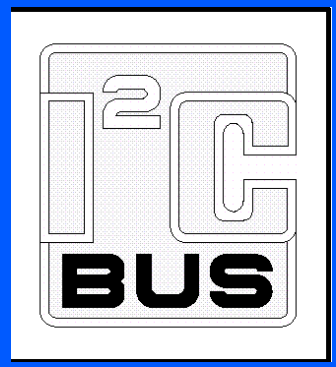
PHILIPS

I²C Device Overview

4Q 2002

Steve Blozis
I²C International Product Manager

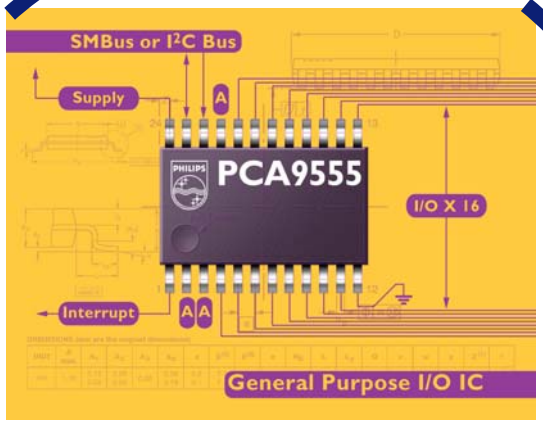


Agenda

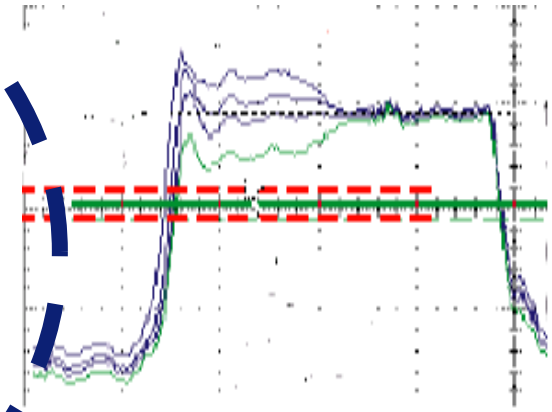
- **I²C Technology Overview**
- **I²C Product Overview**
- **Typical Applications**
- **Resources**

Philips I²C products are produced by several business lines including Logic Product Group - Specialty Logic Product Line, Standard Analog and Mobile Display Driver

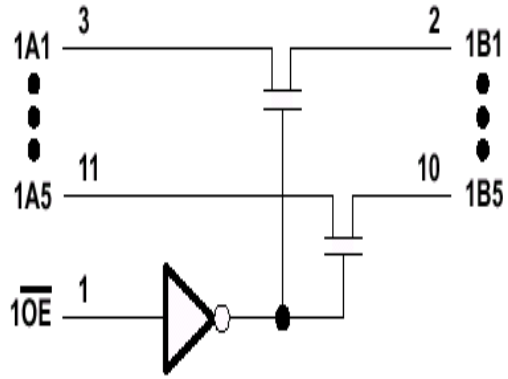
Product Family Overview - Specialty Logic



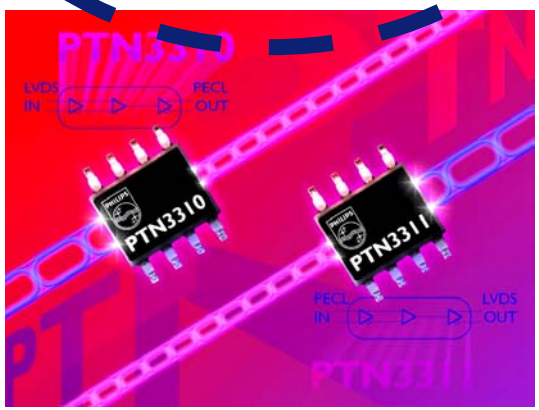
I²C (PCA and PCF)



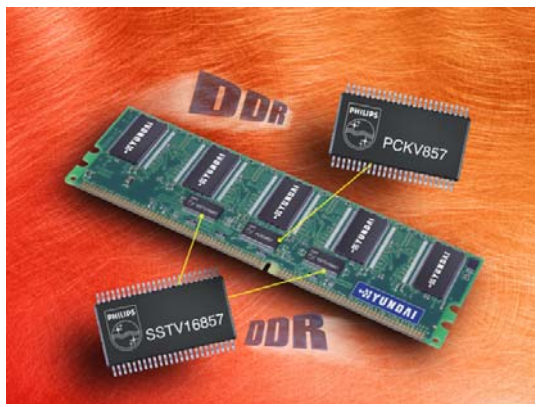
GTL and GTLP



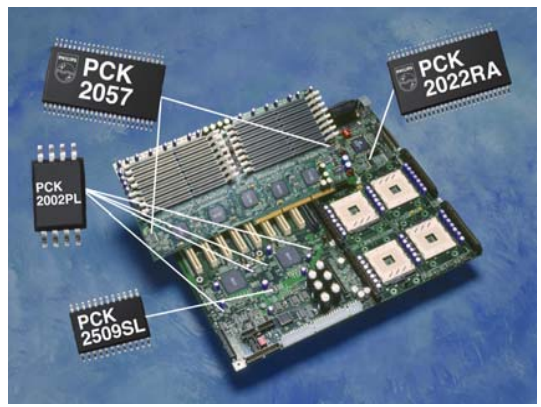
Bus Switch (CBT)



Translators (PTN)



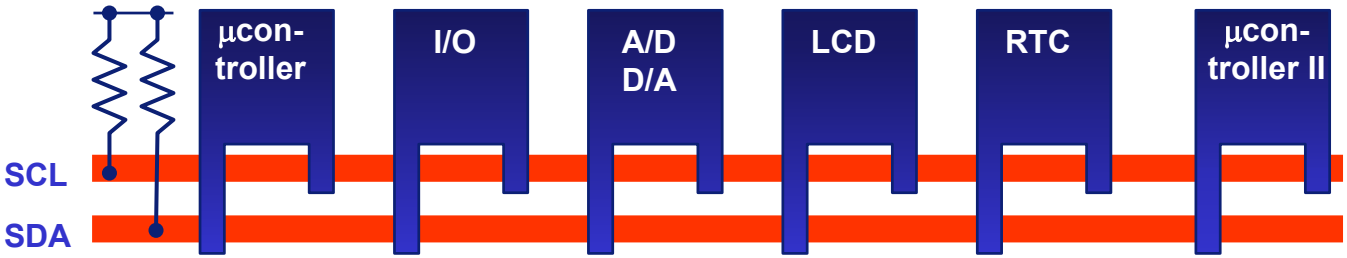
Memory Interface



Clocks (PCK)

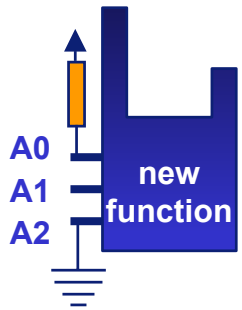
I²C Bus Basics - Address and Data

Data is transmitted at speeds of 100 kHz, 400kHz or 3.4 MHz.



Each device is addressed individually by software with a unique address that can be modified by hardware pins.

$1010A_2A_1A_0R/\overline{W}$



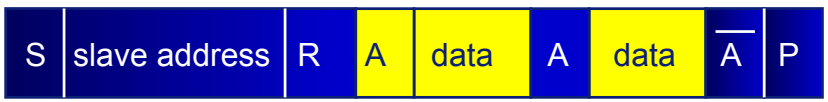
New devices or functions can be easily 'clipped on to an existing bus!

Write data

< n data bytes >

Master transmitter → Slave receiver

Read data



< n data bytes > last data byte

Master receiver → Slave transmitter

S = Start condition
A = Acknowledge
P = Stop condition

$R/\overline{W}$ = read / write not
$\overline{A}$ = Not Acknowledge

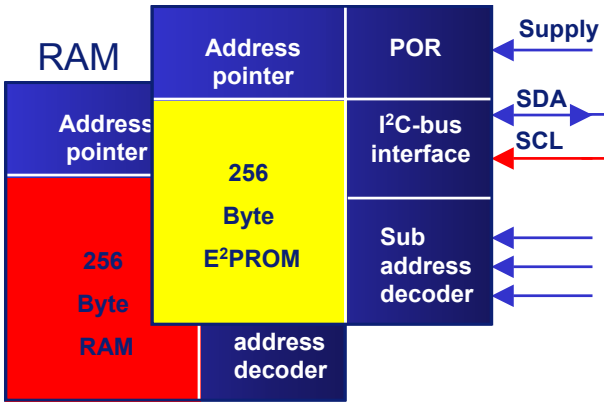
Philips Semiconductor I²C Devices Overview

- TV Reception
- Radio Reception
- Audio Processing
- Infrared Control
- DTMF
- LCD display control
- Clocks/timers
- General Purpose I/O
- LED display control
- Bus Extension/Control
- A/D and D/A Converters
- EEPROM/RAM
- Hardware Monitors
- Microcontroller

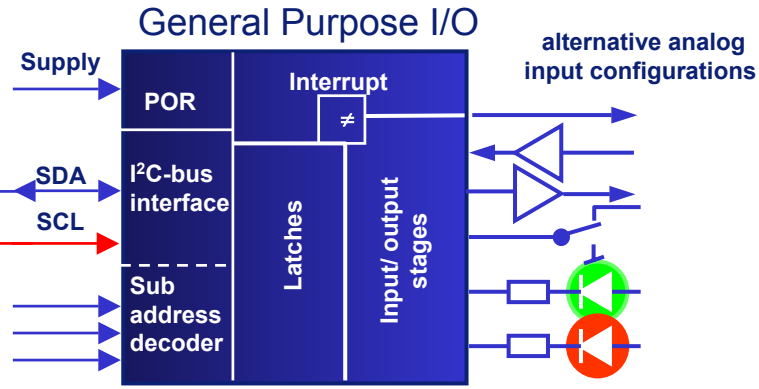
I²C devices are broken down into 14 different categories

Philips offers over 400 different I²C devices

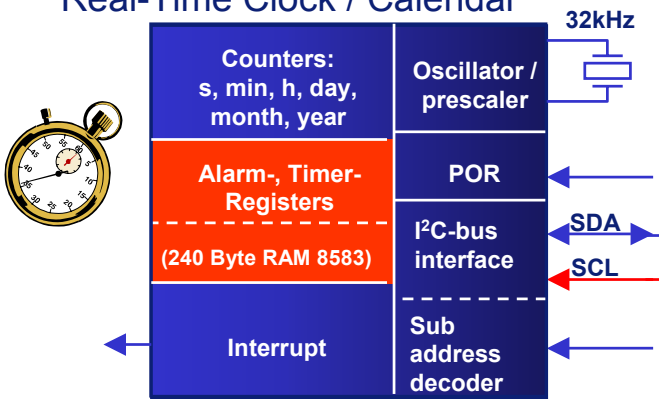
EEPROM



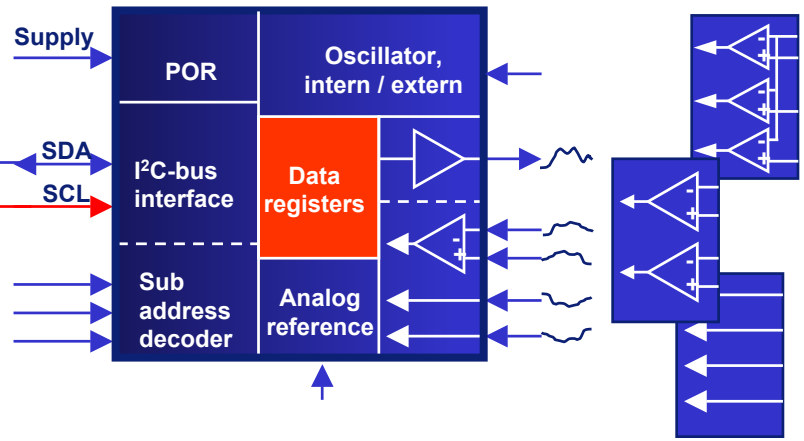
General Purpose I/O



Real-Time Clock / Calendar

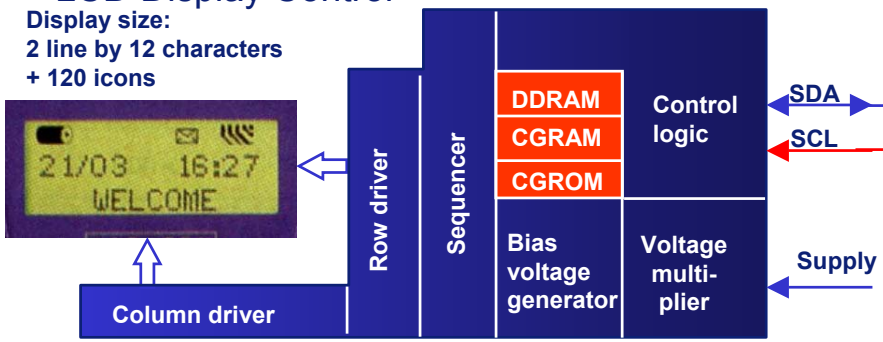


Analog to Digital Converter (ADC)



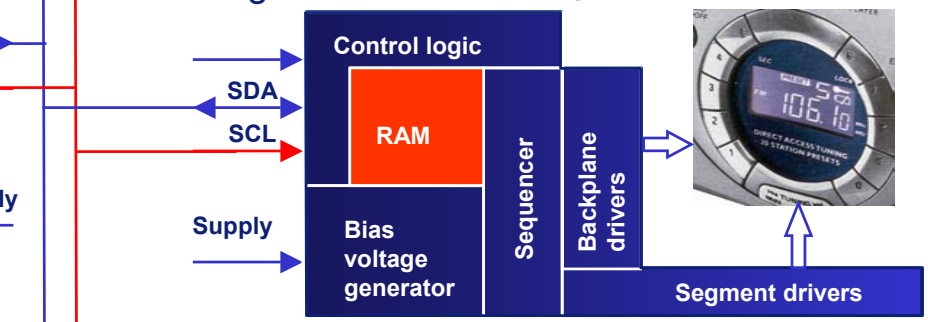
LCD Display Control

Display size:
2 line by 12 characters
+ 120 icons



LCD Segment Control

Display sizes single chip: 1 x 24 … 2 x 40… 4 x 40 ... 16 x 24



I²C Applications and Segments

Appliances	TV	Radio	Audio	Telephony	Industrial	Consumer	Automotive	Telecom	Server/PC
TV reception	•								
Radio reception		•							
Audio Processing	•	•	•	•	•	•	•	•	•
Infrared control	•	•	•		•	•	•	•	•
LCD display control	•	•	•	•	•	•	•	•	•
LED display control	•	•	•	•	•	•	•	•	•
DTMF				•	•	•		•	•
General Purpose I/O	•	•	•	•	•	•	•	•	•
Hardware Monitors	•	•	•	•	•	•	•	•	•
Bus Extension/Control	•	•	•	•	•	•	•	•	•
A/D and D/A converters	•	•	•	•	•	•	•	•	•
Clocks/timers	•	•	•	•	•	•	•	•	•
RAM	•	•	•	•	•	•	•	•	•
EEPROM	•	•	•	•	•	•	•	•	•
8-bit microprocessors	•	•	•	•	•	•	•	•	•
16-bit microprocessors	•				•	•	•	•	•

I²C devices can be used in many different applications and segments

I²C Bus Features

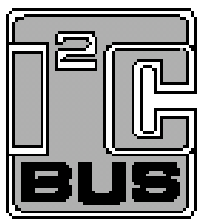
- Only two bus lines are required: a serial data line (SDA) and a serial clock line (SCL)
- Each device connected to the bus is software addressable by a unique address and simple master/slave relationships exist at all times; masters can operate as master-transmitters or as master-receivers
- It's a true multi-master bus including collision detection and arbitration to prevent data corruption if two or more masters simultaneously initiate data transfer.
- Serial, 8-bit oriented, bi-directional data transfers can be made at up to 100 kbit/s in the Standard-mode, up to 400kbits/s in the Fast-mode, or up to 3.4 mbit/s in the High-speed mode.
- On-chip filtering (50 ns) rejects spikes on the bus data line to preserve data integrity.
- The number of ICs that can be connected to the same bus is limited only be a maximum bus capacitance of 400 pF.

I^2C Designer Benefits

- Functional blocks on the block diagram correspond with the actual ICs; designs proceed rapidly from block diagram to final schematic.
- No need to design bus interfaces because the I^2C-bus interface is already integrated on-chip.
- Integrated addressing and data-transfer protocol allow systems to be completely software-defined.
- The same IC types can often be used in many different applications
- Design-time reduces as designers quickly become familiar with the frequency used functional blocks represented by I^2C -bus compatible ICs
- ICs can be added to or removed from a system without affecting any other circuits on the bus
- Fault diagnosis and debugging are simple; malfunctions can be immediately traced
- Software development time can be reduced by assembling a library of reusable software modules.

I²C Manufacturer Benefits

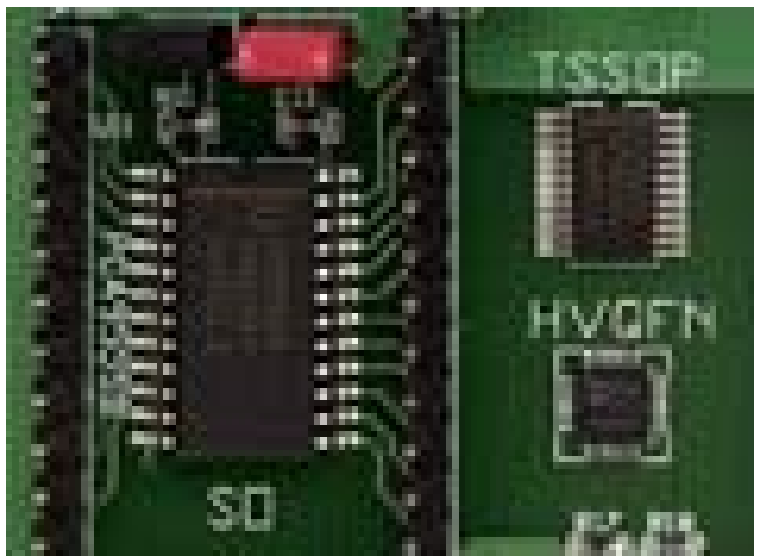
- The simple 2-wire serial I²C -bus minimized interconnections so ICs have fewer pins and there are not so many PCB tracks; result - smaller and less expensive PCBs
- The completely integrated I²C -bus protocol eliminates the need for address decoders and other 'glue logic'
- The multi-master capability of the I²C -bus allows rapid testing/alignment of end-user equipment via external connections to an assembly-line
- Increases system design flexibility by allowing simple construction of equipment variants and easy upgrading to keep design up-to-date
- The I²C-bus is a de facto world standard that is implemented in over 1000 different ICs (Philips has > 400) and licensed to more than 70 companies



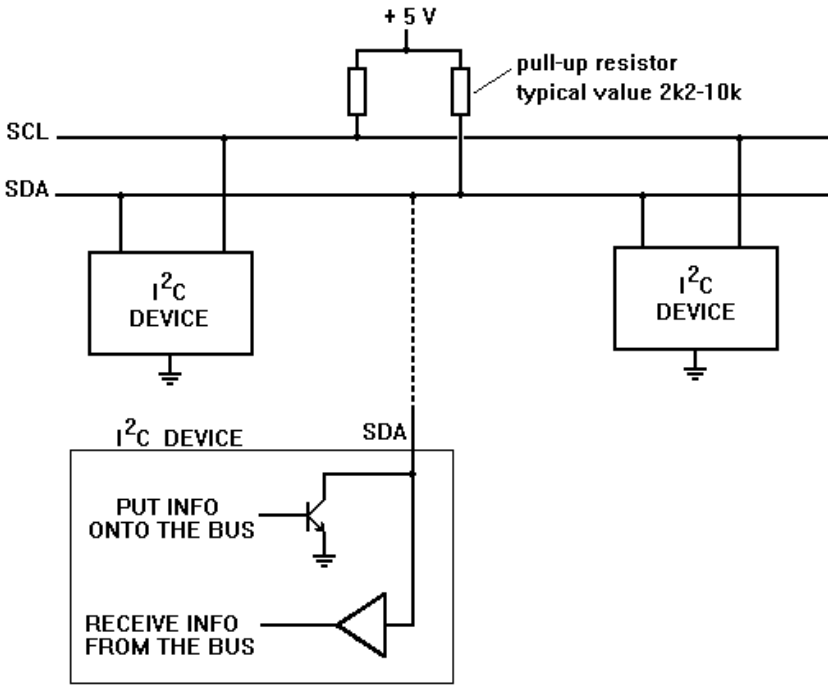
Purchase of Philips I²C components conveys a license under the Philips' I²C patent to use the components in the I²C system provided the system conforms to the I²C specification defined by Philips.

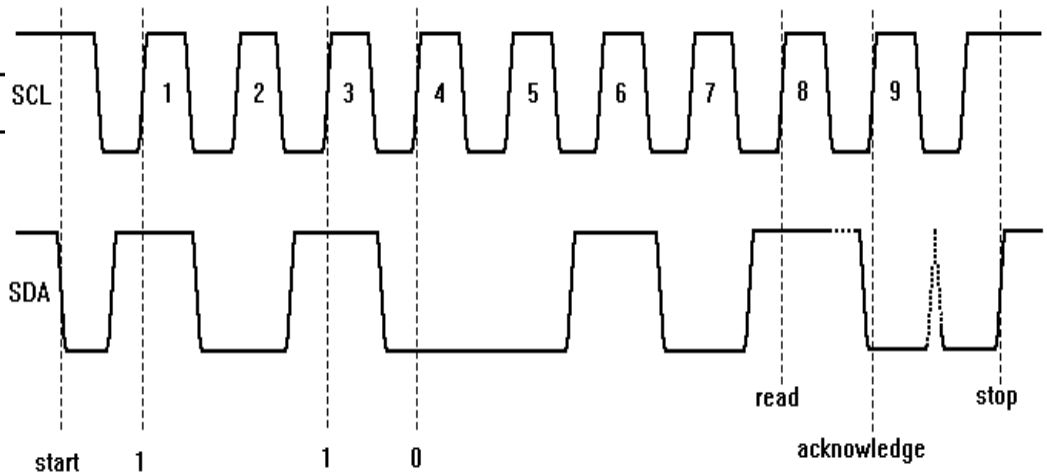
I²C Product Characteristics

- Frequency Range
  - Typically 100 kHz operation with newer devices up to 400 kHz
- Operating Supply Voltage Range
  - Newer devices at 2.3 to 5.5 V or 3.0 to 3.6 V with 5 V tolerance
- Operating temperature range
  - Typically -40 to +85 ºC with some 0 to +70 ºC or 0 to +120 ºC
- Hardware address pins
  - Typically three (A_O, A_1, A_2) are provided to allow up to eight of the identical device on the same I²C bus but sometimes due to pin limitations there are fewer
- Package Offerings
  - Typically DIP, SO, SSOP, QSOP or TSSOP packages are offered with newer devices offered in SO, TSSOP and HVQFN (24 pin shown)



I²C Bus Basics - Bus Operation





The SCL falling edge 'requests' data when reading, or 'advises' data coming when writing

The SDA data changes during the SCL low and is used during or just after the SCL rising edge

I²C bus hardware configuration

Typical bus communication waveforms

The I²C specification and other useful application information can be found on Philips Semiconductors I²C web site at www.semiconductors.philips.com/i2c

I²C Bus Vs SMBus

DC parameter comparison between Standard I²C, Fast I²C and SMBus devices								
Symbol	Parameter	Std I²C mode device		Fast I²C mode device		SMBus device		Units
		MIN	MAX	MIN	MAX	MIN	MAX	
V_{IL}	Fixed input level	-0.5	1.5	-0.5	1.5	-	0.8	V
	V_{DD} related input level	-0.5	$0.3V_{DD}$	-0.5	$0.3\ V_{DD}$	N/A	N/A	V
V_{IH}	Fixed input level	3.0	V_{DD}max+ 0.5	3.0	V_{DD}max+0 .5	2.1	5.5	V
	V_{DD} related input level	$0.7V_{DD}$	V_{DD}max+ 0.5	$0.7V_{DD}$	V_{DD}max+0 .5	N/A	N/A	V
V_{HYS}	V_{IH}-V_{IL}	N/A	N/A	$0.05V_{DD}$	-	N/A	N/A	V
V_{OL}	V_{OL} @ 3mA	0	0.4	0	0.4	N/A	N/A	V
	V_{OL} @ 6mA	N/A	N/A	0	0.6	N/A	N/A	
	V_{OL} @ 350uA	N/A	N/A	N/A	N/A	-	0.4	
I_{PULLUP}		N/A	N/A	N/A	N/A	100	350	uA
I_{LEAK}		-10	10	-10	10	-5	5	uA

The SMBus specification can be found on SMBus web site at www.SMBus.org

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- LED display control
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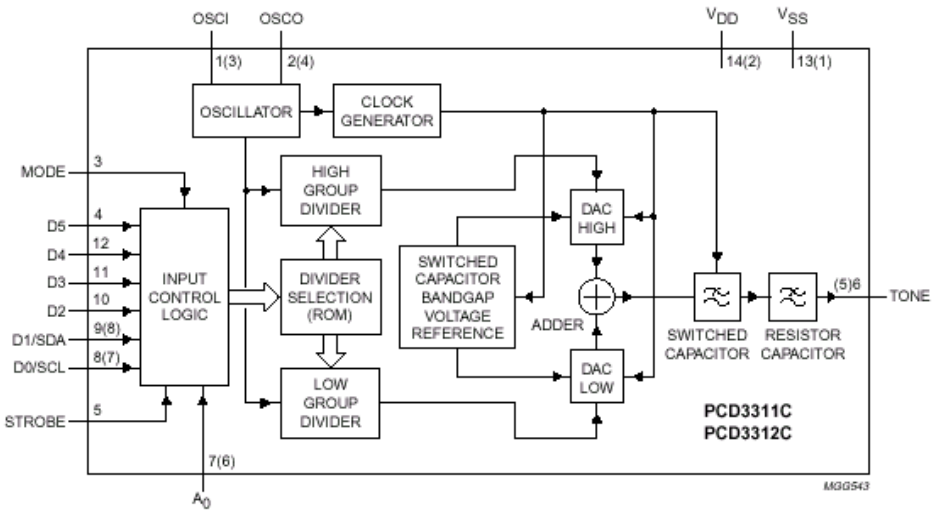
- A/D and D/A Converters
- EEPROM/RAM
- Hardware Monitors
- Microcontrollers

I²C devices are broken down into 14 different categories

Focus on Digital Tone Multi Frequency

DTMF/Modem/Musical Tone Generators



In addition to the standard DTMF frequencies the device can also provide:

- Twelve standard frequencies used in simplex modem applications for data rates from 300 to 1200 bits per second
- Two octaves of musical scales n steps of semitones

PCD3311C/12C FEATURES

- DTMF, modem and musical tone generation
- DTMF used for telephone tone dialing
- Low baud rate modem
- Stabilized output voltage level
- On-chip filtering assures a very low total harmonic distortion in accordance with CEPT recommendations
- Latched inputs for data bus applications
- I²C-bus compatible
- Selection of parallel or serial (I²C-bus) data input (PCD3311C)

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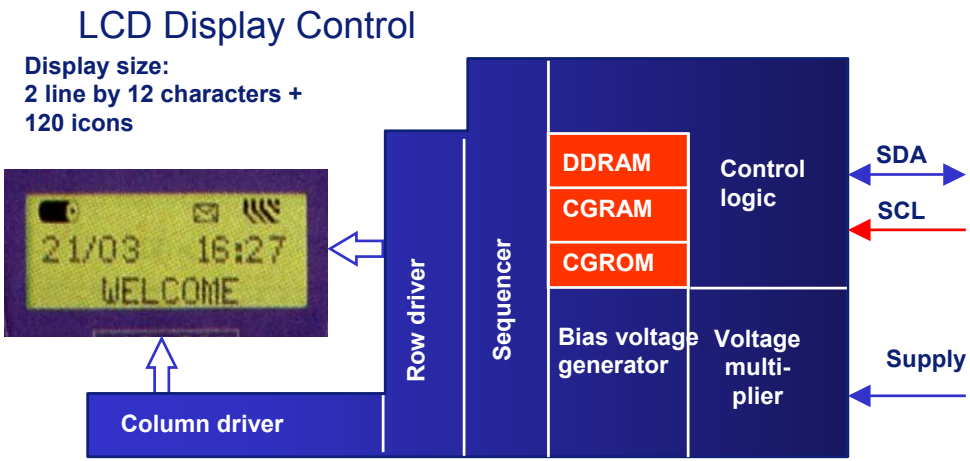
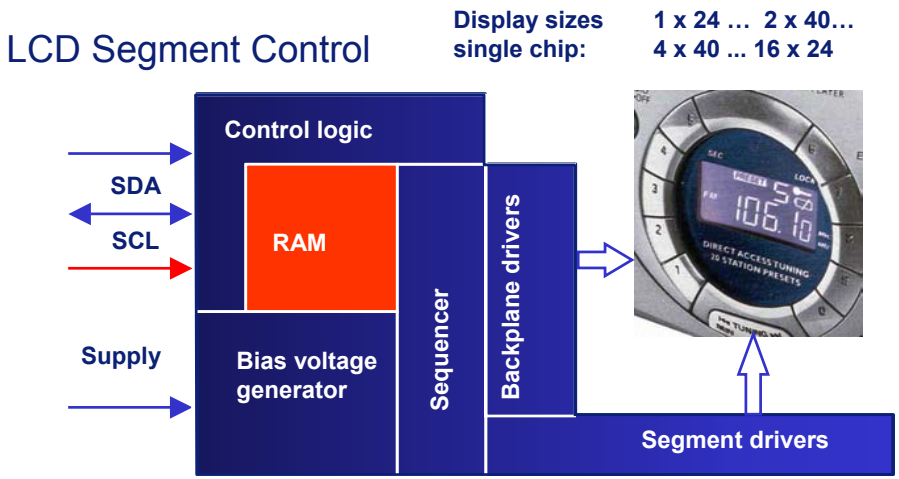
Focus on LCD and RTC categories

I²C LCD Display and Segment Drivers

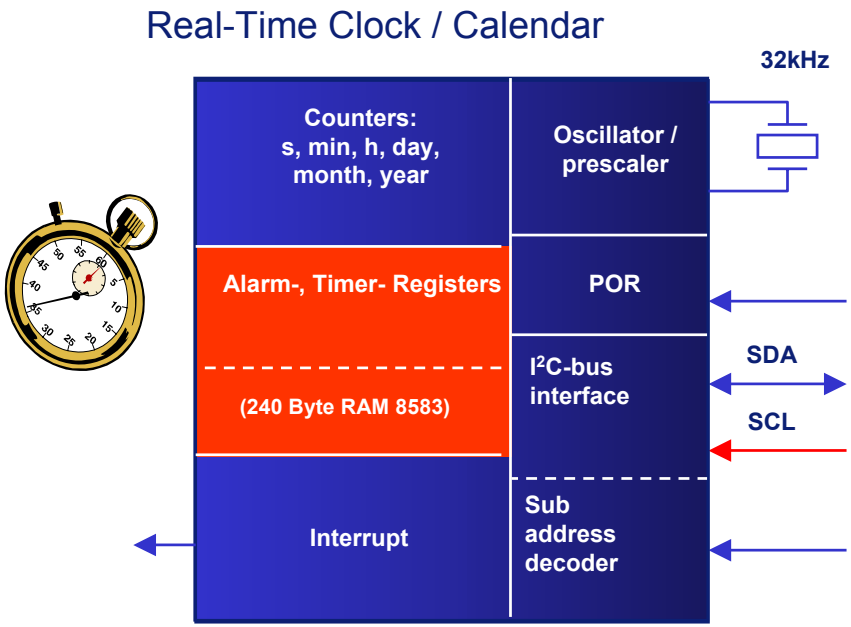


The LCD Display driver is a complex device and is an example of how "complete" a system an I²C chip can be – it generates the LCD voltages, adjusts the contrast, temperature compensates, stores the messages, has CGROM and RAM etc etc.

The LCD Segment driver is a less complex LCD driver (e.g., just a segment driver).



I²C Real Time Clock/Calendar



Philips offers four Real Time Clocks, they are PCF8593, PCF8583, PCF8573 and PCF8563. The RTC is used to provide absolute timing to devices on the I²C Bus.

The latest RTC is the PCF8563, it has the lowest current consumption in the range. Additionally, the PCF8583 has 240 bytes 'scratchpad' RAM integrated with the RTC.

PHILIPS

LCD Graphic and Character Drivers, LCD Segment Drivers & Real Time Clocks

www.semiconductors.philips.com/i2c	TYPE OF FUNCTION IN DEVICE			FEATURES																				
							Vcc RANGE (V)						FREQ (kHz)			TEMP	PACKAGES							
	Real Time Clock	LCD Driver	Description	ADDRESSES	INTERRUPT (Out)	HARDWARE RESET	1.0	1.8	2.5	3.3	5	5V TOLERANT	100	400	3400	- 40 to 85 °C	PIN COUNT	BARE DIE	TCP	OTHER	DIP	SO (narrow)	SO (wide)	TSSOP
OM4085		λ	96 segment LCD driver	16				2	λ	λ	λ	λ	λ			λ				VSO40				
PCF2103		λ	24 character LCD controller/driver	2				λ	λ	λ	λ	λ	λ	λ		λ		λ						
PCF2104		λ	48 character LCD controller/driver	2					λ	λ	λ	λ	λ			λ		λ						
PCF2105		λ	48 character LCD controller/driver	2					λ	λ	λ	λ	λ	λ		λ		λ						
PCF2113		λ	24 character + 120 icon LCD controller/driver	2				λ	λ	λ	λ	λ	λ	λ		λ		λ		LQFP100				
PCF2116		λ	48 character LCD controller/driver	2					λ	λ	λ	λ	λ			λ		λ						
PCF2119		λ	32 character LCD controller/driver	2		λ			λ	λ	λ	λ	λ	λ		λ		λ						
PCF8531		λ	34 x 128 graphic LCD controller/driver	2		λ		λ	λ	λ	λ	λ	λ	λ		λ		λ						
PCF8533		λ	320 segment LCD driver	16				λ	λ	λ	λ	λ	λ	λ		λ		λ			P			
PCF8535		λ	(65 + icon row) x 133 graphic LCD controller/driver	4		λ					λ	λ	λ	λ		λ		λ						
PCF8548		λ	65 x 102 graphic LCD controller/driver	2		λ			λ	λ	λ	λ	λ	λ		λ		λ						
PCF8549		λ	65 x 102 graphic LCD controller/driver	2		λ		λ	λ	λ	λ	λ	λ	λ		λ		λ						
PCF8558		λ	40 x 101 graphic LCD controller/driver	2					λ	λ	λ	λ	λ	λ		λ		λ						
PCF8563	λ		ultra low power real time clock/calendar	1	1		λ	λ	λ	λ	λ	λ	λ	λ		λ	8				P	T		DP
PCF8566		λ	96 segment LCD driver	16					λ	λ	λ	λ	λ			λ		λ		VSO40				
PCF8573	λ		real time clock/calendar with power fail detector	4			1.1	λ	λ	λ	λ	λ	λ			λ	16				P		T	
PCF8576C		λ	160 segment LCD driver	16					λ	λ	λ	λ	λ			λ		λ		LQFP64/VSO56				
PCF8577C		λ	64 segment LCD driver	16					λ	λ	λ	λ	λ			λ		λ		VSO40				
PCF8578		λ	384+ segment LCD driver	2					λ	λ	λ	λ	λ			λ		λ		LQFP64/VSO56				
PCF8579		λ	384+ segment LCD driver	2					λ	λ	λ	λ	λ			λ		λ		LQFP64/VSO56				
PCF8583	λ		real tme clock/calendar with 240 x 8 bit RAM	2	1		λ	λ	λ	λ	λ	λ	λ			λ	8				P	T		
PCF8593	λ		low power real time clock/calendar	1	1	λ	λ	λ	λ	λ	λ	λ	λ			λ	8				P	T		
PCF8811		λ	80 x 128 graphic LCD controller/driver	4		λ	1.5	λ	λ	λ	λ	λ	λ	λ	λ	λ		λ						
PCF8813		λ	(67 + icon row) x 102 graphic LCD controller/driver	4		λ		λ	λ	λ	λ	λ	λ	λ	λ	λ		λ						
PCF8814		λ	80 x 96 graphic LCD controller/driver	4		λ		λ	λ	λ		λ	λ	λ	λ	λ		λ						
PCF8820		λ	67 x 101 4 greyscale graphic LCD controller/driver	4		λ			λ	λ	λ	λ	λ	λ		λ		λ						
PCF8831		λ	160 x 128RGB 256 colour STN controller/driver chipset	4		λ	1.5	λ	λ	λ		λ	λ	λ	λ	λ		λ	λ					
PCF8832		λ	160 x 128RGB 256 colour STN controller/driver chipset	4		λ	1.5	λ	λ	λ		λ	λ	λ	λ	λ		λ	λ					

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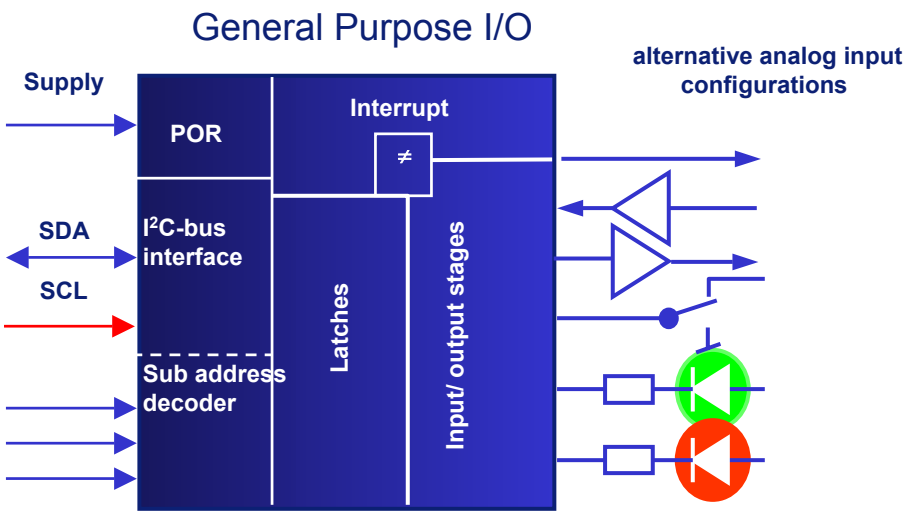
Focus on general purpose categories

Quasi Output I²C I/O Expanders



KEY POINTS

-Transfers keyboard, ACPI Power switch, keypad, switch or other inputs to microcontroller via I²C bus

-Expand microcontroller via I²C bus where I/O can be located near the source or on various cards

-Use outputs to drive LEDs, sensors, fans, enable and other input pins, relays and timers

- Quasi outputs can be used as Input or Output without the use of a configuration register

-The PCA9501 has 6 address pins, allowing up to 64 devices to share the same I²C Bus.

-Application Note, AN469 GPIO Selection, discusses pros and cons of GPIOs

# of Outputs	Interrupt	2Kbit EEPROM	Interrupt and 2Kbit EEPROM
Quasi Output (20-25 ma sink and 100 uA source)			
8	PCF8574/74A	PCA9500	PCA9501
16	PCF8575/75C	-	-

Quasi Output I²C I/O Expanders - Registers

- **To program the outputs**

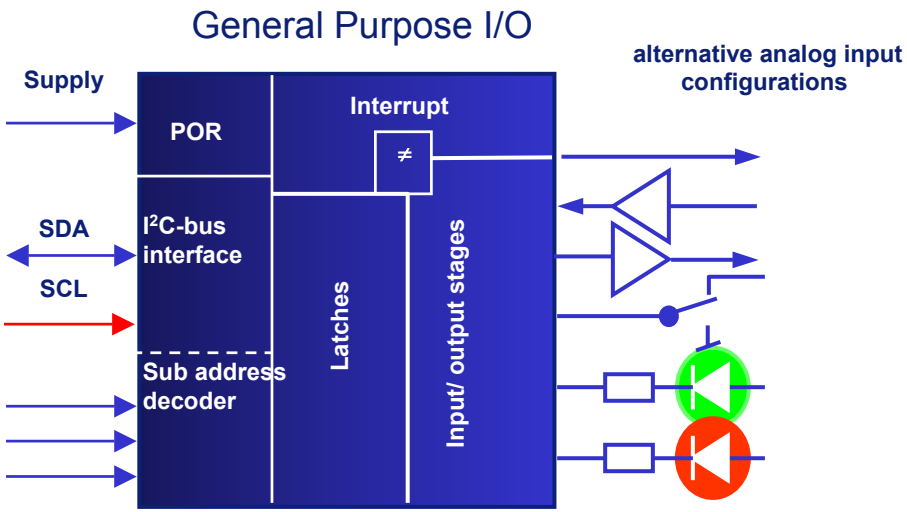
Multiple writes are possible during the same communication

- **To read input values**

Multiple reads are possible during the same communication

- **Important to know**
  - **At power-up, all the I/O's are HIGH; Only a current source to V_{DD} is active**
  - **An additional strong pull-up resistors allows fast rising edges**
  - **I/O's should be HIGH before using them as Inputs**

True Output I²C I/O Expanders



KEY POINTS

-Transfers keyboard, ACPI Power switch, keypad, switch or other inputs to microcontroller via I²C bus

-Use totem pole outputs to drive LEDs, sensors, fans, enable and other input pins, relays and timers

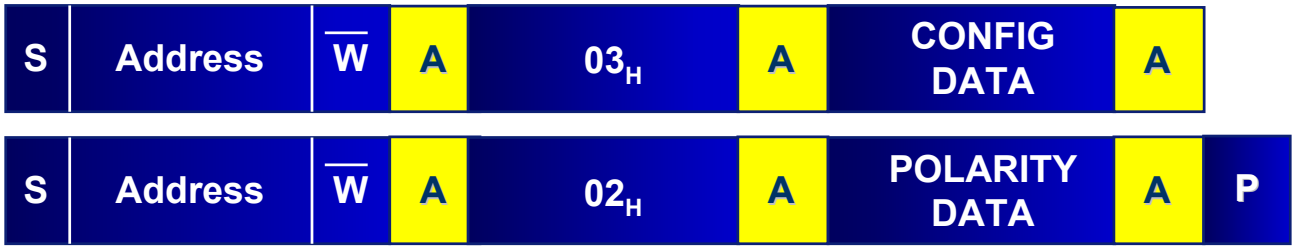
-Extra command byte needed for Input, Output, Polarity and I/O Configuration

-Application Note, AN469 GPIO Selection, discusses pros and cons of GPIOs

# of Outputs	Reset	Interrupt	2Kbit EEPROM
True Output (20-25 ma sink and 10 mA source)			
8	PCA9556/57	PCA9554/54A	PCA9558
16	-	PCA9555	-

True Output I²C I/O Expanders - Registers

- **To configure the device**

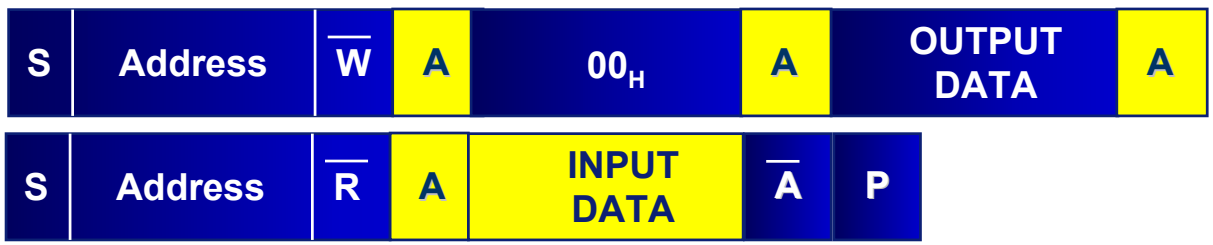


No need to access Configuration and Polarity registers once programmed

- **To program the outputs**

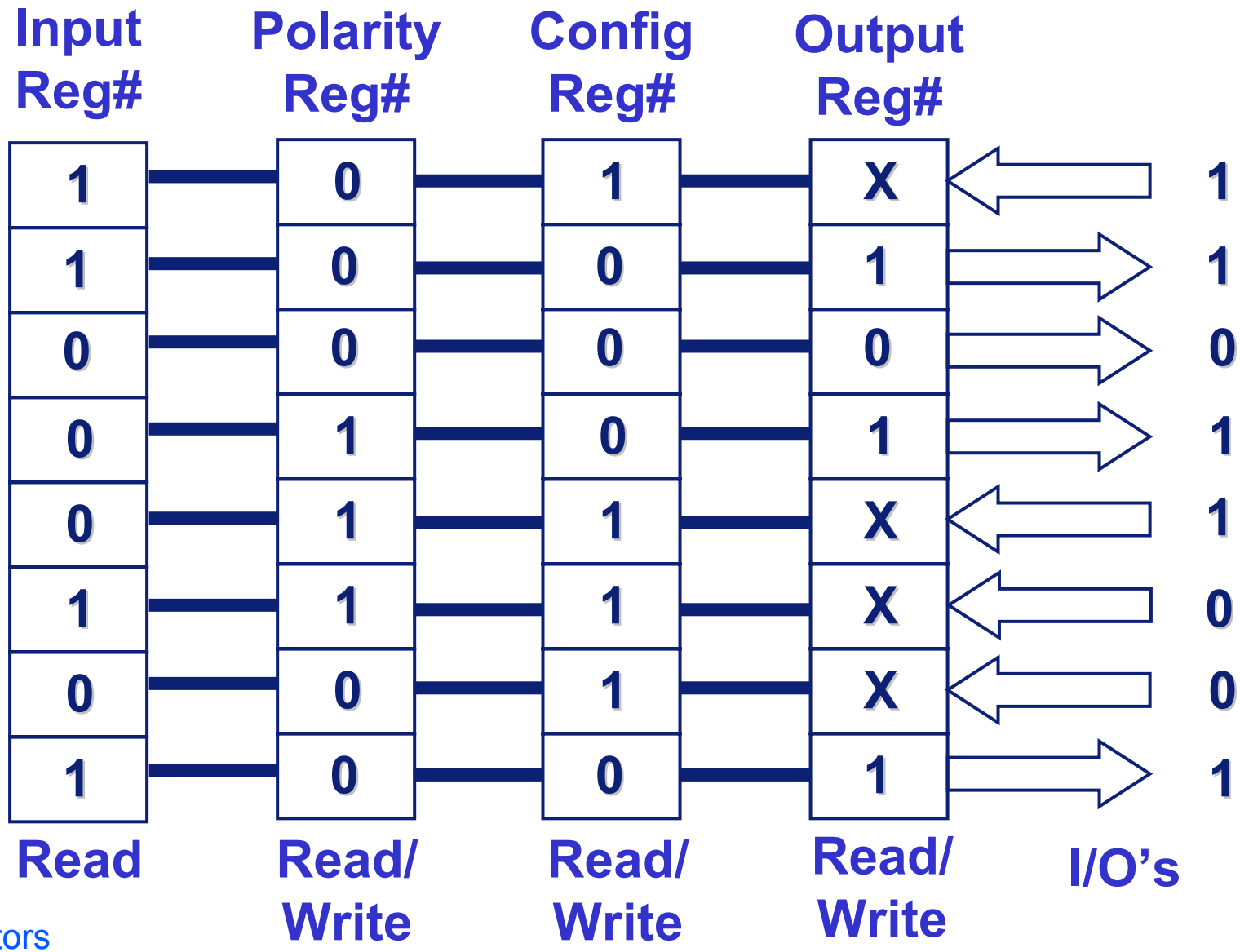
Multiple writes are possible during the same communication

- **To read input values**

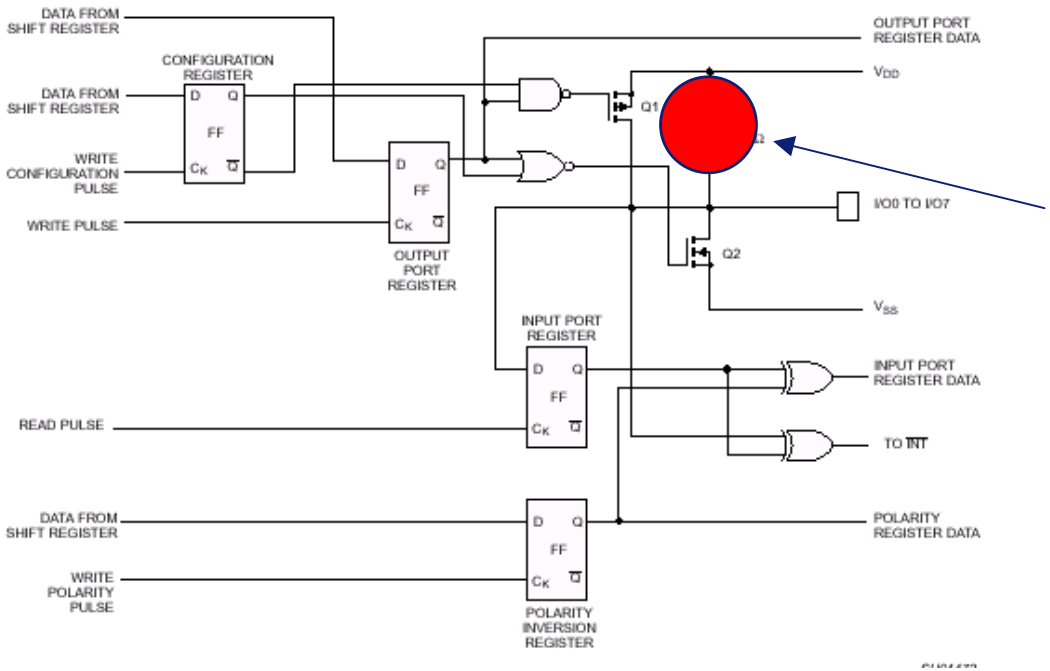


Multiple reads are possible during the same communication

True Output I²C I/O Expanders - Example



Low Power True Output I²C I/O Expanders



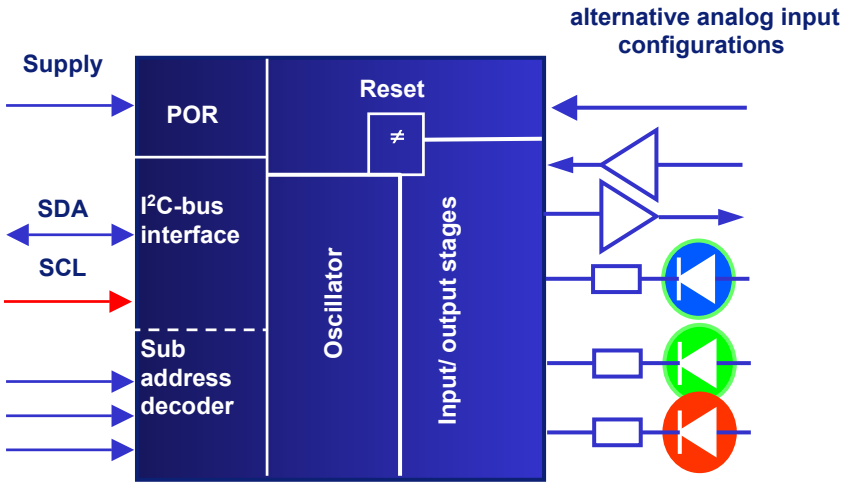
FEATURES

- Same true output structure and I²C address as the PCA9554/55 series (0100AAA.)
- Metal mask change to disconnect the internal pull up resistors to reduce Istbl current to 1 μA maximum (from 750 μ A (8-bit) and 1.5 mA (16-bit)) for battery powered applications.
- 8-bit device in 16-pin package (SO, TSSOP, HVQFN)
- 16-bit device in 24-pin package (SO, TSSOP, HVQFN)

- **PCA9534 8-Bit I²C and SMBus Low Power I/O port with Interrupt**
- **PCA9535 16-Bit I²C and SMBus Low Power I/O port with Interrupt**

Sampling Nov 02

I²C LED Blinkers



# of Outputs	Reset and POR
2	PCA9550
4	PCA9553
8	PCA9551
16	PCA9552

KEY POINTS

-I²C/SMBus is not tied up by sending repeated transmissions to turn LEDs on and then off to “blink” LEDs.
-Frees up the micro’s timer
-Continues to blink LEDs even when no longer connected to bus master
-Can be used to cycle relays and timers

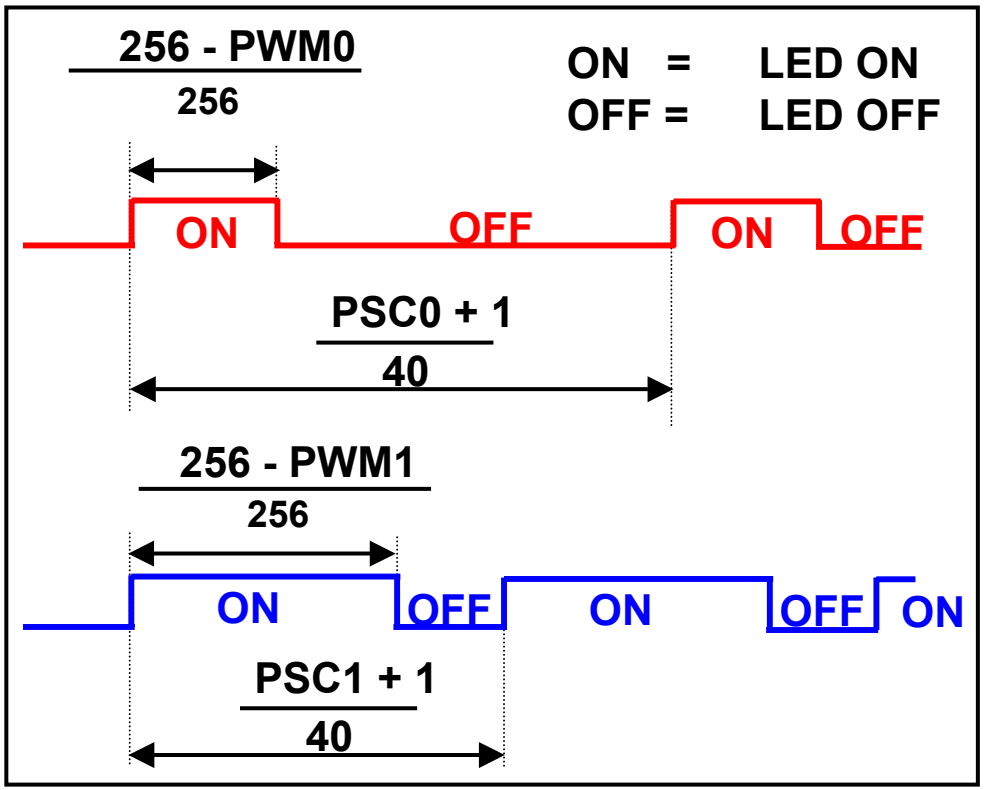
FEATURES

-25 mA open drain outputs
-Internal oscillator (+/- 10%)
-Two user definable blink rates and duty cycles adjustable between 40 Hz and 6.4 seconds in 256 steps
-Unused pins can be used for normal GPIO
-Hardware Reset pin and Power On Reset (POR)

Sampling, all will be released by end of 2002

PCA955x I²C LED Blinkers

	0 (00_H)	255 (FF_H)
Frequency	40 Hz	6.4 s
Duty Cycle	100 %	0.4 %



Input Register(s)

PWM0 (ON Time)

PSC0 (Frequency)

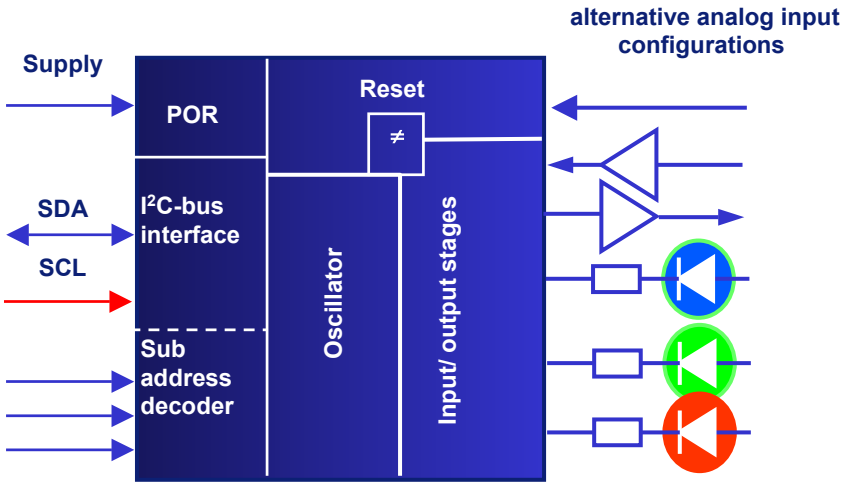
PWM1 (ON Time)

PSC1 (Frequency)

LED Selector

ON, OFF, BR1, BR2

I²C LED Dimmers



# of Outputs	Reset and POR
2	PCA9530
4	PCA9533
8	PCA9531
16	PCA9532

KEY POINTS

-Higher frequency rate allows LEDs to be dimmed by varying the duty cycle for Red/Green/Blue color mixing applications.
- State machine modified to default to highest frequency at power on and duty cycle goes from 0% (off) to 99.6% (almost always on) for better dimming control.

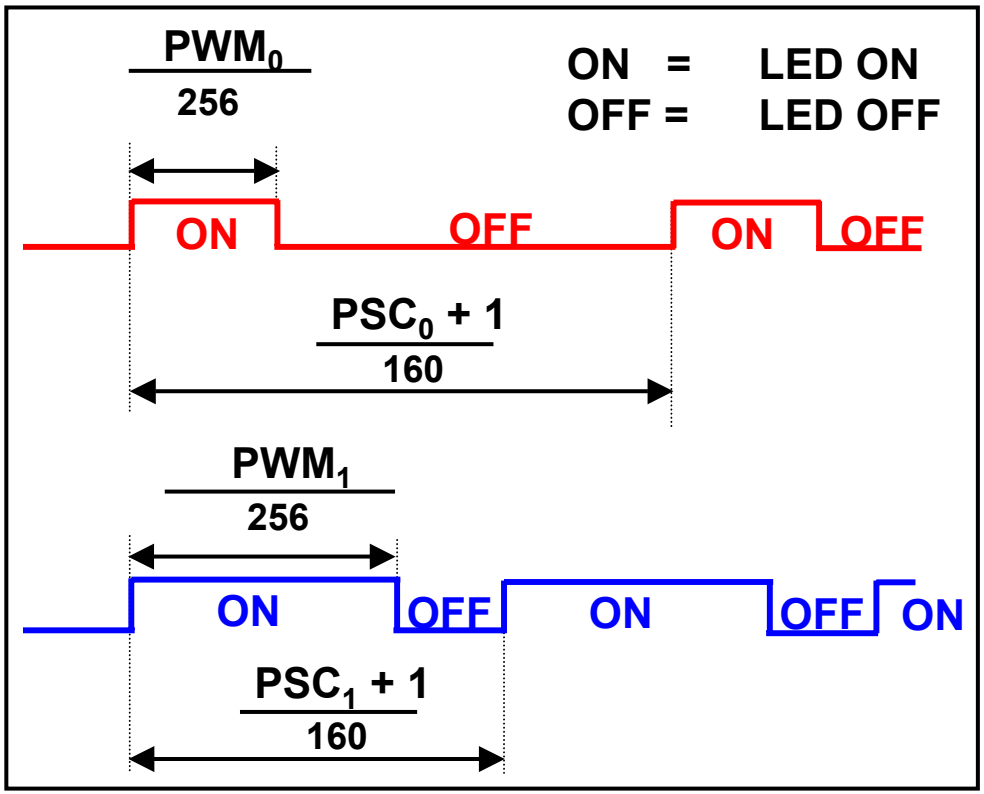
FEATURES

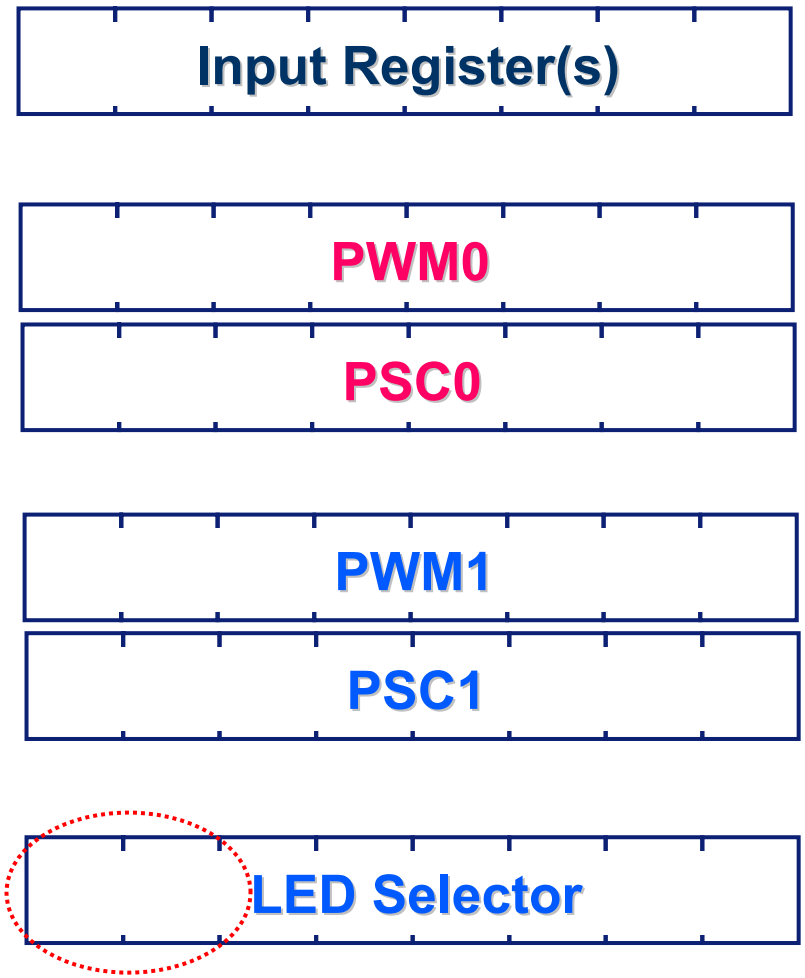
-25 mA open drain outputs
-Internal oscillator (+/- 10%)
-Two user definable blink rates and duty cycles adjustable between 160 Hz and 1.6 seconds in 256 steps
-Unused pins can be used for normal GPIO
-Hardware Reset pin and Power On Reset (POR)

Sampling in Dec 02

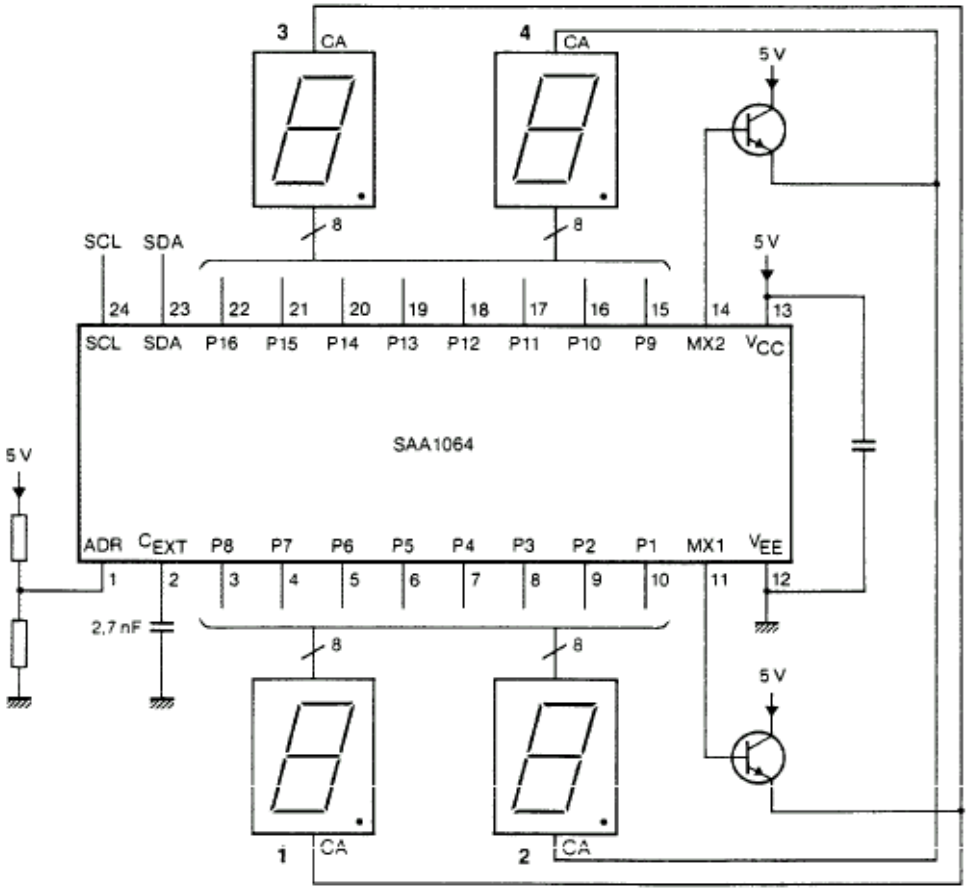
PCA953x I²C LED Dimmers

	0 (00_H)	255 (FF_H)
Frequency	160 Hz	1.6 s
Duty Cycle	0 %	99.6 %





4 Digit I²C LED Driver

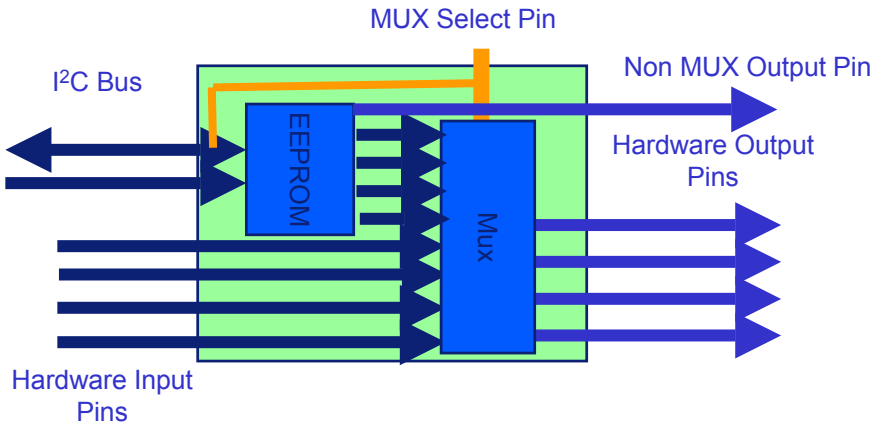


FEATURES

-21 mA open drain outputs
- can drive 32 LEDs or 4 digits with decimal point (16 bits multiplexed twice)
- controls LED brightness in 7 steps of 3 mA.
- offered in SO and DIL package
- DIL dissipates 1 W, no series resistors are needed
- internal oscillator
- four different slave addresses
- V_{CC} range 4.5 V to 15 V

• **SAA1064 4 Digit I²C LED Driver**

I²C Dip Switches



KEY POINTS

-Used for Speed Step™ notebook processor voltage changes when on AC/battery power or when in deep sleep mode

-Also used as replacement for jumpers or dip switches since there is no requirement to open the equipment cabinet to modify the jumpers/dip switch settings

FEATURES

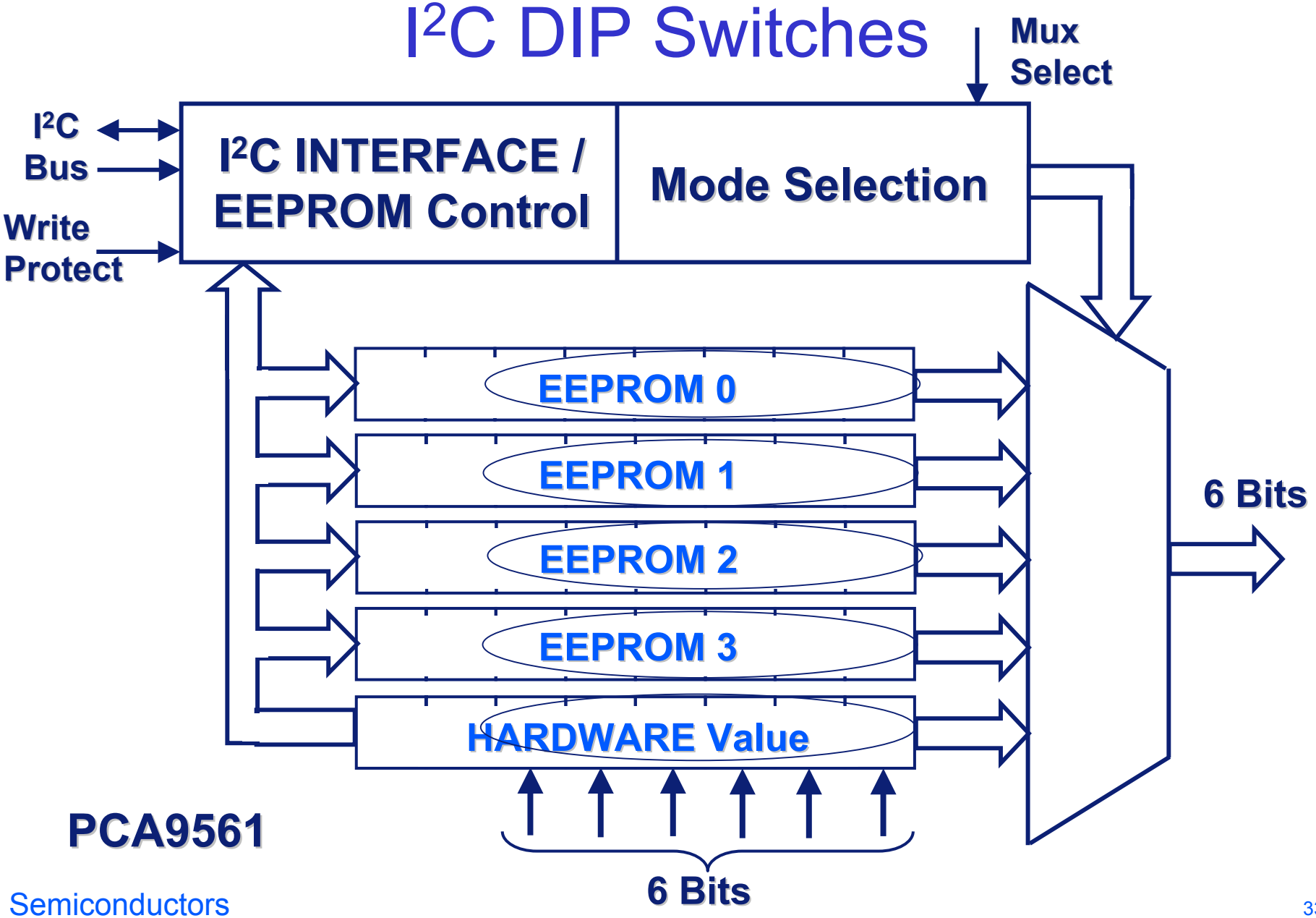
-Non-volatile EEPROM retains values when the device is powered down

-Write or read EEPROM via I²C

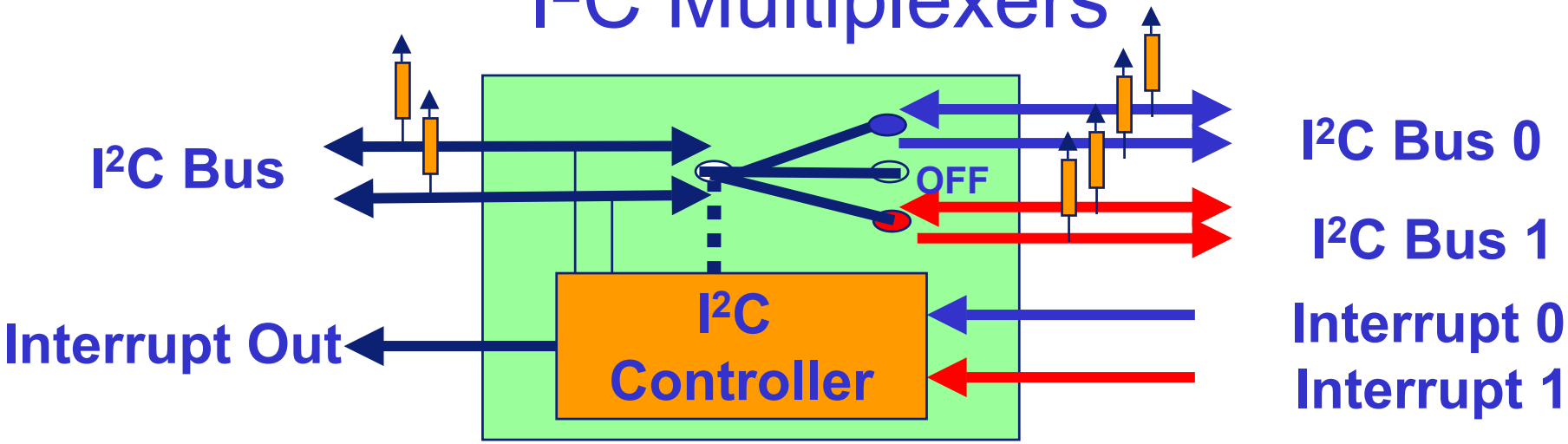
-Use Mux select pin or I²C commands to select output values

	# of Non Volatile registers	# of register bits	# of hardware input pins	# of Muxed outputs	Non-muxed output
PCA8550	1	5	4	4	YES
PCA9559	1	6	5	5	YES
PCA9560	2	6	5	5	YES
PCA9561	4	6	6	6	NO

I²C DIP Switches



I²C Multiplexers



FEATURES

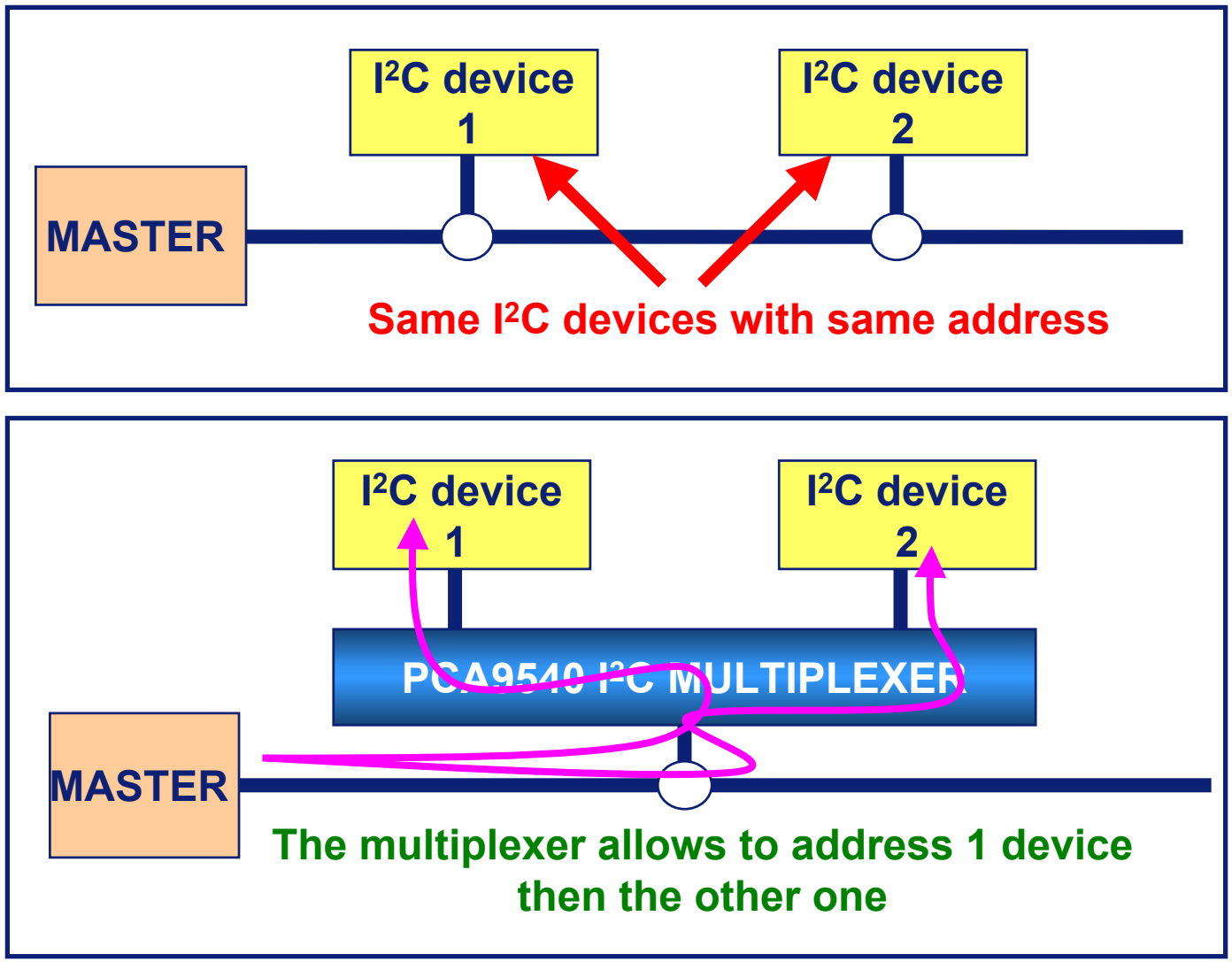
-Fan out main I²C/SMBus to multiple channels
-Select off or individual downstream channel
-I²C/SMBus commands used to select channel
-Power On Reset (POR) opens all channels
-Interrupt logic provides flag to master for system monitoring.

KEY POINTS

-Many specialized devices have only one I²C address and sometimes many are needed in the same system.
-Multiplexers allow the master to communicate to one downstream channel at a time but don't isolate the bus capacitance
-Other Applications include sub-branch isolation.

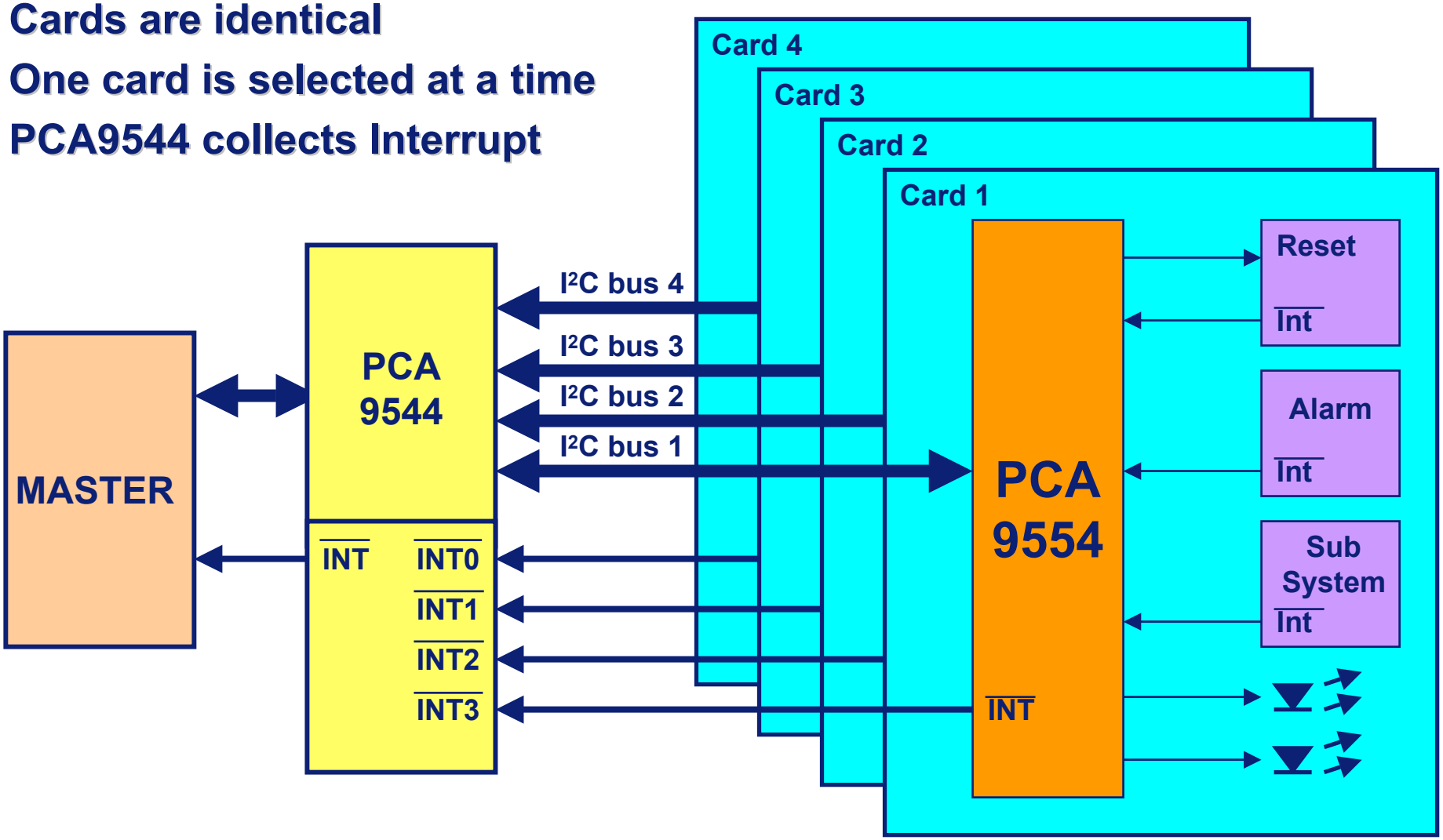
# of Channels	POR Only	Interrupt Logic and POR
2	PCA9540	PCA9542
4	-	PCA9544

I²C Multiplexers: Address Deconflict

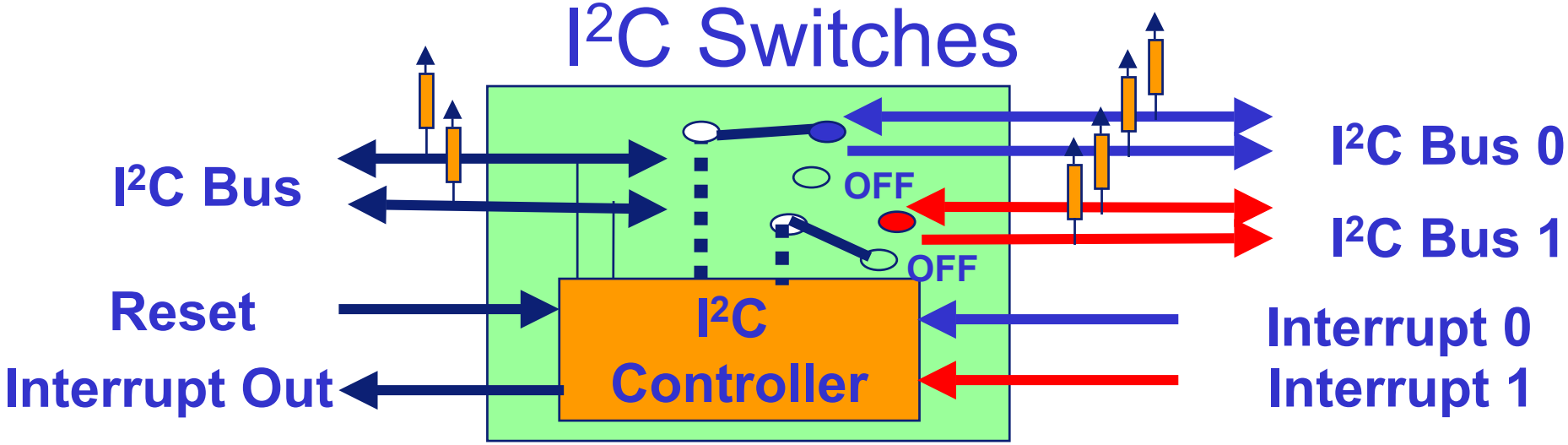


I²C Multiplexers: Multi-card Application

- Cards are identical
- One card is selected at a time
- PCA9544 collects Interrupt



I²C Switches



FEATURES

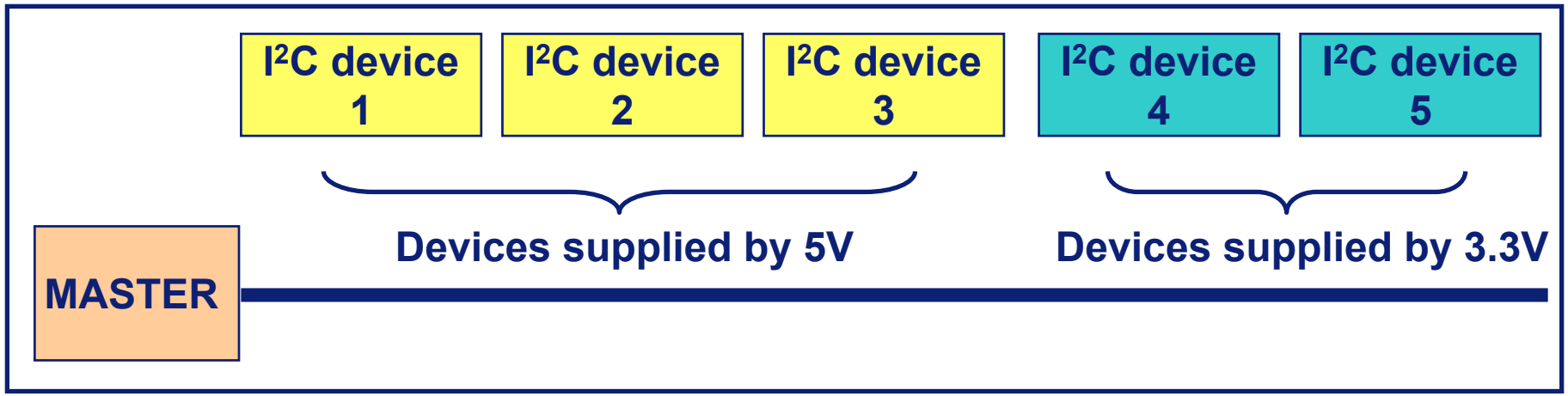
-Fan out main I²C/SMBus to multiple channels
-Select off or individual downstream channels one at a time, all at once or in any combination.
-I²C/SMBus commands used to select channel
-Hardware Reset pin or POR opens all channels
-Interrupt logic provides flag to master

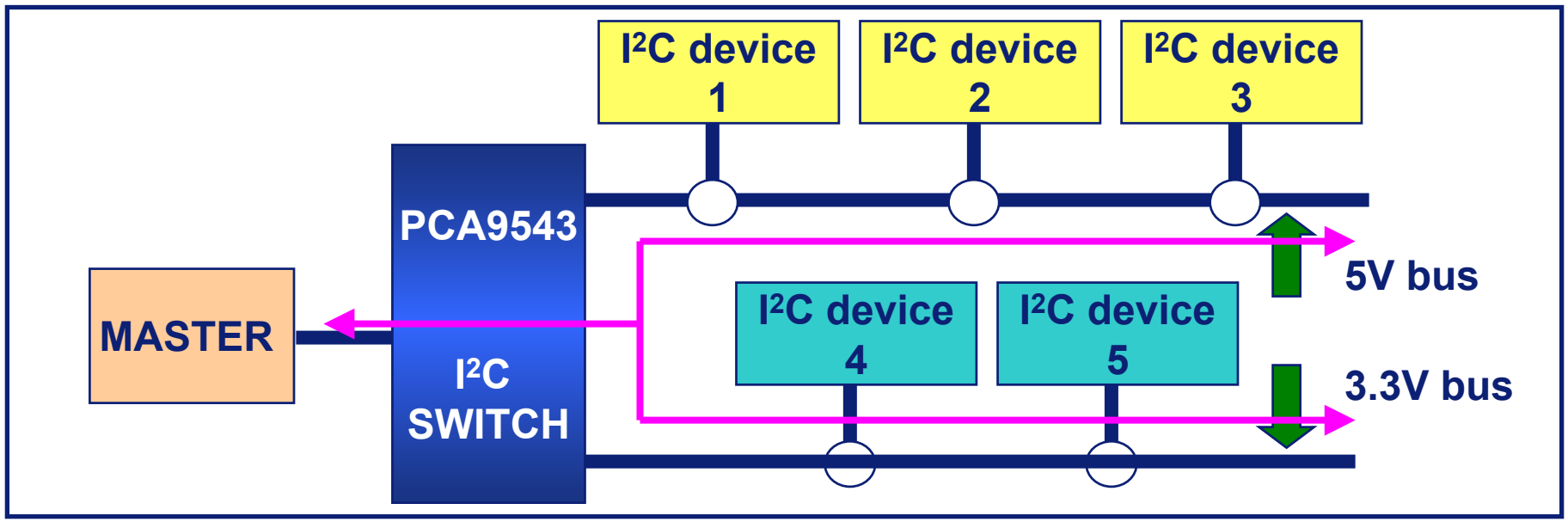
KEY POINTS

-Switches allow the master to communicate to one channel or multiple downstream channels at a time but don't isolate the bus capacitance
-Other Applications include: sub-branch isolation and I²C/SMBus level shifting (1.8, 2.5, 3.3 or 5.0 V)

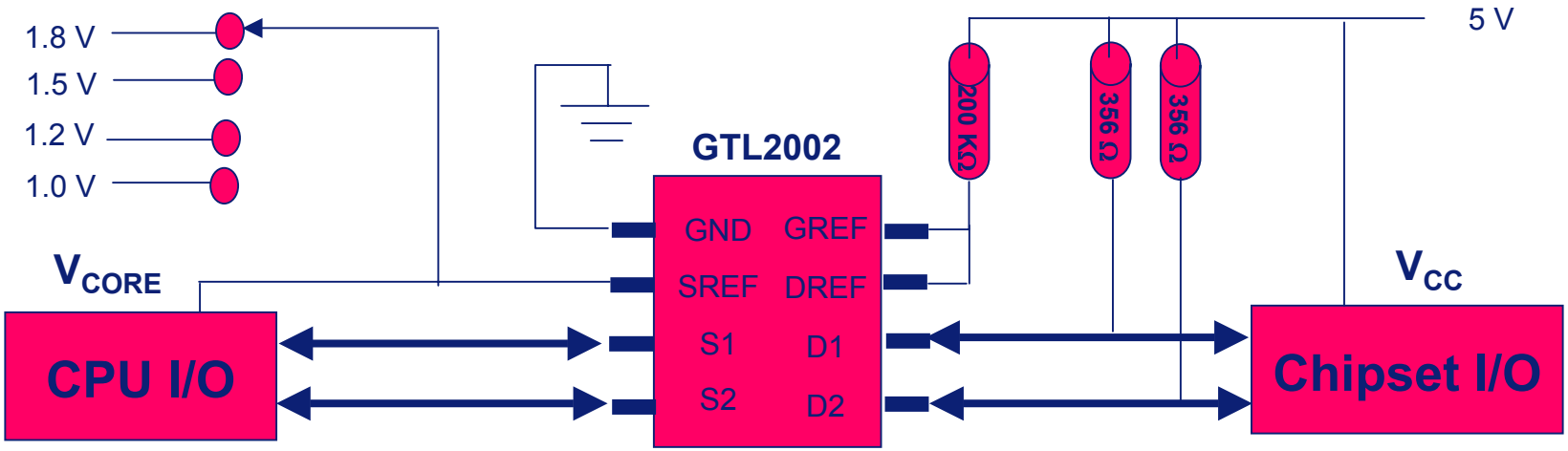
# of Channels	Reset & POR	Interrupt Logic and Reset & POR
2	-	PCA9543
4	PCA9546	PCA9545
8	PCA9548	-

I²C Switches: Voltage Level Shifting





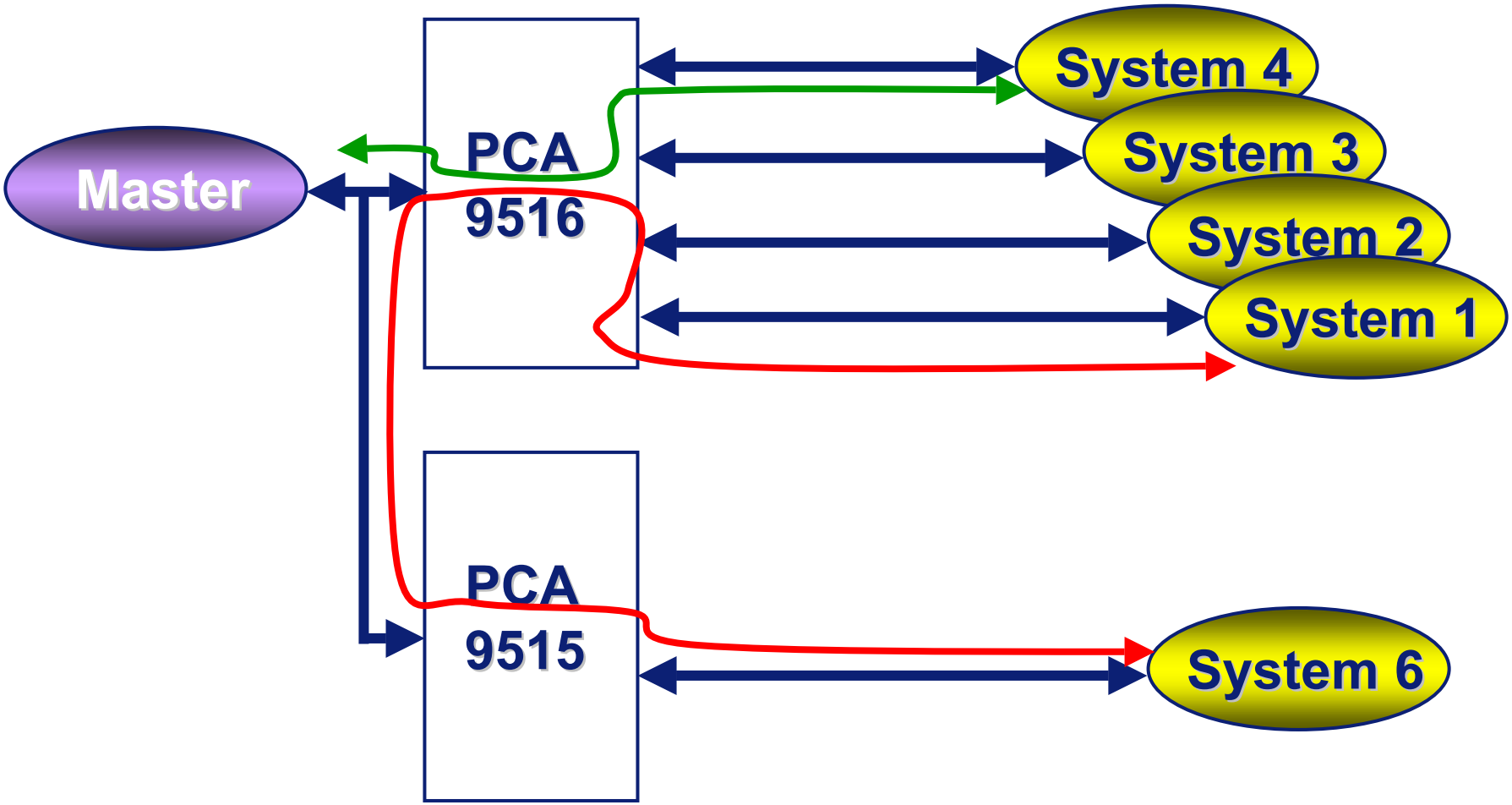
I²C Bus Bi-Directional Voltage Level Translation



- Voltage translation between any voltage from 1.0 V to 5.0 V
- Bi-directional with no direction pin
- Reference voltage clamps the input voltage with low propagation delay

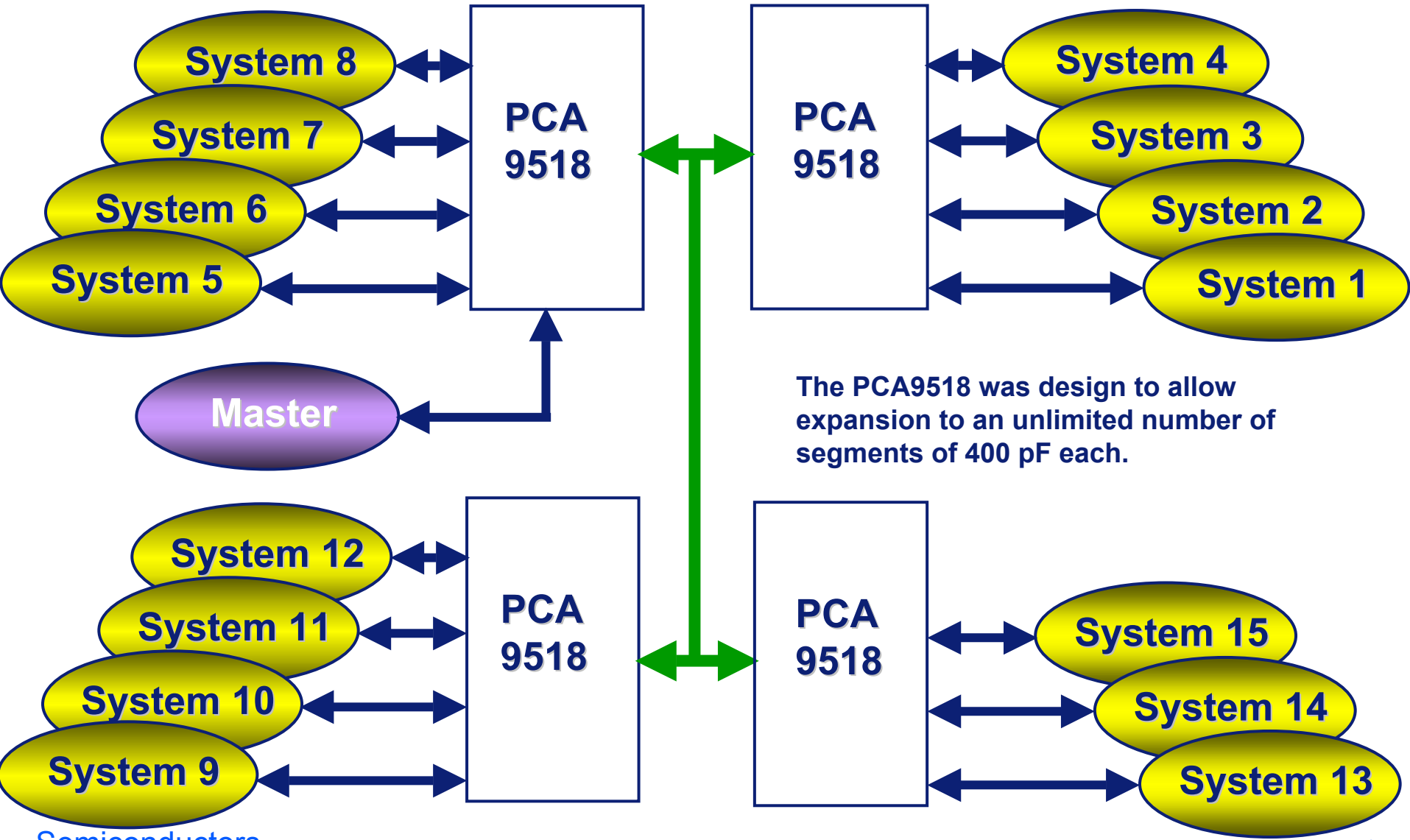
– **GTL2000 22-Bit**
– **GTL2002 2-Bit**
– **GTL2010 10-Bit**

PCA9515 and PCA9516 Applications

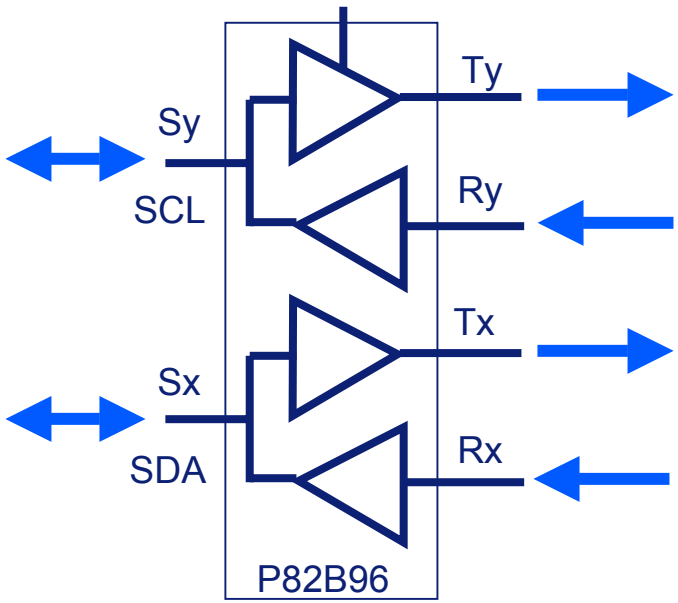


PCA9515 and PCA9516 were designed to isolate up to 400 pF on each segment and uses an offset V_{OL} to allow bi-directional signaling without use of a direction pin. They were not designed to operate on the same bus since a low signal is not passed through two devices.

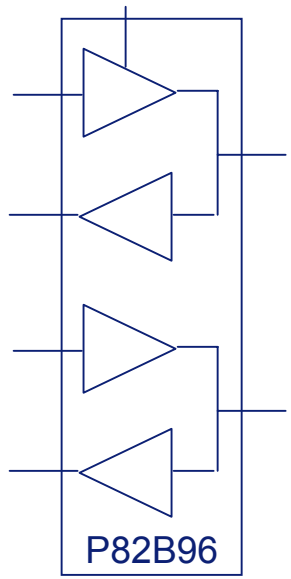
PCA9518 Applications



P82B96 I²C Bus Buffer for many new applications !



- Drive long cables/hot swap
  - 100 m at 70 kHz
  - 1 km at 30 kHz
- Multi-point applications
- Opto-isolate for safety
- Radio or IR links
- Send over other buses
  - USB, CAN, RS485, RS232
  etc.
  through external device
- Increase noise immunity



Bi-directional data streams

Special logic levels (I²C compatible)

I²C currents (3mA)

Uni-directional data streams

Conventional CMOS logic levels (2-15V)

Higher current option, up to 30mA static sink

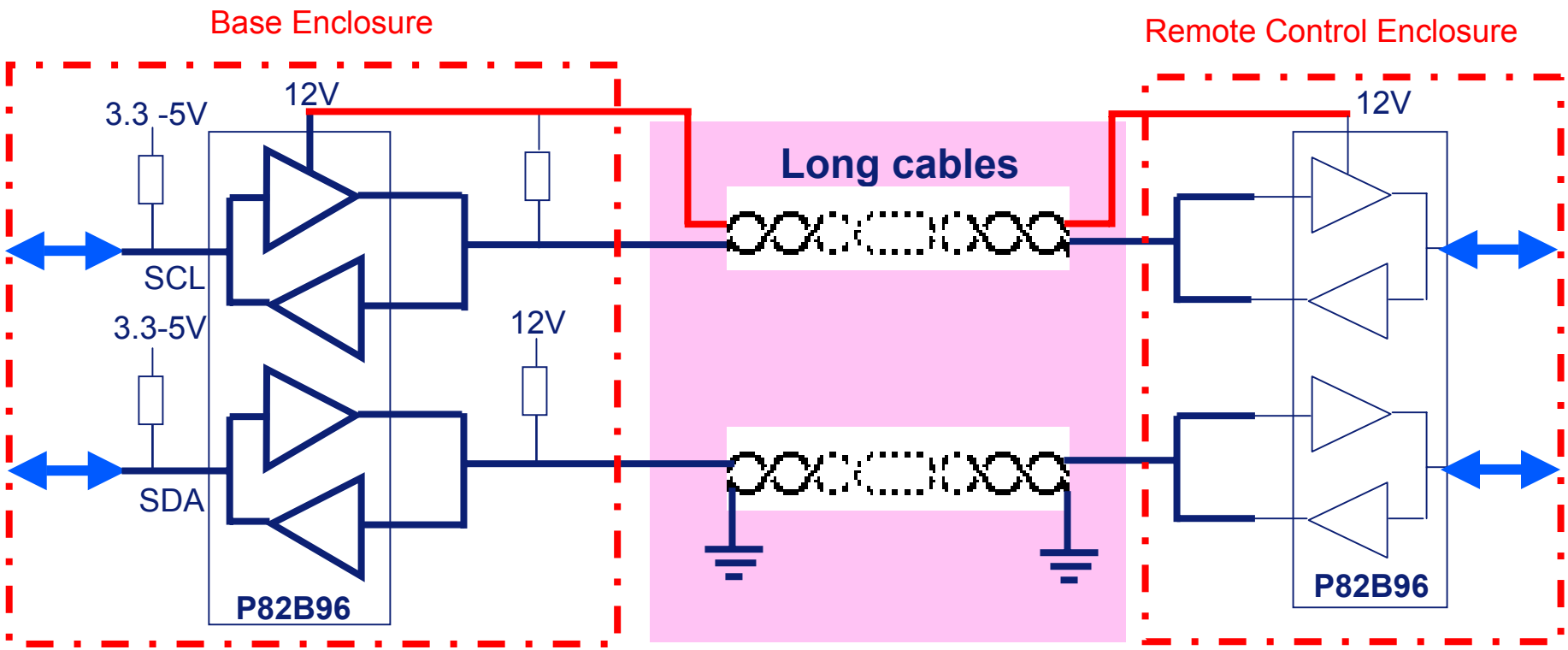
Any data transmission paths and logic levels

NO LIMIT to the number of connected devices !

Re-combine to bi-directional I²C

Convert the logic signal levels back to I²C compatible

Driving I²C bus signals long distances

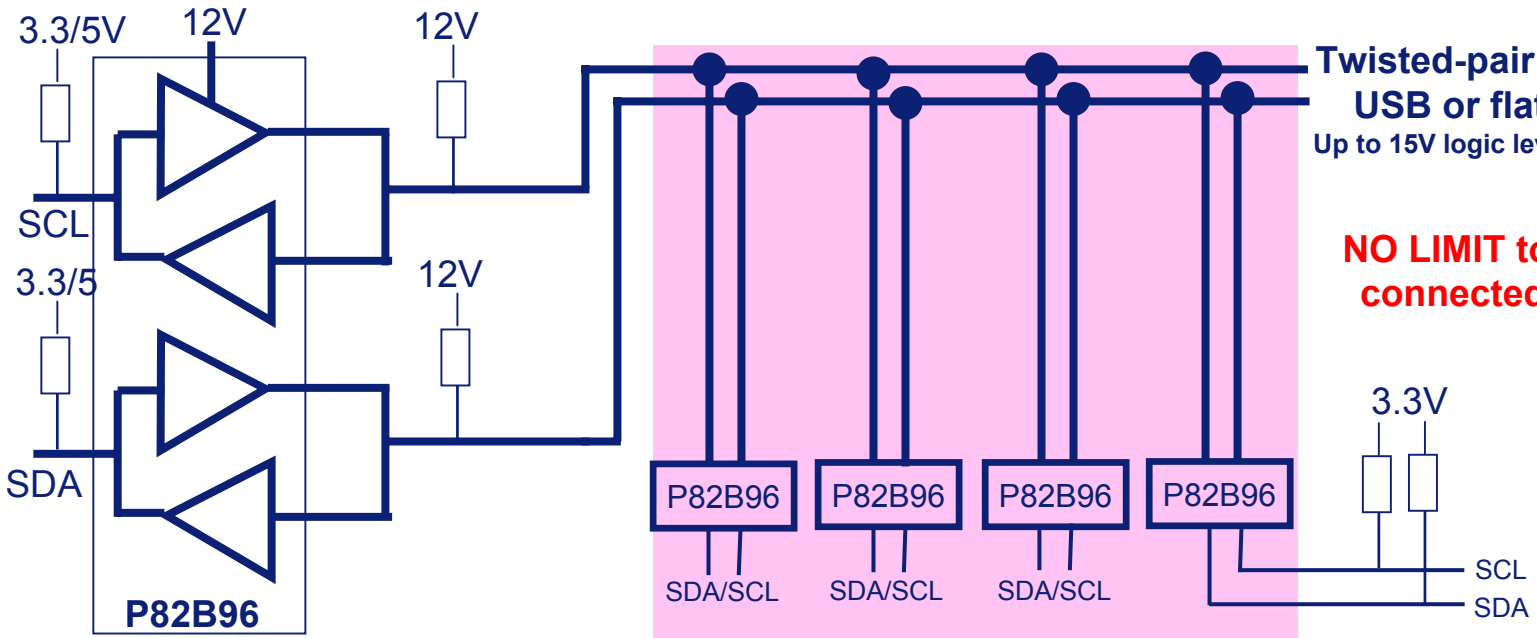


- Normal I2C logic levels (3.3 or 5 V)
- I²C currents (3mA)

- Conventional CMOS logic levels (2-15V)
- Higher current option, up to 30mA static sink

- Normal I2C logic levels (3.3 or 5 V)
- I²C currents (3mA)

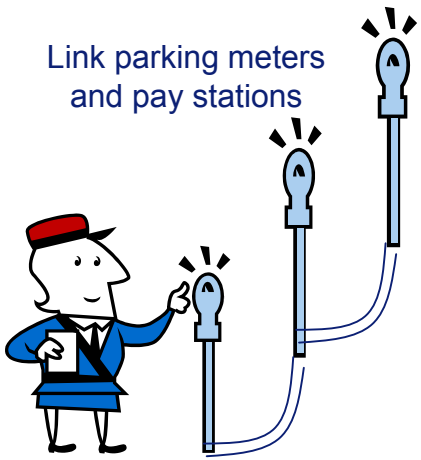
Changing I²C bus signals for multi-point applications!

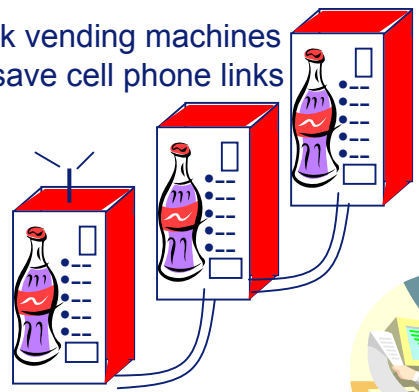


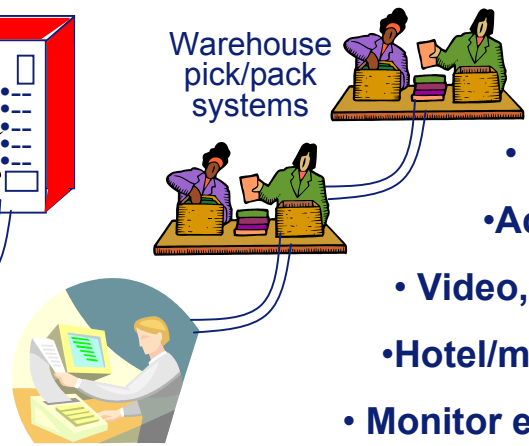
Twisted-pair telephone wires, USB or flat ribbon cables

Up to 15V logic levels, Include V_{CC} & GND

NO LIMIT to the number of connected bus devices !

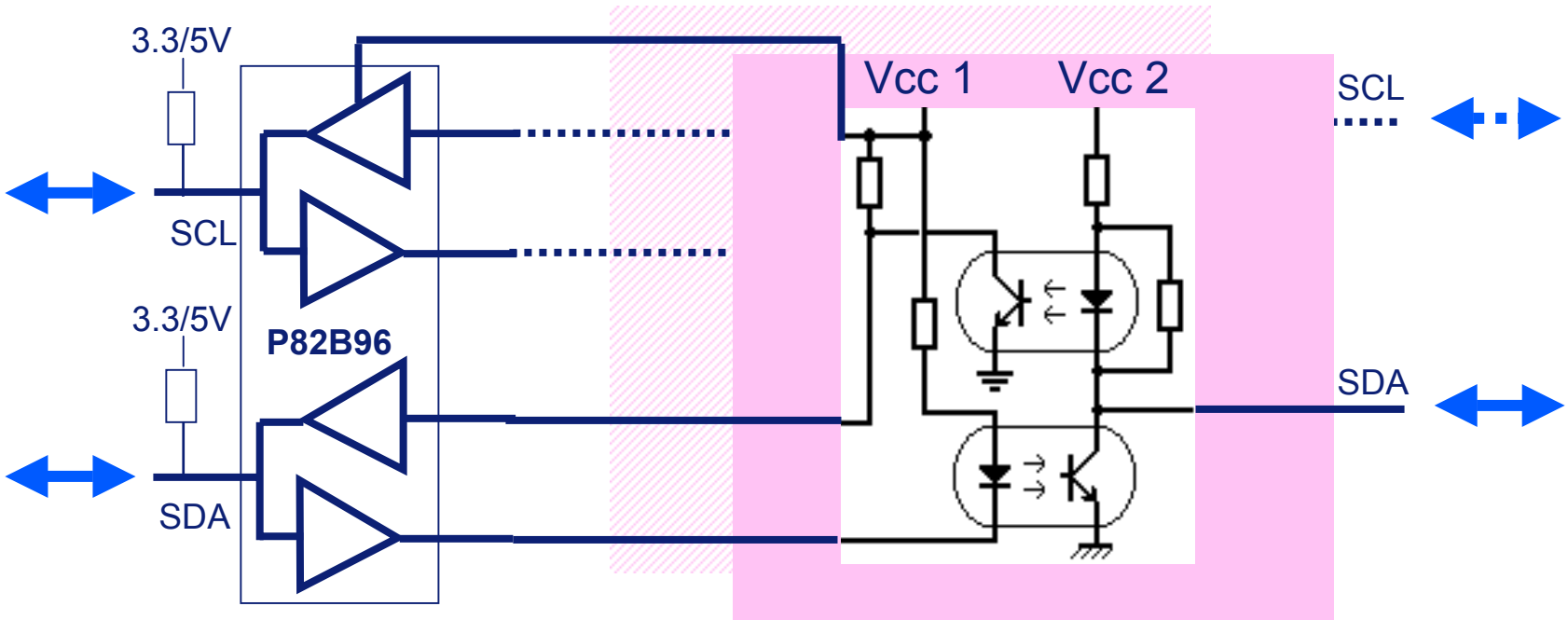






- **Factory automation**
- **Access/alarm systems**
- **Video, LCD & LED display signs**
- **Hotel/motel management systems**
- **Monitor emergency lighting/exit signs**

Changing I²C bus signals for Opto-isolation



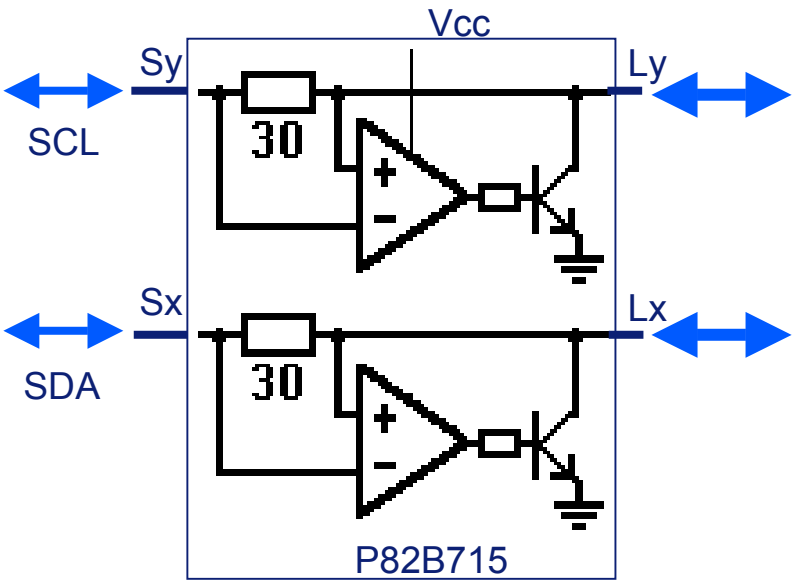
- **Low cost Optos can be directly driven (10-30mA)**

4N36 Optos for ~5kHz
6N137 for 100kHz
HCPL-060L for 400 kHz

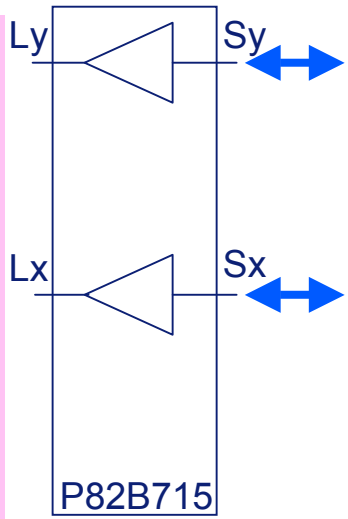
- **Controlling equipment on phone lines**
- **AC Mains switches, lamp dimmers, power supplies**
- **Isolating medical or industrial equipment**

P82B715 I²C Bus Extender allows more bus capacitance

(I²C spec limit is 400pF)



- Drive long cables
  - up to 50 m at 85 kHz
- Multi-point applications
- Up to 3500pF wiring capacitance
- Up to 100 bus ICs in one system
- Increases noise immunity



Bi-directional I2C

Normal logic voltage levels, exactly I²C

I²C currents (3mA)

Bi-directional signals

No change to logic voltage levels

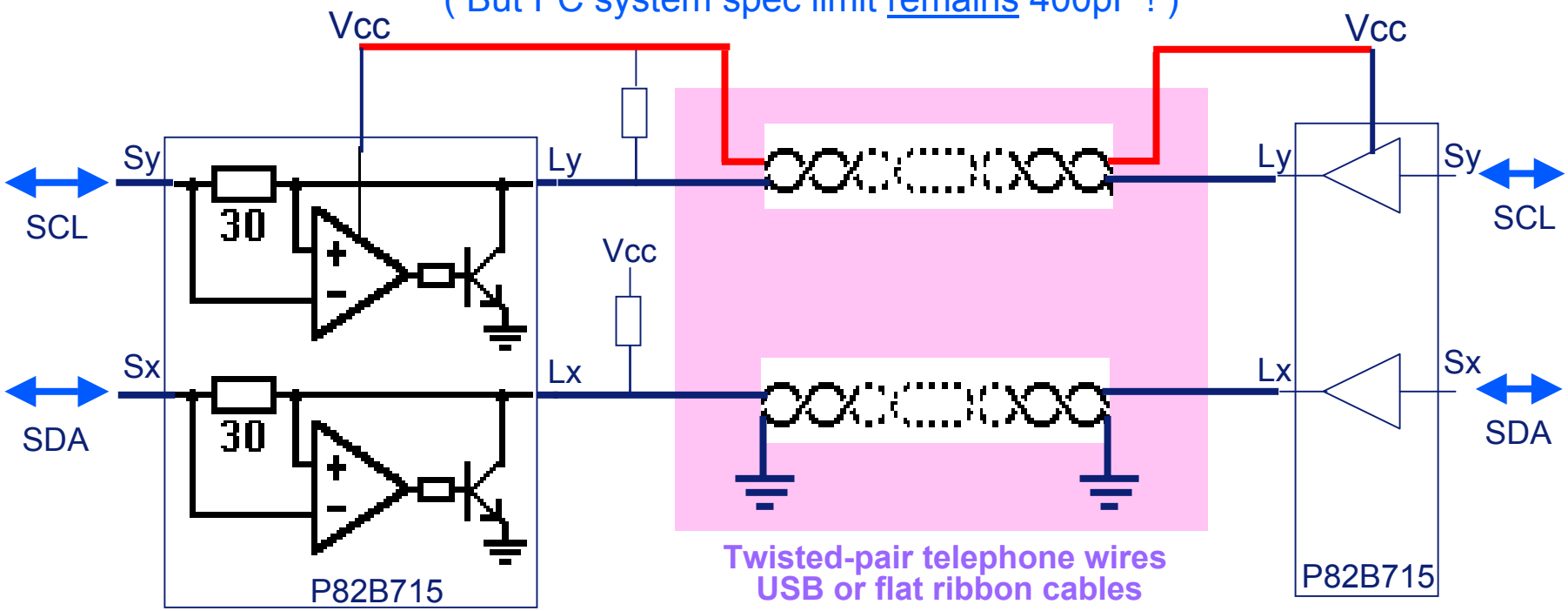
Higher current sink up to 30mA static

Bi-directional I²C

Convert the logic signal impedance level back to I²C compatible (3mA)

P82B715 I²C Bus Extender drives long cables

(But I²C system spec limit remains 400pF !)



I²C system capacitance load = long wiring capacitance divided by 10

Bi-directional I2C

Normal logic voltage levels, exactly I²C

I²C currents (3mA)

Bi-directional signals

No change to logic voltage levels

Higher current sink, up to 30mA static, reduces impedance to increase noise immunity

Bi-directional I²C

Converts the logic signal impedance level back to I²C compatible (3mA)

I²C Bus Extender or I²C Bus Buffer ?

What's the difference ?

Extender: P82B715

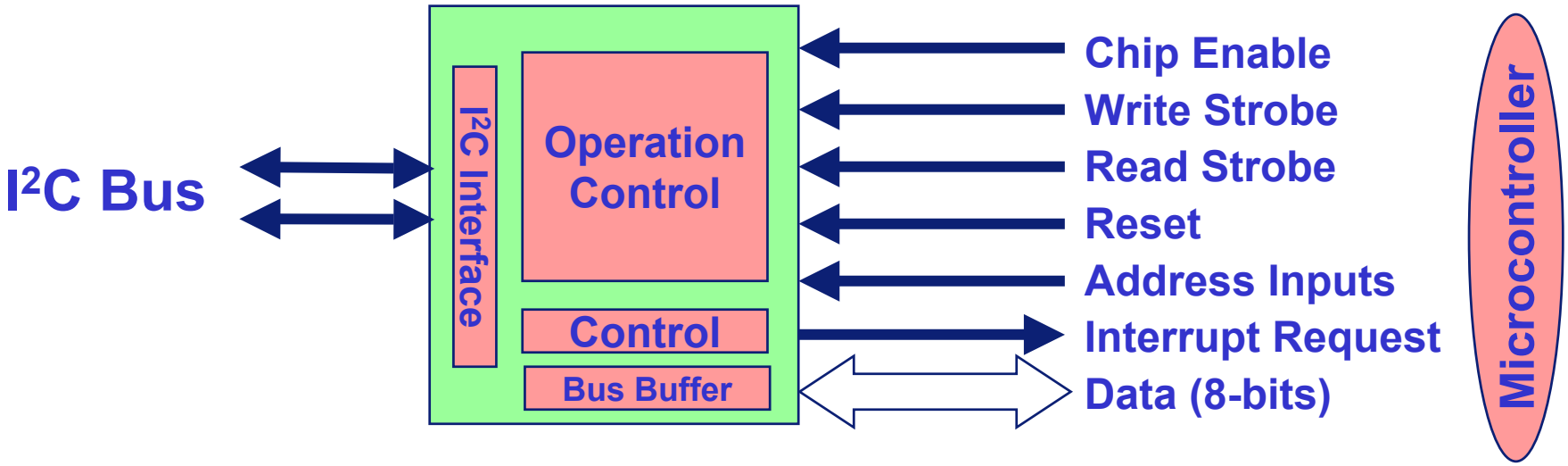
- Doesn't change any logic voltage levels
  - Retains usual noise margins
  - Logic levels set only by I/Os, not by Vcc
  - Only requirement is Vcc >= logic 'hi' level
- No 'isolation' of connected devices
  - Sum of all the connected I²C bus capacitances normally remains at 400pF, can be exceptions
  - Crashes buses if its Vcc is removed
- Fixed X10 current gain
  - Amplifies one direction only, and only when sinking
  - Input 'lo' drive is 1/10 output sink current
  - 3mA drive allows 30mA sink on extended bus
- Always need at least two in a system
  - Normal I²C devices are not allowed on 30mA side

See AN255-02 for details

Buffer: PCA9515/16/18, P82B96

- Uses special logic voltages on some I/Os
  - Necessary to prevent system latching
  - Input logic threshold fixed around 0.5 - 1V
  - Outputs don't pull right down to GND.
  - These special I/Os have reduced noise margins
- Provides isolation of connected devices
  - Bus loading is simply I/O pin capacitance, < 7pF
  - Will free all buses if its supply fails
- Current gain is essentially infinite (=buffer !)
  - Input current < 1uA
  - Adding external amplification to P82B96 is allowed so NO LIMIT to load (=devices) that can be driven
- Simple buffering needs only one chip
  - Using standard I²C bus impedances each side
- P82B96 offers X10 impedance conversion
  - Then use multiple buffers to convert back to I²C

Parallel Bus to I²C Bus Controller



FEATURES

-Provides both master and slave functions.
-Controls all the I²C bus specific sequences, protocol, arbitration and timing
-Internal oscillator (PCA9564 only)
-Hardware Reset pin and Power On Reset (POR)

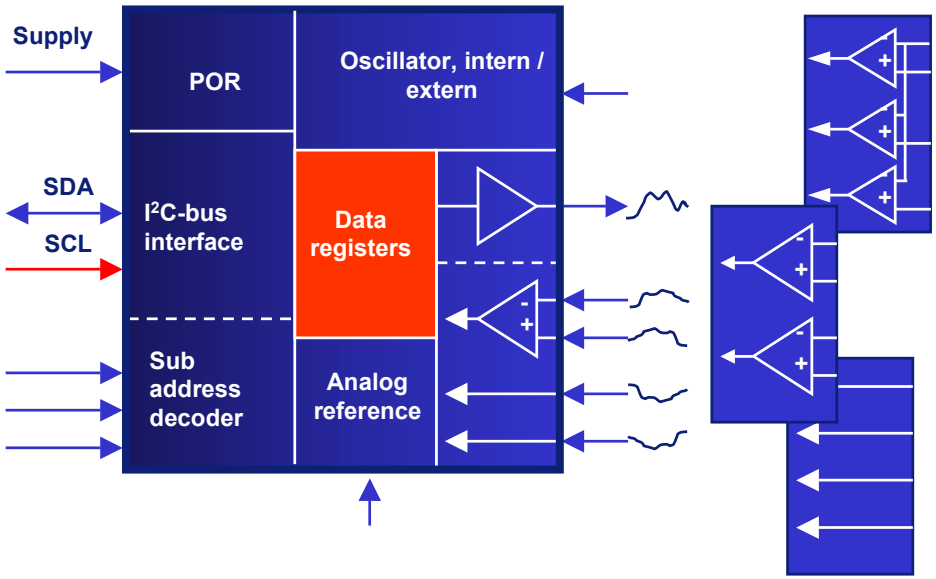
KEY POINTS

-Serves as an interface between most standard parallel-bus microcontrollers/ microprocessors and the serial I²C bus.
-Allows the parallel bus system to communicate with the I²C bus

	Voltage range	Max I²C freq	Clock source	Parallel interface
PCF8584	4.5 - 5.5V	90 kHz	External	Slow
PCA9564	2.3 - 3.6V w/5V tolerance	360 kHz	Internal	33 MHz - Fast

PCA9564 is sampling

Analog to Digital Converter



KEY POINTS

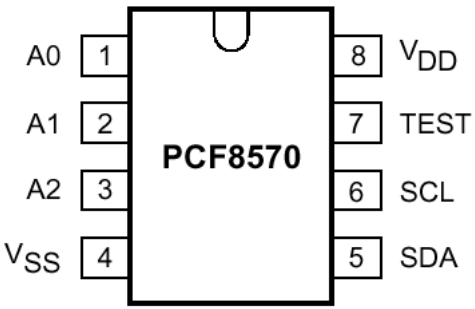
-Converts signals from digital to analog and analog to digital

FEATURES

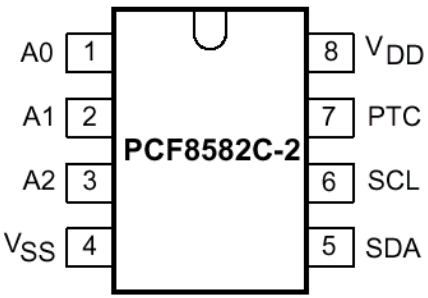
-4 channel A to D
-1 channel D to A
-Internal oscillator
-Hardware Reset pin and Power On Reset (POR)

	Voltage range	Max I^2C freq	Resolution
PCF8591	2.5 - 5.5V w/5V tolerance	100 kHz	8-bit

I²C Serial CMOS RAM/EEPROMs

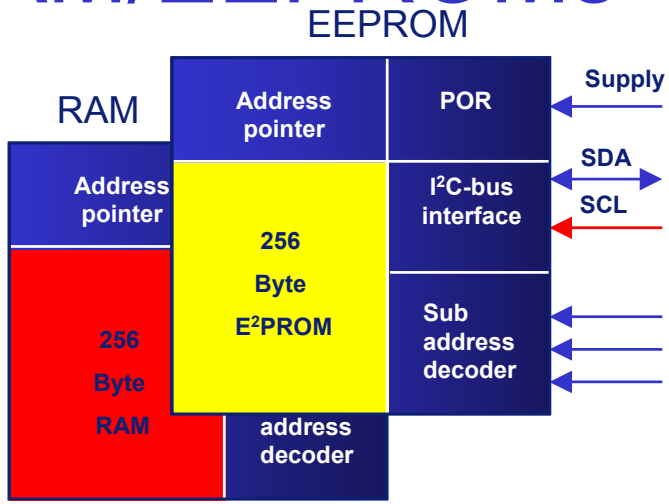


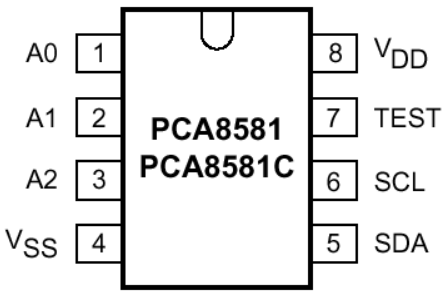
256 x 8-bit RAM



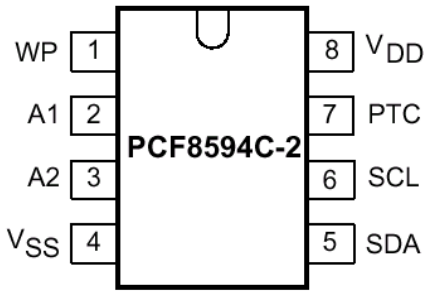
256 x 8-byte (2 kbit)

Also PCF85102C-2 and PCF85103C-2

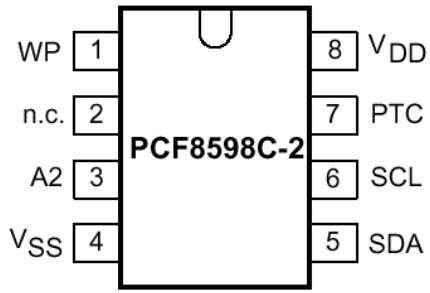




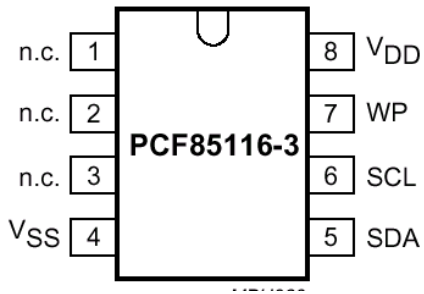
128 x 8-byte (1 kbit)



512 x 8-byte (4 kbit)



1024 x 8-byte (8 kbit)



2048 x 8-byte (16 kbit)

FEATURES

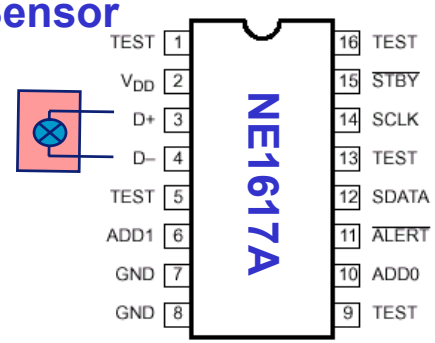
-Wide voltage range of 2.5 to 5.5V
-1,000,000 read and write cycles
-10 year data retention

KEY POINTS

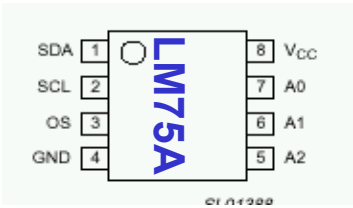
-I²C bus is used to read and write information to and from the memory
-Wide voltage range minimizes the number of EEPROMs that need to be in inventory

I²C Hardware Monitors

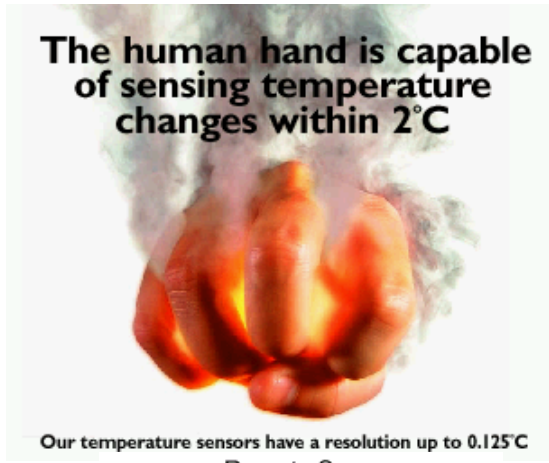
Remote Sensor

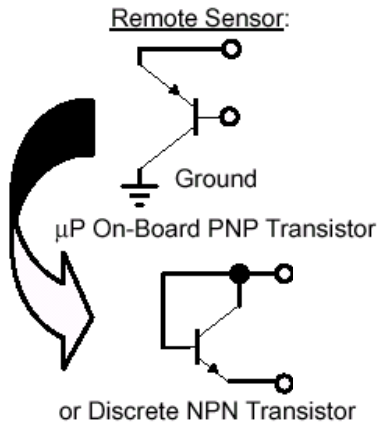


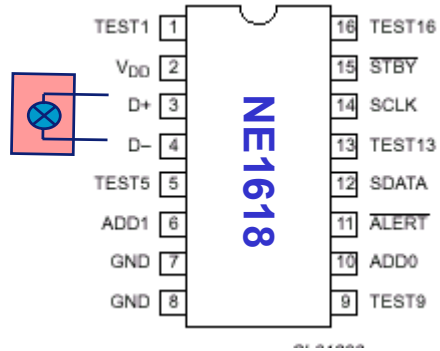
I²C Temperature Monitor



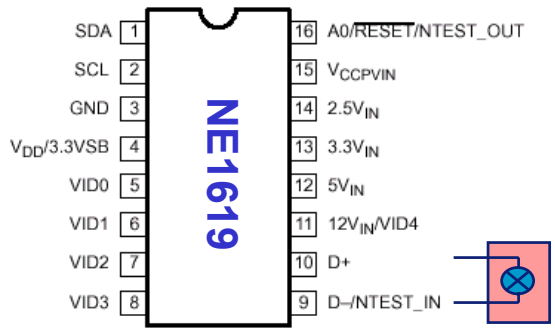
Digital Temperature Sensor and Thermal Watchdog™







High Accuracy Temp Monitor



I²C Temperature and Voltage Monitor

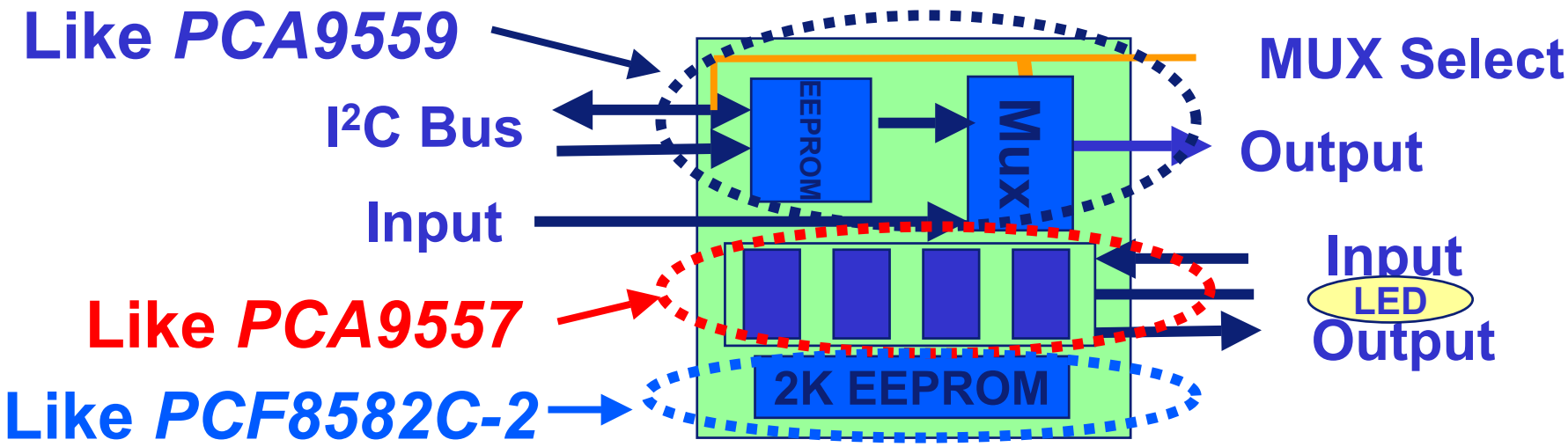
FEATURES

–High temperature accuracy
–Open drain interrupt output

KEY POINTS

–Sense temperature and/or monitor voltage via I²C
–Remote sensor can be internal to microprocessor

Integrated I²C ASICs



- **PCA9558**, 5-bit Multiplexed/1-bit Latched 6-bit I²C EEPROM and Octal SMBus Registered Interface with Integrated 256 Byte EEPROM (shown above)
- **PCA9504A**, 56-pin TSSOP Glue Chip 4 for Pentium® III & 4 motherboards
- **PCA9500**, 8-bit I²C/SMBus I/O Port with 256 Byte EEPROM
- **PCA9501**, 8-bit I²C/SMBus I/O Port with 256 Byte EEPROM & Interrupt

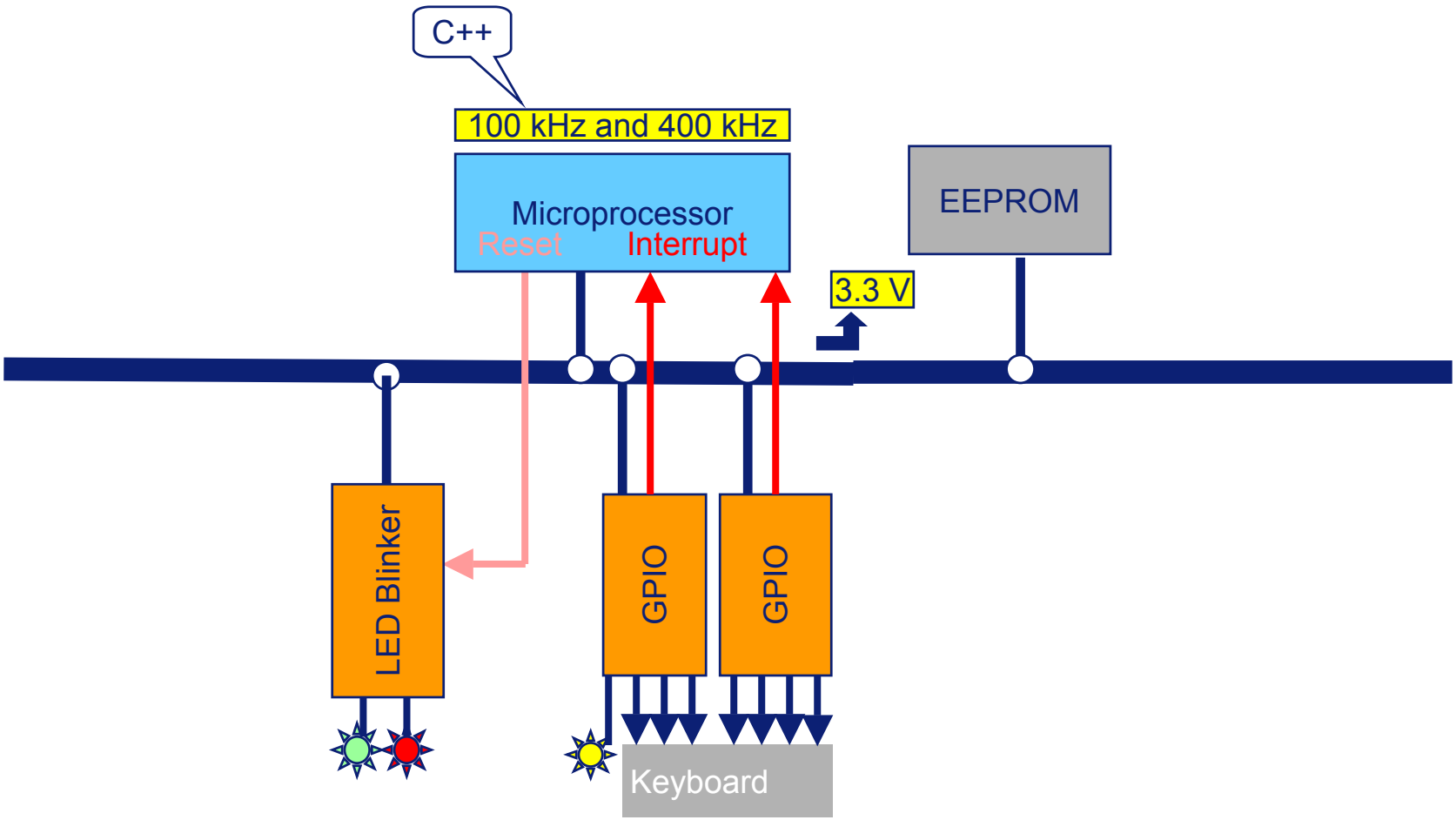
FEATURES

-Integration of many functions into one device to help reduce part count, cost and board space requirements

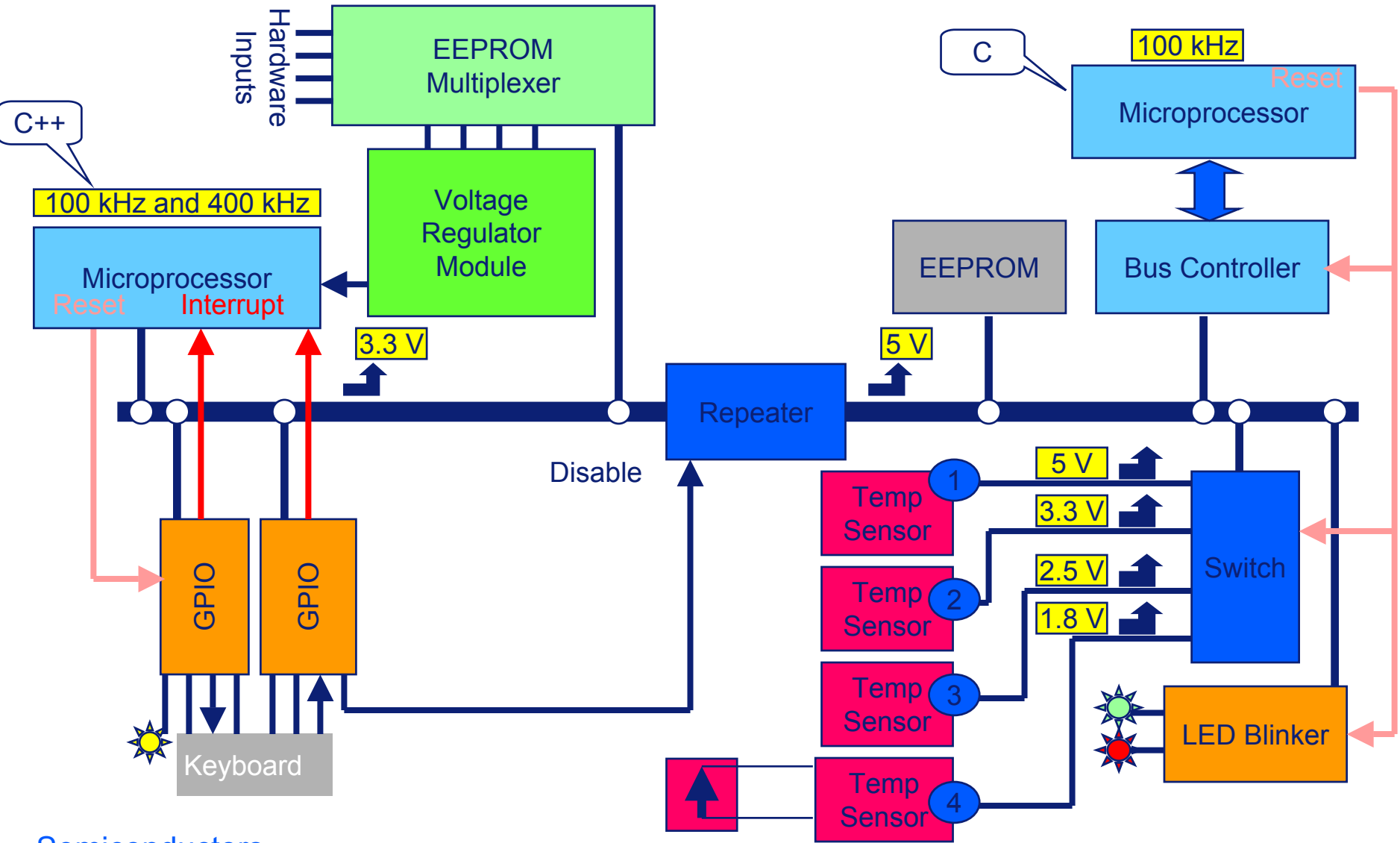
KEY POINTS

-Customer input is welcome on other possible combination devices

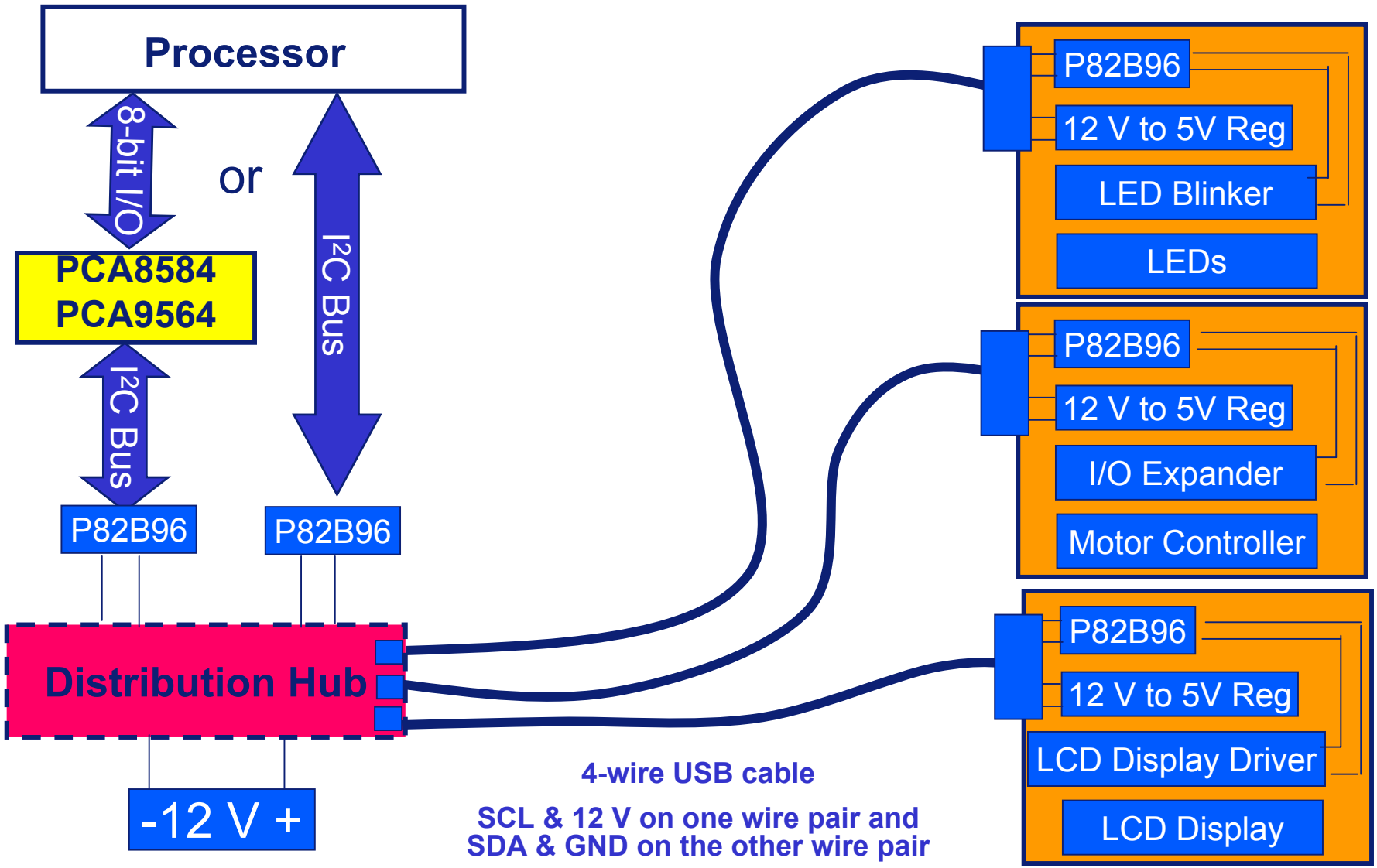
I²C Bus Basics - Simple Bus Arrangement



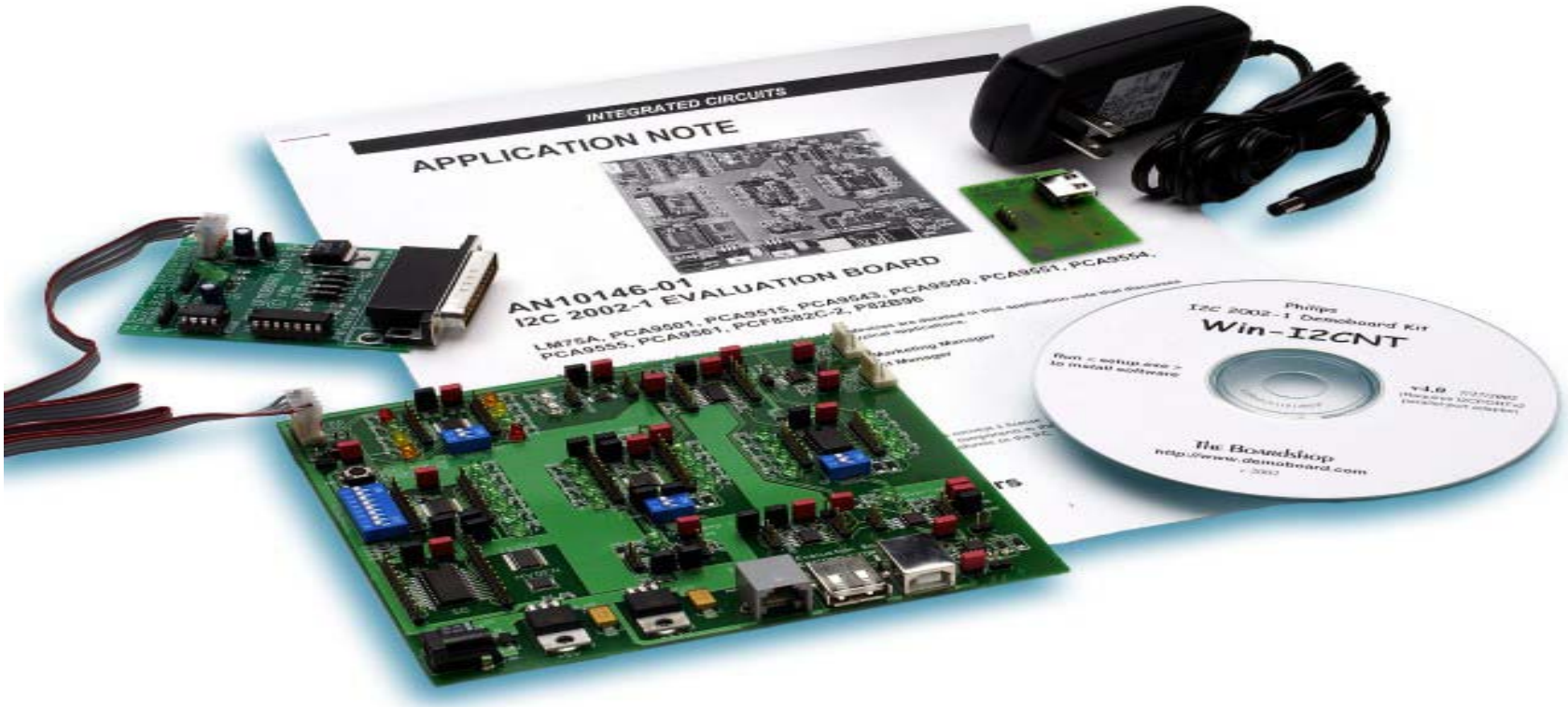
I²C Bus Basics - Complex Bus Arrangement



Slot or Gaming Machine Setup



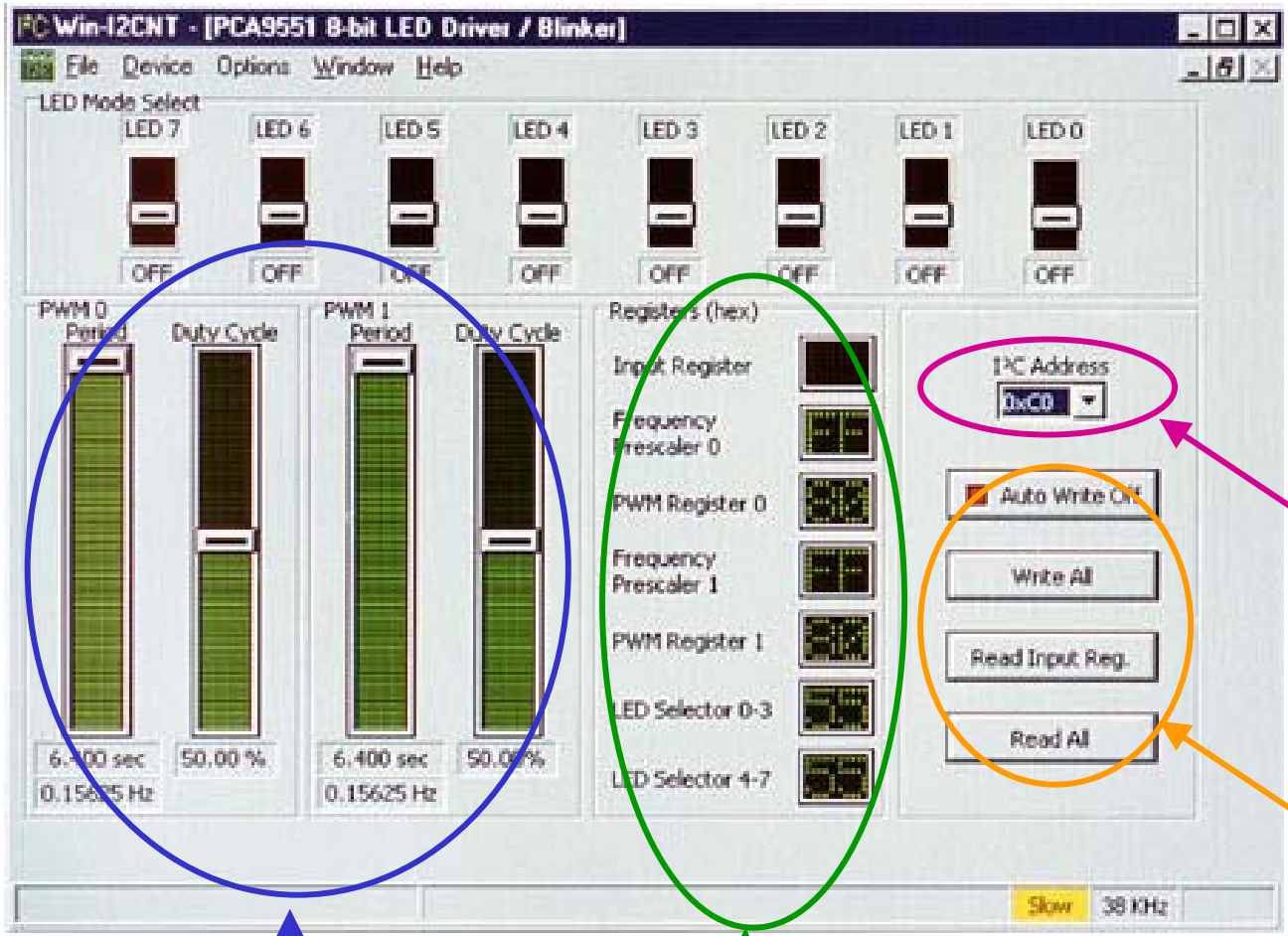
I2C 2002-1 Evaluation Board Kit



FEATURES

- Converts Personal Computer parallel port to I²C bus master
- Simple to use graphical interface for I²C commands
- Win-I2CNT software compatible with Windows 95, 98, ME, NT, XP and 2000
- Order kits at www.demoboard.com

PCA9551 LED Blinkers Win-I2CNT Interface Screen



Select LEDs mode

Device address CC for PCA9551

Write and Read Registers

Select blinking options

Registers information

I²C Sample Kit

The I²C Sample Kit consists of eight different I²C devices in tape inserted into the I²C Sample Kit box with an informative insert.

Devices include three each of the GTL2010PW, P82B96TD, PCA9551D, PCA9545D, PCA9555D, PCA9557D, PCA9515D and PCA9501D

Request the I²C Sample Kit or individual device samples from your Philips Sales Representative or directly from PC.MB.SVL@philips.com

Technical Support Information

Application Notes

AN250 PCA8550 4-Bit Multiplexed/1-Bit Latched 5-Bit I²C E2PROM

AN255 I²C and SMBus Hubs, Buffers, and Repeaters

AN256 PCA9500/PCA9501 Provides Simple Card Maintenance and Control Using I²C

AN444 P82B715 I²C Bus Buffer

AN469 I²C I/O Port Selection

AN460 Introducing the P82B96 I²C Bus Buffer

AN262 PCA954X Multiplexers and Switches

AN264 I²C Devices for LED Display Control

AN463 I²C slave routines for the 87LPC76X

AN464 Using the 87LPC76X microcontroller as an I²C bus master

AN465 Using the 87LPC76X in multi-master I²C applications

Download from > www.philipslogic.com/support/appnotes/

I²C Product Flyers

Mobile Display Drivers	Order Number: 9397 750 09071
LM75A	Order Number: None
NE1617A/18/19	Order Number: 9397 750 07609
PCA8550	Order Number: 9397 750 04323
PCA9500/01	Order Number: 9397 750 09897
PCA9504A	Order Number: 9397 750 08562
PCA9515/16	Order Number: 9397 750 08205
PCA9540/42/44	Order Number: 9397 750 06542
PCA954X	Order Number: 9397 750 09222
PCA9550/51/52	Order Number: 9397 750 09208
PCA9554/54A/55	Order Number: 9397 750 08924
PCA9556	Order Number: 9397 750 06812
PCA9558	Order Number: 9397 750 08211
PCA9559	Order Number: 9397 750 06813
PCA9560/61	Order Number: 9397 750 09206
PCF EEPROM	Order Number: 9397 750 09209
P82B715	Order Number: 9397 750 09XXX
P82B96	Order Number: 9397 750 09084

Download from > www.philipslogic.com/products/collateral/i2c

I²C Device Data Sheets, IBIS models Application Notes and Other Information

Product family
descriptions
line cards
cross reference
data sheets

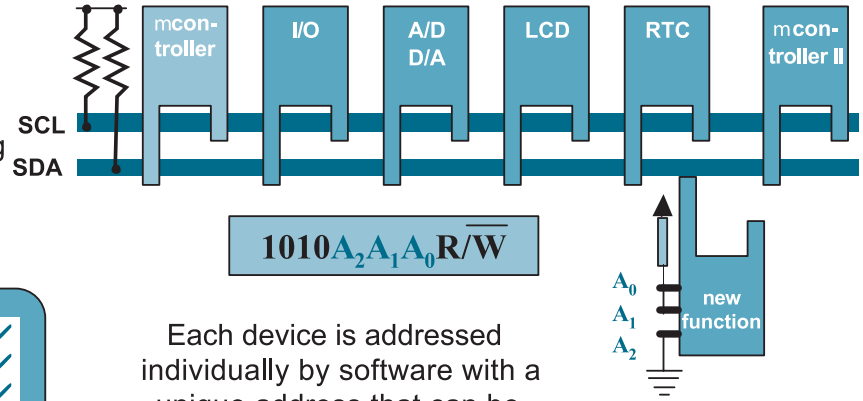
Link to
app notes
models
user guides
PLL design
software
datasheets

Semiconductors

I²C Bus Solutions

I²C Bus Basics

This universal 2 wire bus, developed by Philips, is a de facto standard for controlling and monitoring applications in computing, communications and industrial segments.



Each device is addressed individually by software with a unique address that can be modified by hardware pins.

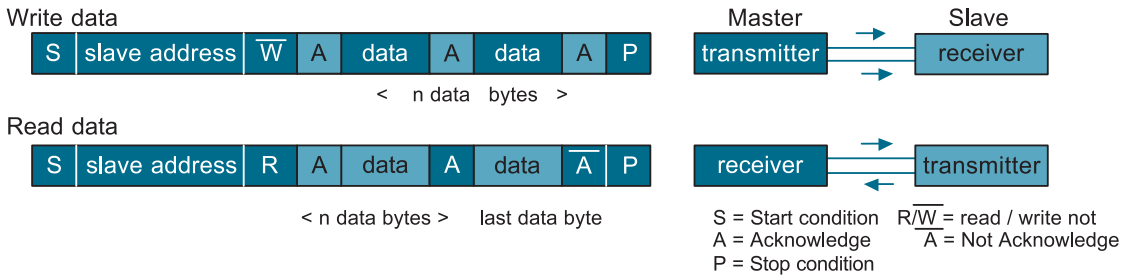
It is the only 2 wire bus where devices are addressed completely by software! This saves PC-board costs and design-in time.

- Easily expandable ✔
- Support from many semiconductor companies ✔
- More than 150 different devices ✔
- Multi master capability e.g. for diagnostics ✔
- Proven applications in *Telecom* market ✔
- Proven in *Industrial* environment ✔
- Used in *Consumer* applications ✔
- Every year new additional products ✔

- I²C-bus handbook, I²C Website: www.semiconductors.philips.com/i2c
- Application notes for GPIOs, RTCs, multiplexers and level shifters.
- Training programs
- Application / design-in support

- Bus speed 100 kHz ✔
- 400 kHz ✔
- 3400 kHz ✔
- V_{DD} range 2.3 - 5.5V ✔
- wiring overhead: low ✔
- power consumption: low ✔ ✔

New devices or functions can be easily clipped on to an existing bus!



Data is transmitted between the master and slave at speeds of 100 kHz, 400 kHz or 3.4 MHz.

The master always sends the clock signal.

www.philipslogic.com/i2c

PHILIPS

I²C Bus Solutions
I²C Product Summary

Data sheets can be downloaded at www.philipslogic.com/i2c or www.semiconductors.philips.com/i2c

	TYPE OF FUNCTION IN DEVICE												FEATURES																							
																	Vcc RANGE (V)						FREQ (kHz)		TEMP (°C)				PACKAGES							
Device	I/O EXPANDER (bits)	LED BLINKER (bits)	MUX / LATCH / EEPROM (bits-latched bits-registers)	MUX / SWITCH (In/Out channels)	REPEATER / HUB (In/Out segments)	BUS CONTROLLER	TEMPERATURE SENSOR	VOLTAGE MEASUREMENT	RAM / EEPROM (Kbits)	REAL TIME CLOCK / CALENDER	ANALOG / DIGITAL CONVERTER	LCD DRIVER (segments)	# of ADDRESSES	INTERRUPT (In/Out)	HARDWARE RESET	CURRENT (per bit/total mA)	1.0	1.8	2.5	3.3	5	5V TOLERANT	100	400	0 to 70	- 40 to 85	- 55 to 125	PIN COUNT	DIP	SO (narrow)	SO (wide)	SSOP	QSOP	TSSOP	HVQFN
LM75A							2°C						8	0-1						●	●		●	●			●	8		D				DP	
NE1617A							3°C						9							●	●	●	●			0 to 125		16					DS		
NE1618							1°C						9							●		●	●			0 to 125		16					DS		
NE1619							3°	●					2							●	●	●	●	●		0 to 125		16					DS		
OM4085												96	16					2	●	●	●	●	●			●		40			VSO40				
P82B715					●								NA								●	●	●			●		8	PN	TD					
P82B96					●								NA						●	●	●	●	●			●		8	PN	TD					
PCA8550			4-1-1										1							●		●	●	●	●			16		D		DB		PW	
PCA8581C									1				8						●	●	●	●	●			-25 to 85		8	PN	TD					
PCA9500	8								2				2-8			25-100				●		●	●	●		●		16			D			PW	BS
PCA9501	8								2				2-64	8-1		25-100				●	●		●	●		●		20						PW	BS
PCA9511					1-1								NA							●		●	●	●		●		8		D				DP	
PCA9515					1-1								NA							●		●	●	●		●		8		D				DP	
PCA9516					1-4								NA							●		●	●	●		●		16		D				PW	
PCA9518					1-4								NA							●		●	●	●		●		20			D			PW	
PCA9540				1-2									1						●	●	●	●	●	●		●		8		D				DP	
PCA9542				1-2									8	2-1					●	●	●	●	●	●		●		14		D				PW	
PCA9543				1-2									4	2-1	●				●	●	●	●	●	●		●		14		D				PW	
PCA9544				1-4									8	4-1					●	●	●	●	●	●		●		20			D			PW	BS
PCA9545				1-4									4	4-1	●				●	●	●	●	●	●		●		20			D			PW	BS
PCA9546				1-4									8		●				●	●	●	●	●	●		●		16		D				PW	
PCA9548				1-8									8		●				●	●	●	●	●	●		●		24			D			PW	BS
PCA9550		2											2		●	25-50			●	●	●	●	●	●		●		8		D				DP	
PCA9551		8											8		●	25-100			●	●	●	●	●	●		●		16		D				PW	BS
PCA9552		16											8		●	25-200			●	●	●	●	●	●		●		24			D			PW	BS
PCA9553		4											2			25-100			●	●	●	●	●	●		●		8		D	D			DP	
PCA9534/54/54A	8												8	8-1		25-100			●	●	●	●	●	●		●		16			D	DB		PW	BS
PCA9535/55	16												8	16-1		25-200			●	●	●	●	●	●		●		24			D	DB		PW	BS
PCA9556	8												8		●	20-80				●	●		●		●			16						PW	
PCA9557	8												8		●	25-100			●	●	●	●	●	●		●		16		D				PW	BS
PCA9558	8		5-1-1						2				2			25-100				●		●	●	●	●			28						PW	
PCA9559			5-1-1										4			20-80				●		●	●	●	●			20						PW	
PCA9560			5-1-2										4			25-100				●		●	●	●	●			20			D			PW	
PCA9561			6-0-4										4			25-100				●		●	●	●	●			20			D			PW	
PCA9564						●							128	0-1	●				●	●		●	●	●		●		20			D			PW	BS
PCF2113												24 ch	2					●	●	●	●	●	●	●		●		100			LQFP100				
PCF85102C-2									2				8						●	●	●	●	●			●		8	N	D					
PCF85103C-2									2				8						●	●	●	●	●			●		8	N	D					
PCF85116-3									16				8							●	●	●	●	●		●		8	N	D					
PCF8563										●			1	0-1			●	●	●	●	●	●	●	●		●		8	PN		TD			DP	
PCF8566												96	16						●	●	●	●	●			●		40	PN		VSO40				
PCF8570									2				8						●	●	●	●	●			●		8	PN	TD					
PCF8573										●			4				1.1	●	●	●	●	●	●			●		16	PN		TD				
PCF8574/74A	8												4	0-1		20-100			●	●	●	●	●			●		16	PN		TD	TDK			
PCF8575	16												8	0-1		20-100			●	●	●	●	●	●		●		24				TSDB			
PCF8576C												160	16						●	●	●	●	●			●		56/64			VSO56/LQFP64				
PCF8577C												64	16						●	●	●	●	●			●		40	PN		VSO40				
PCF8578/79												384	2						●	●	●	●	●			●		56/64			VSO56/LQFP64				
PCF8582C-2									2				8						●	●	●	●	●			●		8	N	D					
PCF8583									2	●			2	0-1			●	●	●	●	●	●	●			●		8	PN	TD					
PCF8584						●							128	0-1	●						●	●	●			●		20	PN		TD				
PCF8591											8		8						●	●	●	●	●			●		16	PN		TD				
PCF8593										●			1	0-1	●		●	●	●	●	●	●	●			●		8	N		TD				
PCF8594C-2									4				8						●	●	●	●	●			●		8	N	D					
PCF8598C-2									8				8						●	●	●	●	●			●		8	N		D				
SAA1064		4 x 8											4			21 - mA					●	●	●			●		24	P	T					

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