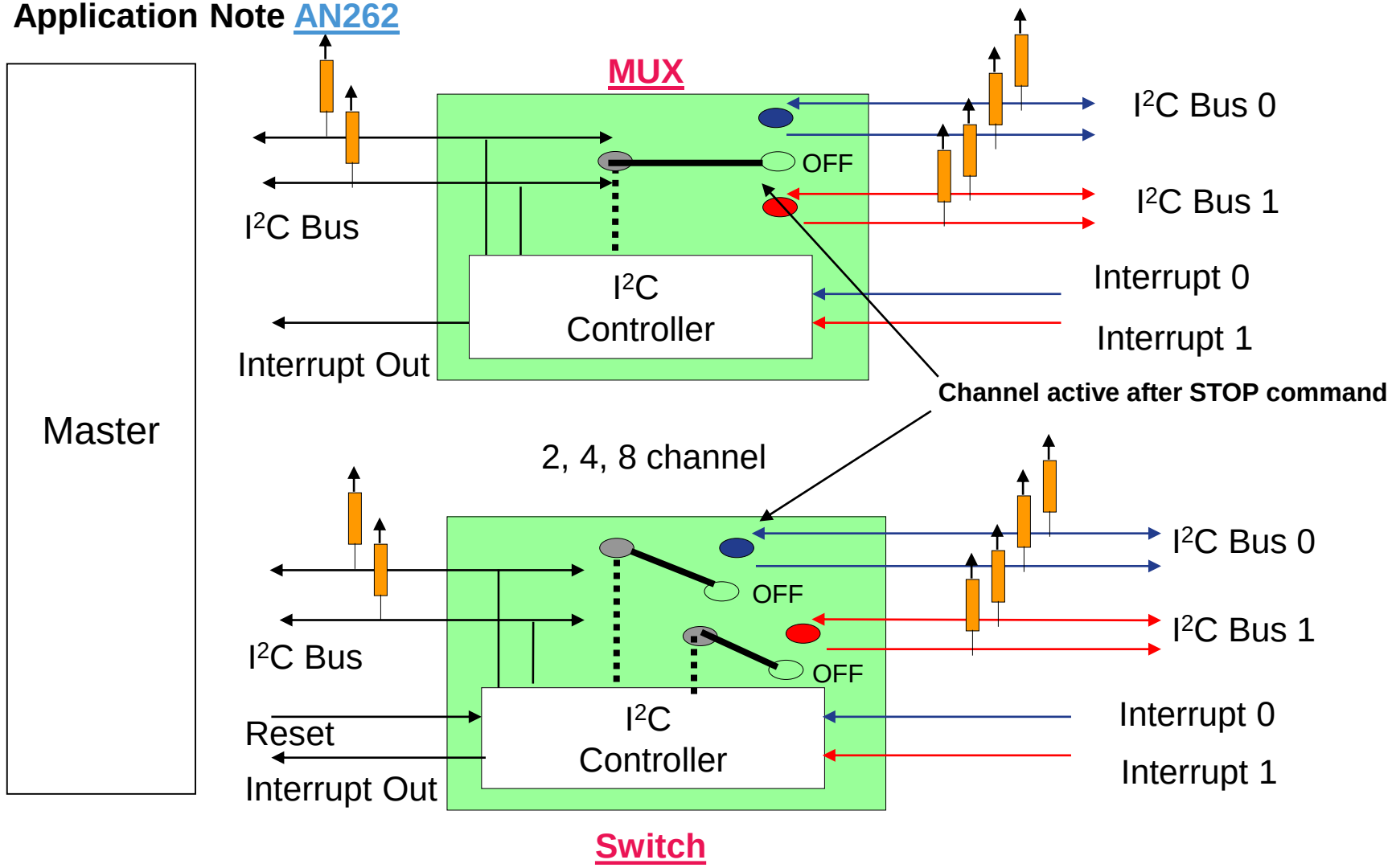
- MIPI cameras requiring four data signals and 2 clock signals can be supported with dual 3 port switch such as NX3DV642.



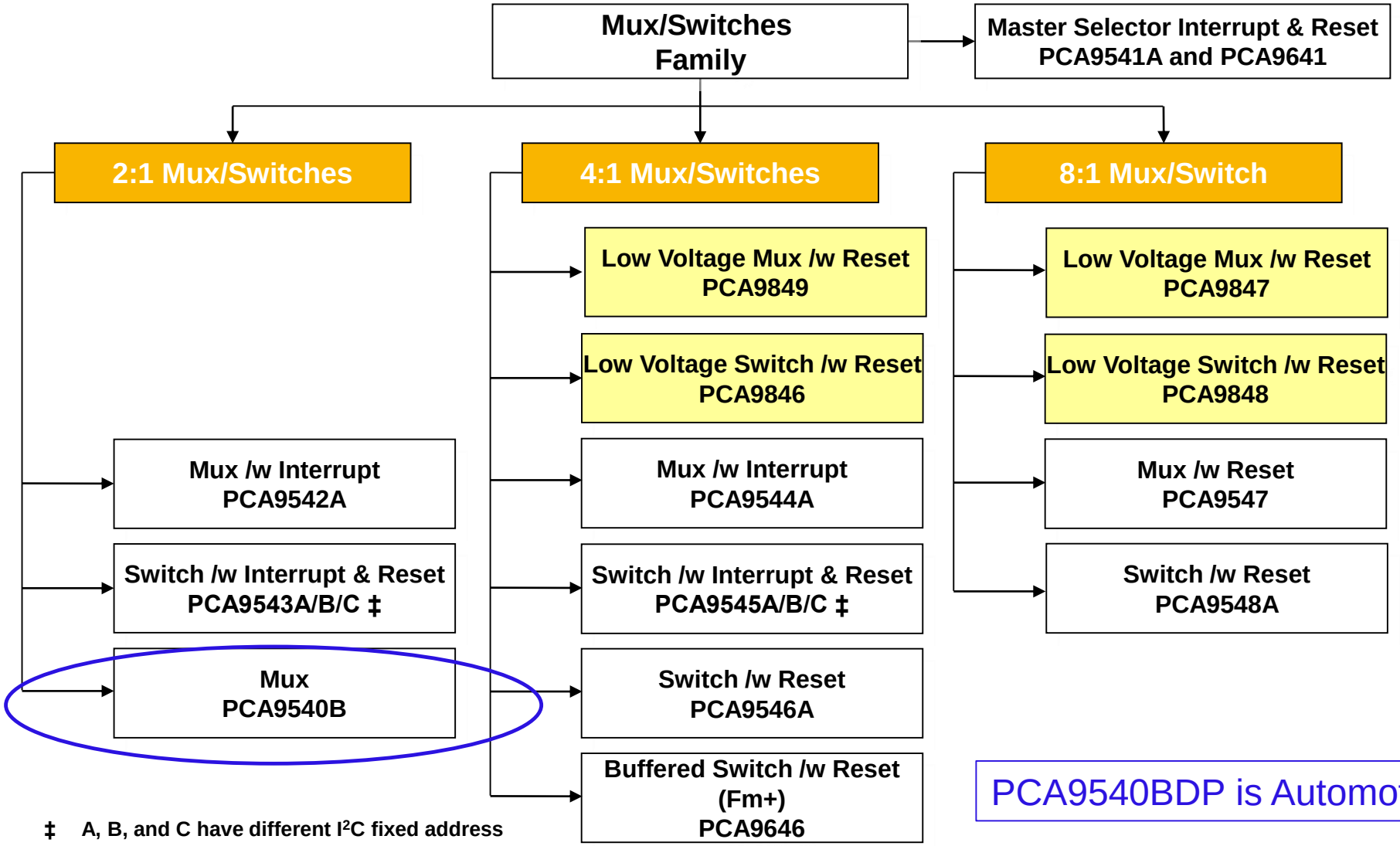
- NX3DV3899 & NX3DV221/42 can be used for 3D camera systems that use a second regular camera.
- 3D camera requires 2 lenses, and occupy both I/O of the processor.
- Utilizing a high speed switch allows to also activate a second camera for video conferencing application when only 2 I/Os are available.

Mux & Switches for I²C-Bus Applications

Application Note AN262



Mux & Switches for I²C-Bus Applications



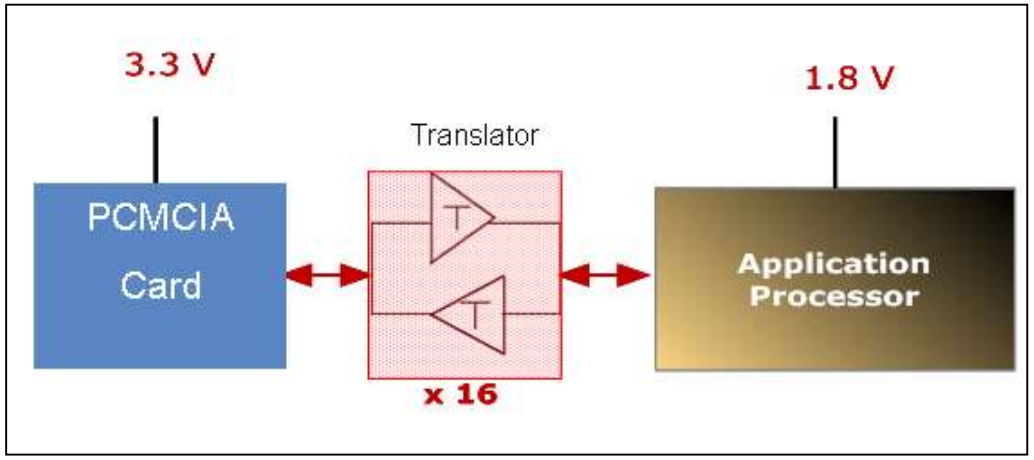
‡ A, B, and C have different I²C fixed address

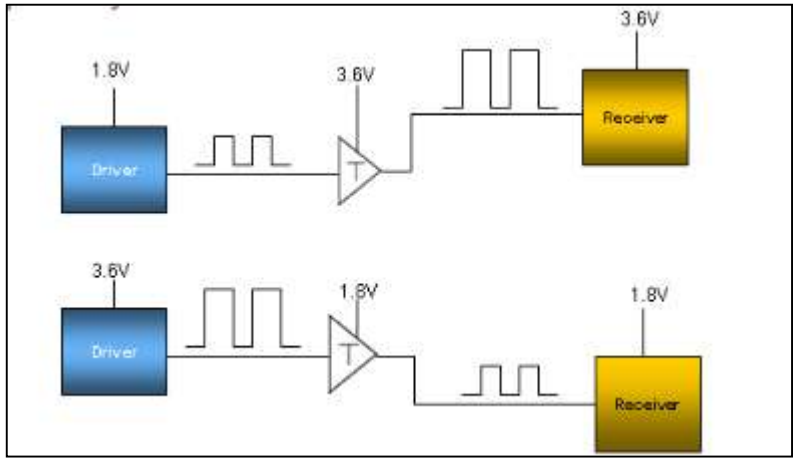
PCA9540BDP is Automotive Qualified

Voltage-Level Translators

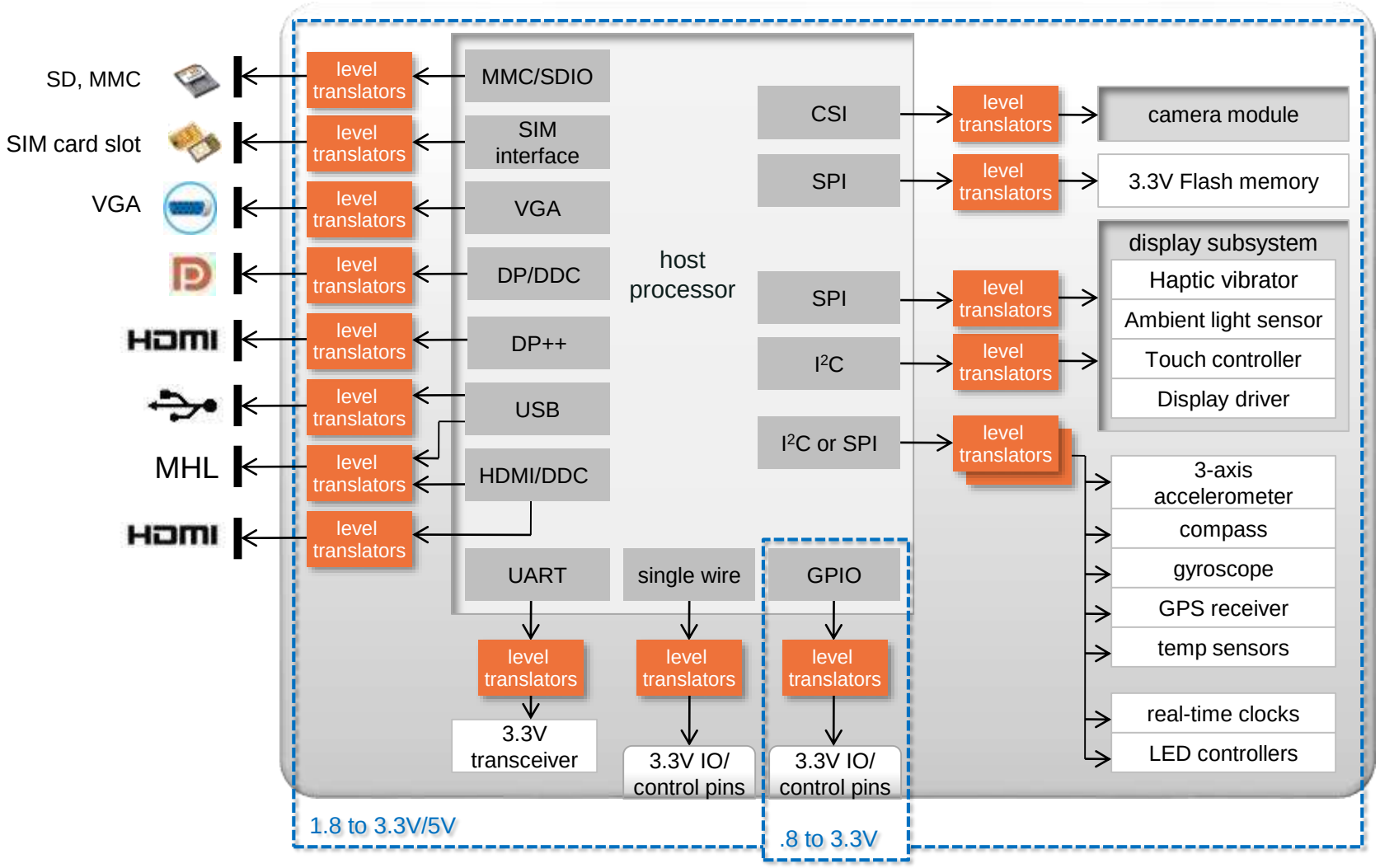
Why Voltage Level Translators are Needed

- New designs/applications use lower supply voltage i.e. 3.0V or lower
- All the devices used in a design/application do not use same supply voltage
- A newly designed CPU, uses a lower voltage e.g. 1.8V but a proven old peripheral uses higher supply voltage e.g. 3.3V. Memory devices, image sensors, PCMCIA cards, RF transceivers are some peripheral examples.
- Voltage-Level Translator is used to prevent the current flow in mismatched voltage supplies





Wide Selection of Voltage Level Translators



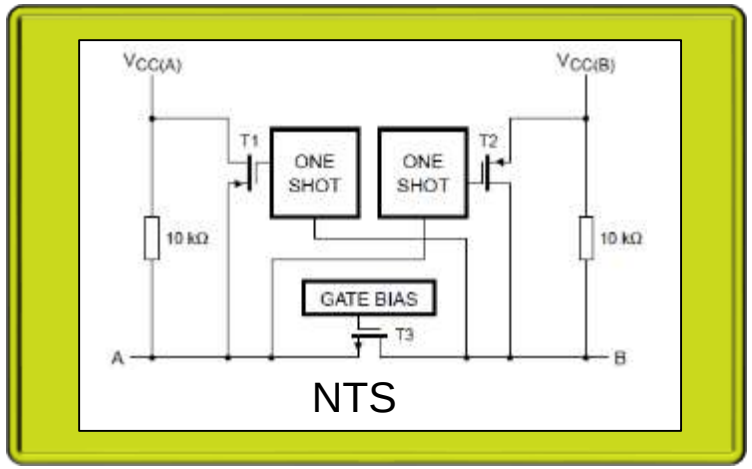
NTS & NTB Family of Auto-Direction Sensing Translators

Features

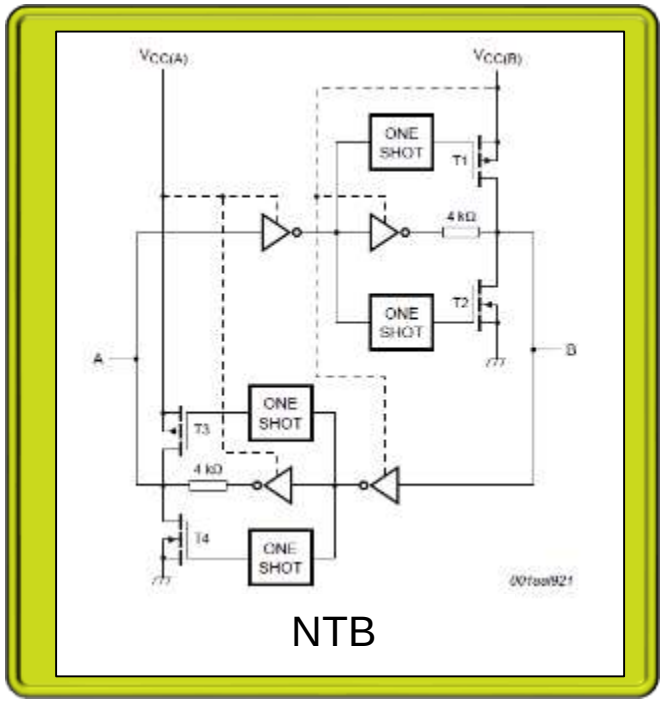
- Flow through architecture
- Auto direction sensing
- High speed (t_{PD} = 3.2 ns typ.)
- Low power dissipation (C_{PD} = 10 pF typ.)
- 3-state outputs
- AEC Q100, grade 1
- 8 kV ESD IEC61000-4-2 contact
- Fully specified (–40 to 85 and –40 to 125°C)
- Pb-free, RoHS and Dark Green compliant

Automotive Qualified Versions:

NTB0102DP-Q100
NTB0102GD-Q100
NTB0104BQ-Q100
NTB0104UK-Q100
NTS0102DP-Q100
NTS0102GD-Q100
NTS0104BQ-Q100
NTS0104PW-Q100



NTS

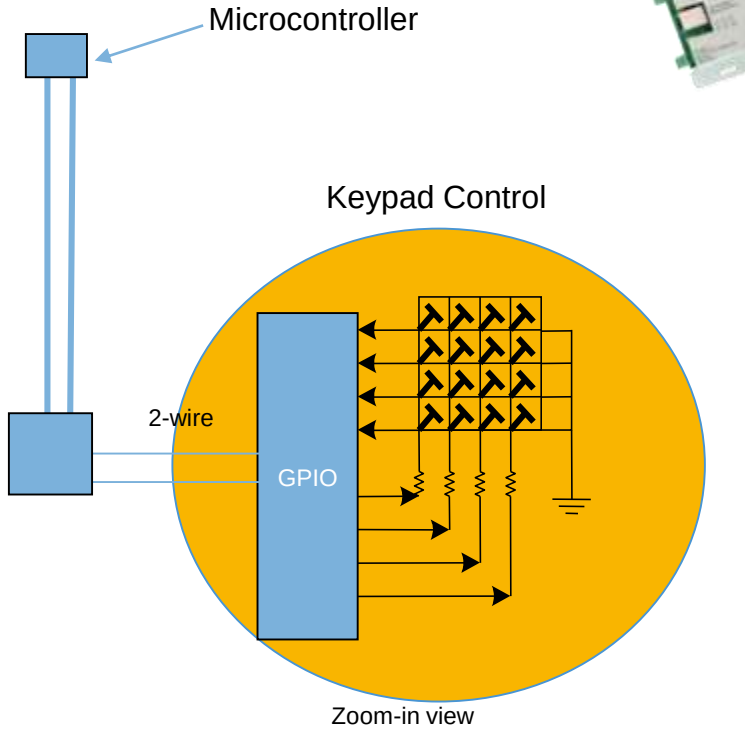


NTB

GPIO Expanders

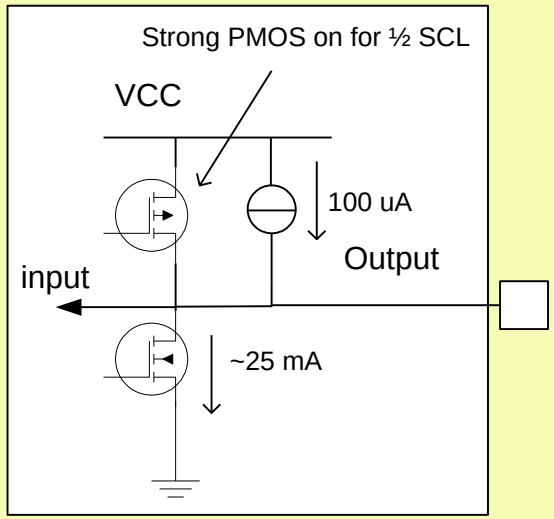
GPIO Expanders Overview

- Why used?
  - Easily adds I/O via I2C-bus
  - Additional inputs for keypad, switch, signal monitoring, etc.
  - Additional outputs for LED control, relay, timers and sensor
- Where used?
  - Automotive
  - Computing
  - Industrial Controls
  - Medical Equipment
  - Cell Phones
  - Gaming Machines
- Why NXP GPIOs?
  - Largest selection of 4, 8, 16 and 40-bit GPIO in Quasi-bidirectional and Push-pull outputs with Interrupt and/or reset in a wide range of packages
  - Invented the I2C-bus. Continuously developing newer devices with added features to support different applications.



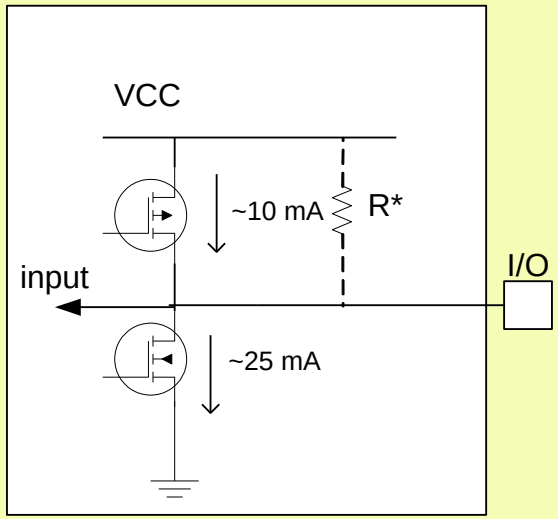
Flexible I/O (Output) Structures

Quasi Output



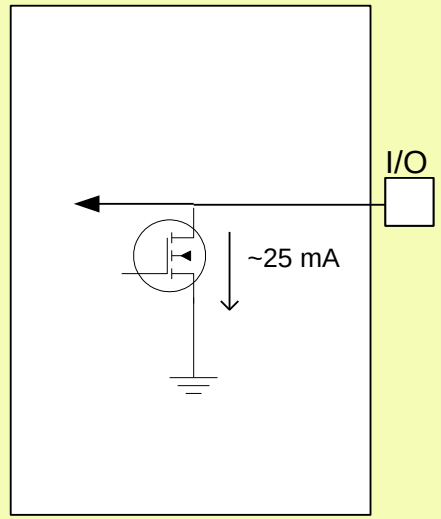
- Strong PMOS transistor is turned on only during the LH transition
- PMOS transistor is off during static drive
- Weak current source at the output

Totem-Pole Output



- Upper PMOS transistor is turned on during static high drive
- Some devices have weak pull-ups at the output

Open-Drain Output



- No upper PMOS transistor
- No pull-up resistor
- No weak current drive

GPIO Expanders with Totem-Pole Output Structure

BITS	V RANGE	BW	RESET	INT	I/O PULL-UP	NOTES	PART#
4	2.3 to 5.5V	400 kHz	NO	NO			PCA9536
			YES	YES			PCA9537
8	2.5 to 3.6V	400 kHz	YES	YES		SPI & I^2C	PCA9502
	2.3 to 5.5V			YES			PCA9534
	2.3 to 5.5V		YES	YES		Open Drain Interrupt output	PCA9538
	2.3 to 5.5V			YES	100 KΩ	Use PCA9554A for alternate I^2C address	PCA9554/A
	2.3 to 5.5V		YES				PCA9557
	1.1 to 3.6V		YES	maskable	prog. PU / PD or bus hold	low voltage, 2 supplies for level trans. selectable open drain	PCA9574
16	2.3 to 5.5V	400 kHz	NO	YES			PCA9535
	2.3 to 5.5V		YES	YES			PCA9539
	2.3 to 5.5V					"R" version resets I^2C-bus state machine	PCA9539R
	2.3 to 5.5V			YES	100 KΩ		PCA9555
	1.1 to 3.6V		YES	maskable	prog. PU / PD or bus hold	Active low, low voltage, 3 supplies for level trans., selectable open drain	PCA9575
40	2.3 to 5.5V	400 kHz	YES	YES	100 KΩ	Output enable	PCA9505
			YES	YES		Output enable	PCA9506
	2.3 to 5.5V	1 MHz	YES	YES		Output enable, selectable open drain	PCA9698
LOW VOLTAGE							
8	1.65 to 5.5V	400 kHz	YES	YES		Low standby current: 1.5 µA typ at 5V supply; 1.0 µA typ at 3.3V supply	PCA9538A
				YES	100 KΩ	Use PCA9554C for alternate I^2C address	PCA9554B/C
			YES	YES		Standby current: 3 µA max dual V_{CC}	PCA6408A
16	1.65 to 5.5V	400 kHz	NO	YES		Low standby current: 1.5 µA typ at 5V supply; 1.0 µA typ at 3.3V supply	PCA9535A
			YES	YES			PCA9539A
			YES	100 KΩ			PCA9555A
			YES	YES		Dual $V_{CC;}$ low standby current: 1.5 µA typ at 5V supply; 1.0 µA typ at 3.3V supply	PCA6416A

GPIO Expanders with Quasi Output Structure

BITS	V RANGE	BW	RESET	INT	I/O PULL-UP [1]	NOTES	PART#
8	2.5 to 6.0V	100 kHz	NO	YES	weak PU		PCF8574/A
	2.3 to 5.5V	400 kHz	NO	YES	weak PU		PCA8574/A
	2.2 to 3.6V	400 kHz	NO	NO	weak PU	2 Kb EEPROM	PCA9500
		400 kHz	NO	YES	weak PU	2 Kb EEPROM	PCA9501
	2.3 to 5.5V	1 MHz	YES	NO	weak PU		PCA9670
		1 MHz	YES	YES	weak PU		PCA9672
		1 MHz	NO	YES	weak PU		PCA9674/A
16	4.5 to 5.5V	400 kHz	NO	YES	weak PU		PCF8575
	2.3 to 5.5V	400 kHz	NO	YES	weak PU		PCA8575
	2.3 to 5.5V	1 MHz	YES	NO	weak PU		PCA9671
		1 MHz	YES	YES	weak PU		PCA9673
		1 MHz	NO	YES	weak PU		PCA9675

Note [1]: The Quasi-outputs have a strong pull-up (transistor) to V_{DD} to allow fast rising edges into heavy loaded outputs. The devices with weak pull-ups have a 100-µA current source to V_{DD}.

GPIO Expanders with Open-Drain Output Structure

- No upper PMOS transistor
- Prevent current leakage through protection diode

BITS	V RANGE	BANDWIDTH	RESET	INTERRUPT	I/O Pull-Up	NOTES	PART(S)
8	3.0 to 3.6V	400 kHz	NO	NO	weak PU	2 Kb EEPROM, with 5-bit mux, 1-bit latch DIP SWITCH	PCA9558
16	2.3 to 5.5V	400 kHz	NO	YES			PCA9535C
	4.5 to 5.5V		NO	YES			PCF8575C

GPIO Expanders with Agile I/O (PCALxxxx)

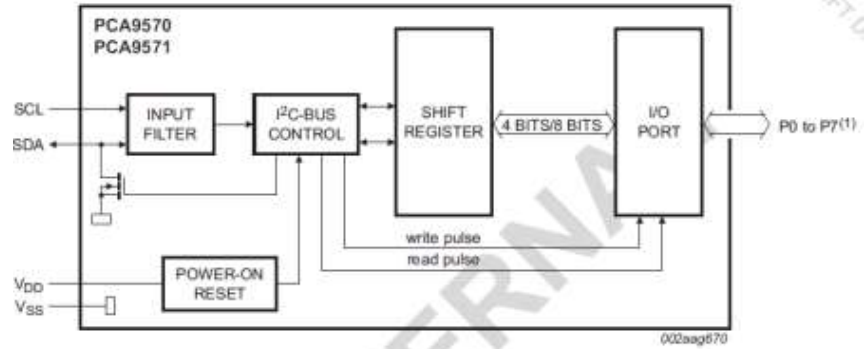
- Operate down to 1.65V and Up to 5.5V
- PCAL95XX are pin-to-pin compatible with PCA95xx devices
- Features input latch, /INT mask and other new Agile IO features

	BITS	V RANGE	BW	RESET	INT	I/O PULL-UP	NOTES	PACKAGE	PART#
	8	1.65 to 5.5V	400 kHz	YES	YES	programmable	single V_{CC}	HVQFN16, TSSOP16	PCAL9554B PCAL9554C
				YES	YES	programmable	single V_{CC}	HVQFN16, TSSOP16	PCAL9538A
				YES	YES	programmable	dual V_{CC}	HVQFN16, TSSOP16, XQFN16, XFBGA16	PCAL6408A
	16	1.65 to 5.5V	400 kHz		YES	programmable	single V_{CC} & advanced IO	HWQFN24, TSSOP24	PCAL9555A
					YES	programmable	single V_{CC} & advanced IO	HWQFN24, TSSOP24	PCAL9535A
				YES	YES	programmable	single V_{CC} & advanced IO	HWQFN24, TSSOP24	PCAL9539A
				YES	YES	programmable	Voltage Level Translation	TSSOP24, HWQFN24, 24-pin BGA (XFBGA, VFBGA & UFBGA)	PCAL6416A
NEW	24	0.8 to 3.6V	1 MHz	YES	YES	programmable	Additional Agile I/O features	QFN32, TSSOP32, UFBGA32	PCAL6524

Small, Low-Cost, Low-Voltage GPO Expander

Features

- 1.1 V to 3.6 V operation with 4- or 8-bit, 4mA push-pull outputs
- 1 MHz I2C-bus interface with 6mA SDA sink capability for lightly loaded buses and improved power consumption
- Compliant with the I2C-bus Fast and Standard modes
- Readable device ID (manufacturer, device type, and revision)
- Software Reset and power-on reset
- Low standby current
- −40°C to +85°C operation
- ESD protection exceeds 2000 V HBM per
  - JESD22-A114 and 1000 V CDM per
  - JESD22-C101
- Latch-up testing is done to JEDEC standard
  - JESD78 which exceeds 100 mA
- Packages offered: XQFN8 and XQFN12



(1) P0 to P7 for PCA9571; P0 to P3 for PCA9570.

Part Number	Package Type	Package Description	Version
PCA9570GM4 (In Dev)	XQFN8	plastic, extremely thin quad flat package; no leads; 8 terminals; body 1.20 × 1.40 × 0.50 mm; 0.4mm pitch	SOT1309-1
PCA9570GM	XQFN8	plastic, extremely thin quad flat package; no leads; 8 terminals; body 1.6 × 1.6 × 0.5 mm; 0.5mm pitch	SOT902-2
PCA9571GU	XQFN12	plastic, extremely thin quad flat package; no leads; 12 terminals; body 1.70 × 2.00 × 0.50 mm; 0.4mm pitch	SOT1174-1

AEC-Q100 Qualified GPIO Expanders

PCA9554PW/Q900 released

- IO Expander 8x; Interrupt; -40°C to +85°C; TSSOP16 ; AEC-Q100 compliant automotive qualification

PCA9538PW/Q900 released

- 8-bit I2C-bus and SMBus I/O port with interrupt and reset; -40°C to +125°C; TSSOP16; AEC-Q100 compliant automotive qualification

PCA9539PW/Q900 released

- 16-bit I2C-bus and SMBus I/O port with interrupt and reset; -40°C to +125°C; TSSOP24; AEC-Q100 compliant automotive qualification

PCA9703PW/Q900 released

- General Purpose Input (GPI); 16x; SPI; up to 18V tolerant; maskable inputs; -40°C to +85°C; TSSOP24; AEC-Q100 compliant automotive qualification

PCA9704PW/Q900 released

- General Purpose Input (GPI); 8x; SPI; up to 18V tolerant; maskable inputs; -40°C to +125°C; TSSOP16; AEC-Q100 compliant automotive qualification

LED Controllers

LED Controller Portfolio

Voltage-Source LED Controllers

Number of Outputs	LED Blinkers (25mA / 5V)	LED Dimmers (25mA / 5V)	Color Mixing LED Controllers (25mA / 5V)	Color Mixing LED Controllers (100mA / 40V)
2	PCA9550	PCA9530		
4	PCA9553	PCA9533	PCA9632 [1] PCA9633	
8	PCA9551	PCA9531	PCA9634	PCA9624
16	PCA9552	PCA9532	PCA9635 [3] PCA9685 [2] [3]	PCA9622
24				PCA9626

[1] Low power version of PCA9633
[2] The PCA9685 has 12-bit PWM while the PCA9635 has 8-bit PWM
[3] AEC-Q100 qualified

Current-Source LED Controllers

Device	# of Outputs	F_{osc}	Output Current	Active-Low /OE	Interface
PCA9952 [1]	16	8MHz	5mA ~ 57mA	Yes	Fm+ I^2C; 8 Addresses
PCA9955 [1]	16	8MHz	5mA ~ 57mA		Fm+ I^2C; 16 Addresses
PCA9955B [1]	16	8MHz	225µA ~ 57mA	Yes	Fm+ I^2C; 125 Addresses
PCA9745B [1]	16	8MHz	225µA ~ 57mA	Yes	Serial-Shift; No Address
PCA9755B [1]	16	8MHz	225µA ~ 57mA	Yes	SPI; 25 Addresses
PCA9956B	24	8MHz	225µA ~ 57mA	Yes	Fm+ I^2C; 125 Addresses

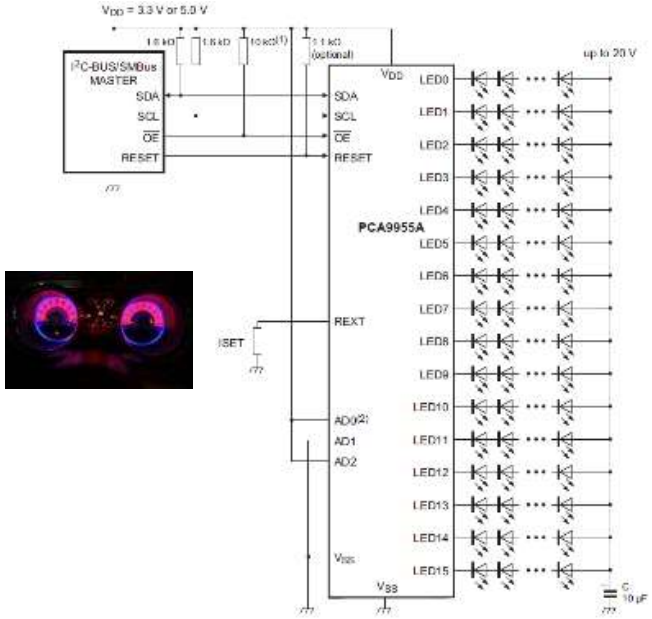
[1] AEC-Q100 Qualified

PCA9955B: 57mA 16-CH Constant-Current LED Controller

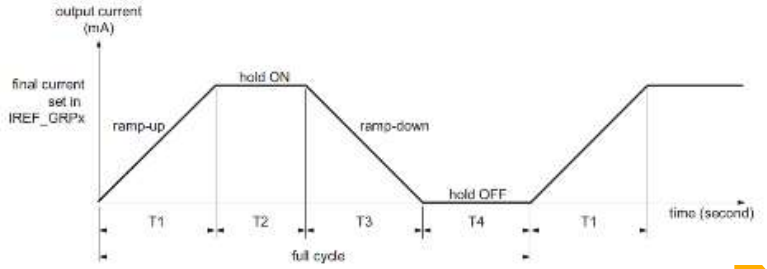
Features

- VCC = 3.0V to 5.5V
- Output
  - Constant current; Up to 57mA current drive/channel
  - 20V sustaining voltage
  - REXT sets ILED for all channels
  - ±4% channel-to-channel matching
  - ±6% IC-to-IC matching
  - 0.8V (typ) regulation voltage
  - 256:1 LED current peak adjustment
  - Gradation Control for all channels
    - Programmable step time from 0.5ms to 512ms
    - Programmable output current adjustment between linear and exponential curve
  - Real-time LED short or open detect
- Digital Interface
  - I2C (Fm+), 1 MHz (bi-directional)
  - Three quinary (five states) input address pins allow up to 125 devices to be connected on the same bus
  - Four software programmable I2C-bus addresses (one LED group call address and three LED sub call addresses)
- PWM Generator
  - 256:1 Individual PWM dimming range (31.25kHz)
  - 256:1 Global PWM dimming range (122Hz)
  - 256:1 Global blinking (0.05Hz to 15Hz)
  - Programmable phase shifting (125ns to1.875us)
- Over-Temperature Protection (150 ˚C typ)
- HTSSOP28 Package with Thermal Relief Pad

Simplified Applications Diagram



Gradation Control Timing

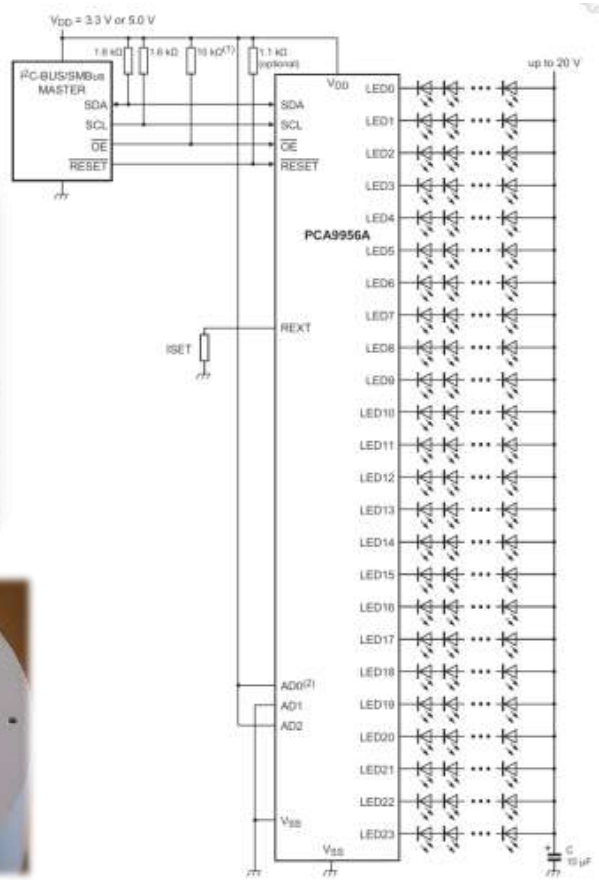


PCA9956B: 57mA 24-CH Constant-Current LED Controller

Features

- VCC = 3.0V to 5.5V
- Output
  - Constant current; Up to 57mA current drive/channel
  - 20V sustaining voltage
  - REXT sets ILED for all channels
  - ±4% channel-to-channel matching
  - ±6% IC-to-IC matching
  - 0.8V (typ) regulation voltage
  - 256:1 LED current peak adjustment
  - Real-time LED short or open detect
- Digital Interface
  - I2C (Fm+), 1 MHz (bi-directional)
  - Three quinary (five states) input address pins allow up to 125 devices to be connected on the same bus
  - Four software programmable I2C-bus addresses (one LED group call address and three LED sub call addresses)
- PWM Generator
  - 256:1 Individual PWM dimming range (31.25kHz)
  - 256:1 Global PWM dimming range (122Hz)
  - 256:1 Global blinking (0.05Hz to 15Hz)
  - Programmable phase shifting (125ns to1.875us)
- Over-Temperature Protection (150 ˚C typ)
- HTSSOP38 Package with Thermal Relief Pad

Simplified Applications Diagram



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