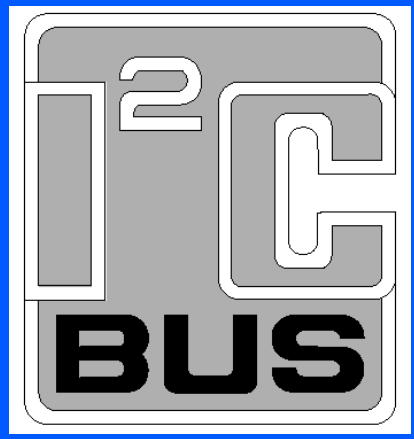
PHILIPS



Interface Products Business Line
Specialty Logic Product Line
I²C Logic Family Overview

2Q 2004

Steve Blozis - I²C International Product Marketing Manager
Jean-Marc Irazabal – I²C Technical Marketing Manager

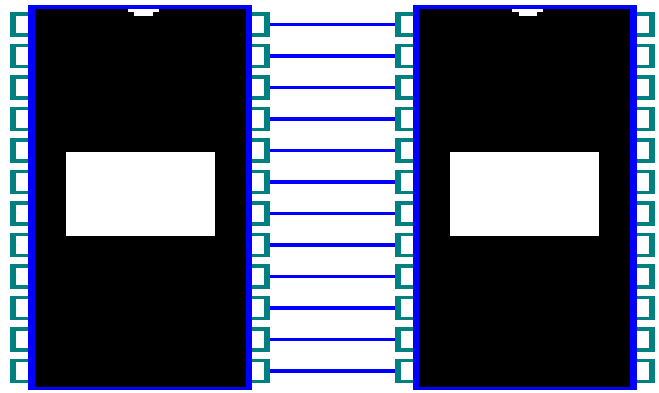
Introduction

How the I²C Bus Works

The I²C (Inter-Integrated Circuit) Bus is a two-wire, low to medium speed, communication bus (a path for electronic signals) developed by Philips Semiconductors in the early 1980s. I²C was created to reduce the manufacturing costs of electronic products.

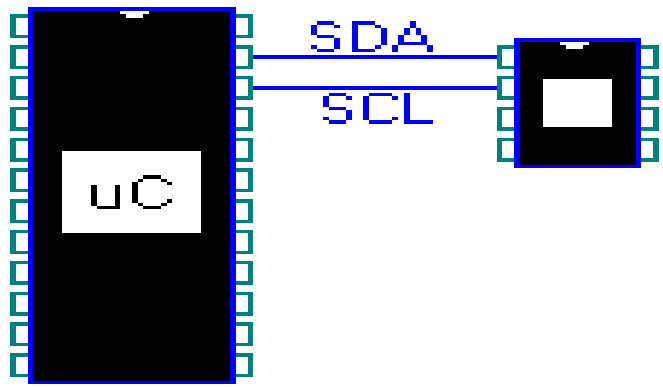
Low Cost

Prior to I²C, chip-to-chip communications used many pins in a parallel interface. Many of these pins were used for inter-chip addressing, selection, control, and data transfers. In a parallel interface, 8 data bits are typically transferred from a sender IC to a receiver IC in a single operation.



Parallel Interface

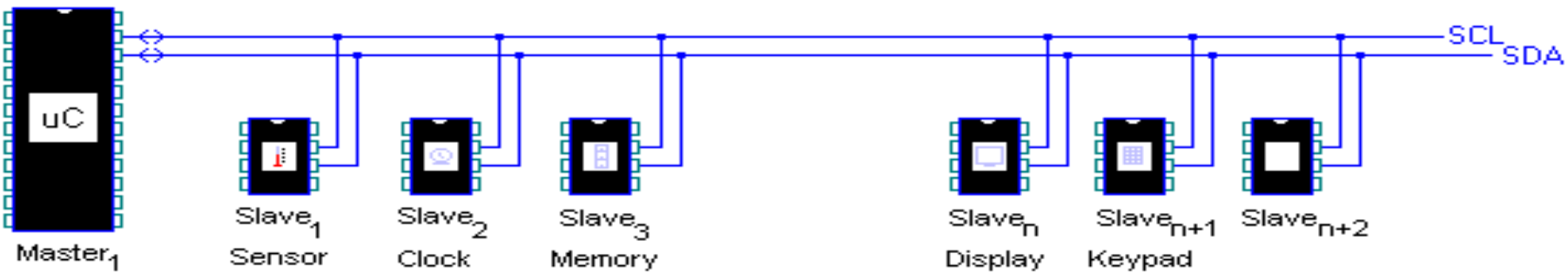
I²C performs chip-to-chip communications using only two wires in a serial interface, allowing ICs to communicate with fewer pins. The two wires in the I²C Bus carry addressing, selection, control, and data, one bit at a time. The Data (SDA) wire carries the data, while the Clock (SCL) wire synchronizes the sender and receiver during the transfer. ICs that use the I²C Bus can perform the same function as their larger parallel interface counterparts, but with far fewer pins.



I²C Serial Interface

Courtesy of www.mcc-us.com

How the I²C Bus Works (II)



One I²C Master, Multiple Slaves

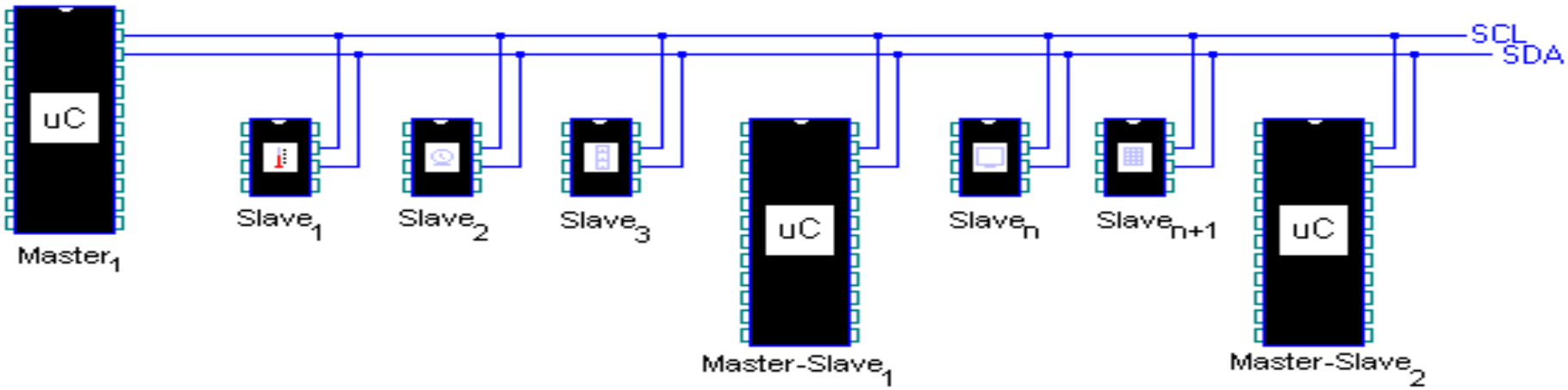
Master-Slave Hierarchy

I²C devices are classified as master or slave. A device that initiates a message is called a master, while a device that responds to a message is called a slave. A device can be master-only, slave-only, or switch between master and slave, as the application requires.

Multiple Devices

I²C can connect many ICs on just two-wires. Each I²C slave device has its own unique slave address. When a master sends a message, it includes the slave address at the beginning of the message. All devices on the bus hear the message, but only the slave that recognizes its own address participates in the transfer.

How the I²C Bus Works (III)

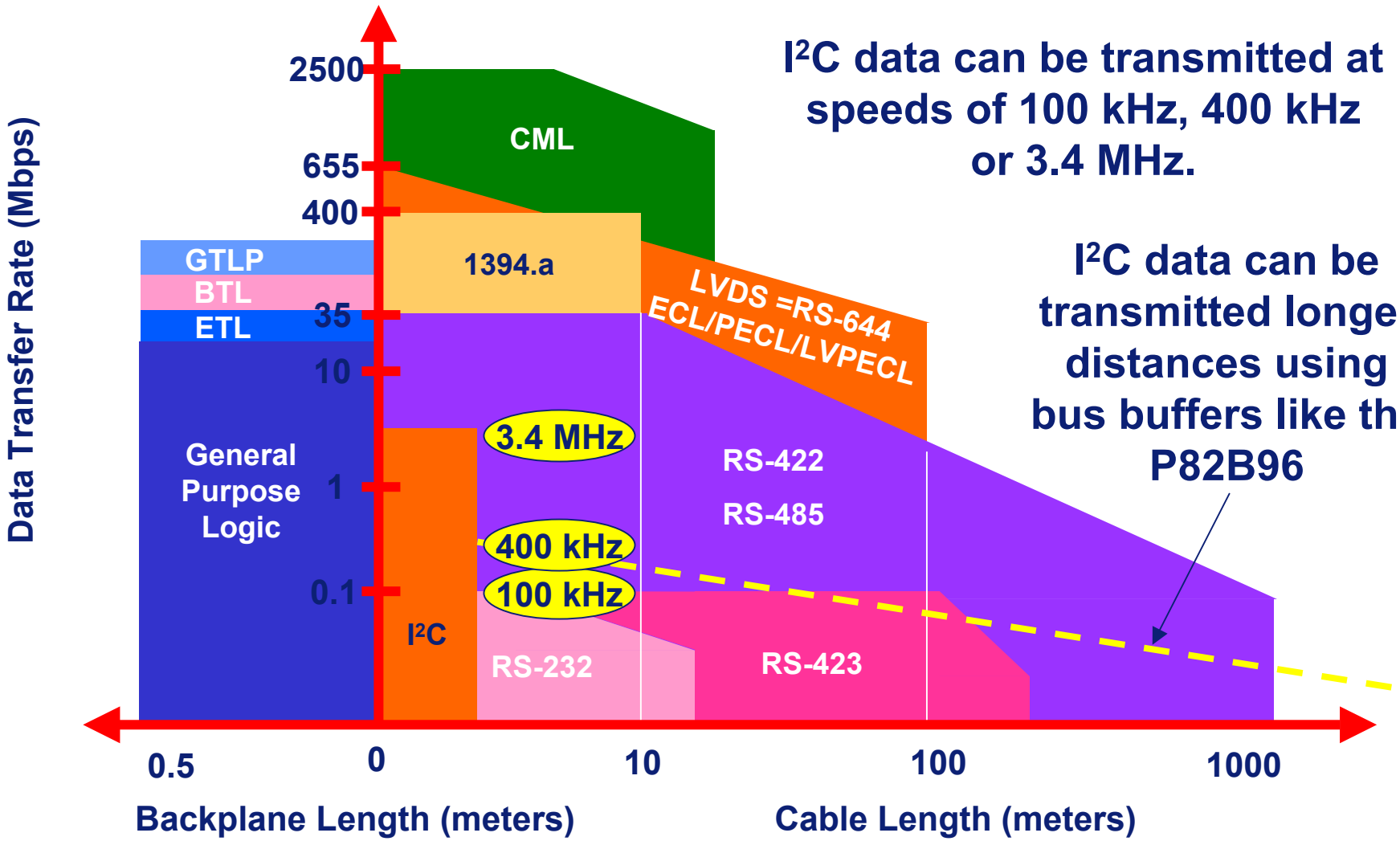


Multi-Master Support

I²C also supports multiple master devices on the bus at the same time, a powerful feature that optimizes bus use by keeping bus message traffic to a minimum. To support multiple masters, I²C must resolve signal conflicts, should two or more master devices try to talk on the bus at the same time. This feat, called bus arbitration loss detection, allows a master to detect when its bus signals are conflicting with those of another master. A master that detects arbitration loss terminates its use of the bus, allowing the message generated by another master to cross the bus unharmed.

The I²C Bus is a time-proven, industry standard, communication protocol used in a wide variety of electronic products. I²C is found in products we use every day, like cellular and conventional telephones, computers, and ATMs (automatic teller machines). Its low cost and powerful features make I²C ideal for low to medium speed chip-to-chip communications.

Transmission Standards

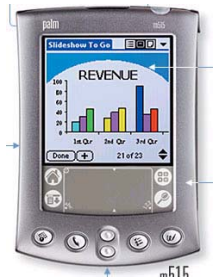


I²C data can be transmitted at speeds of 100 kHz, 400 kHz or 3.4 MHz.

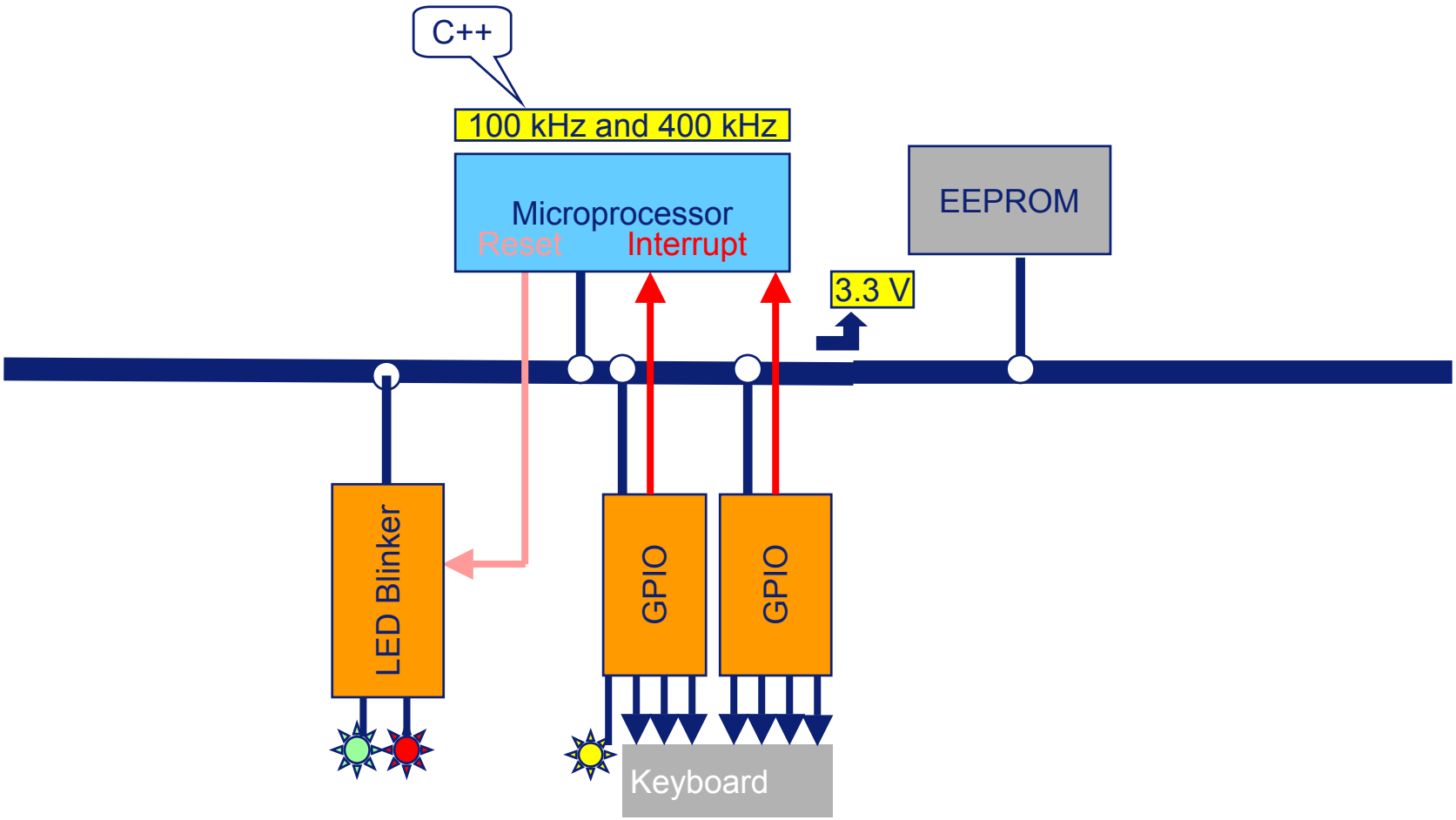
I²C data can be transmitted longer distances using bus buffers like the P82B96

Typical Applications

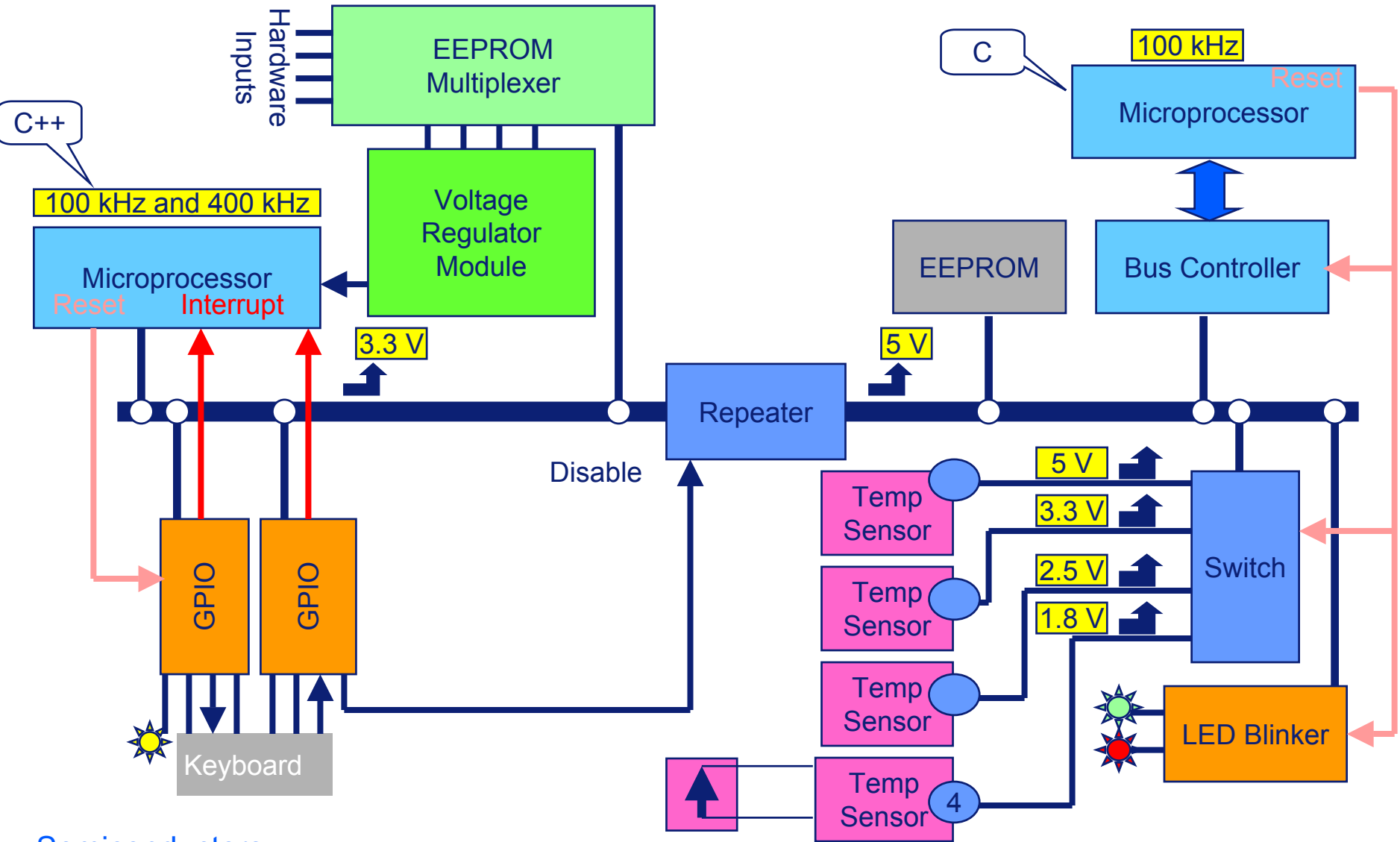
- Cell phones
- PDA’s
- Lap top computers
- Digital cameras
- Portable test equipment
- Servers
- cPCI and AdvancedTCA



Typical I²C Bus Arrangement



Complex I²C Bus Arrangement



I²C Bus Features

- Only 2 bus lines required: data (SDA) and clock (SCL)
- Each device connected to the bus is software addressable by a unique address
- 2 modes: Master-Transmitter and as Master-Receiver
- Multi-master capable protocol:
  - collision detection
  - arbitration
- Serial bi-directional data transfers:
  - 100 kbit/s Standard-mode
  - 400 kbit/s Fast-mode
  - 3.4 Mbit/s High-speed mode
- Maximum bus capacitance = 400 pF (without repeaters) which is about 20 – 30 devices or 10 ft of wire

I²C Bus Benefits

- Well known bus:
  - Created and developed by Philips
  - More than 20 years of existence
  - Has become a world-wide standard
- Standard adopted by all the industry:
  - Computing
  - Networking
  - Automotive
  - Industrial
  - Telecom
  - Consumer
- Used in many types of applications:
  - PC
  - DVD
  - Cell Phones
  - Printers
  - Set Top Boxes
  - PDA
- Adopted by a lot of leading High-Tech companies
  - Intel
  - IBM
  - Compaq
  - Nokia
  - Cisco
  - HP
- Life of products: designed to stay in the market several years

I^2C Designer Benefits

- 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.
- 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.

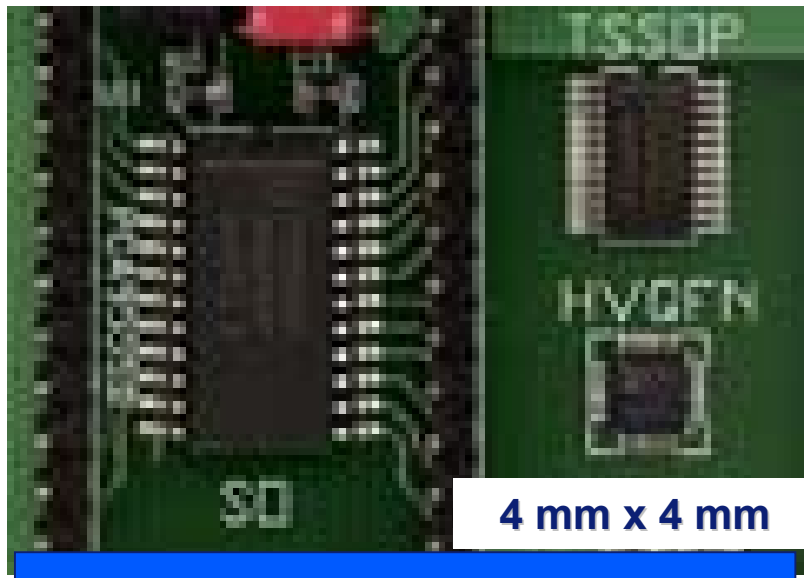
I²C Manufacturer Benefits

- Simplicity: 2 wire protocol
  - Minimum inter connections
  - Minimum footprint
  - Simpler, smaller and less expensive PCB
- Robustness of the protocol
  - Completely integrated protocol
  - No need for address decoding and “glue logic”
  - Interrupt oriented architecture
  - Multi-master capable
- Upgrade path:
  - Speed: 100 kHz → 400 kHz
  - Modular architecture allowing easy design and architecture updates and upgrades

Technical

I²C Product Characteristics

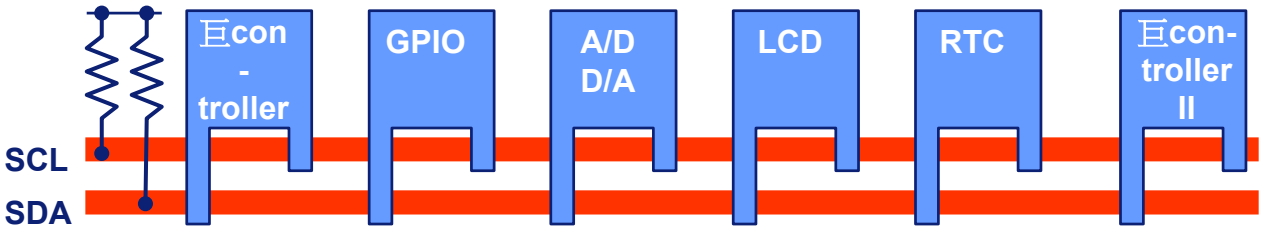
- Package Offerings
  - Typically DIP, SO, SSOP,
  - TSSOP and/or HVQFN packages
- Frequency Range
  - Older devices 100 kHz operation
  - Newer devices operating up to 400 kHz
- Operating Supply Voltage Range
  - 2.3 to 5.5 V or
  - 3.0 to 3.6 V with 5 V tolerance
- Operating temperature range
  - Typically -40 to +85 ºC
  - Some 0 to +70 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 address pins



24 pin 16-bit PCA9555 shown

I²C Bus Basics - Address and Data

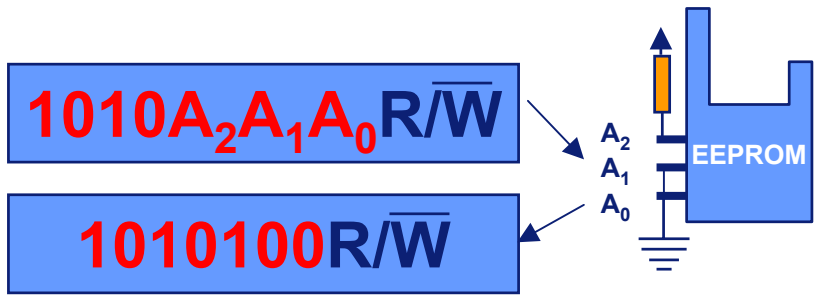
The master always sends the SCL (clock) signal.



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

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

The open drain/collector outputs provide for a "wired-AND" connection that allows devices to be added or removed without impact and always require a pull-up resistor.



Write data

Master transmitter → Slave receiver

< n data bytes >

Read data

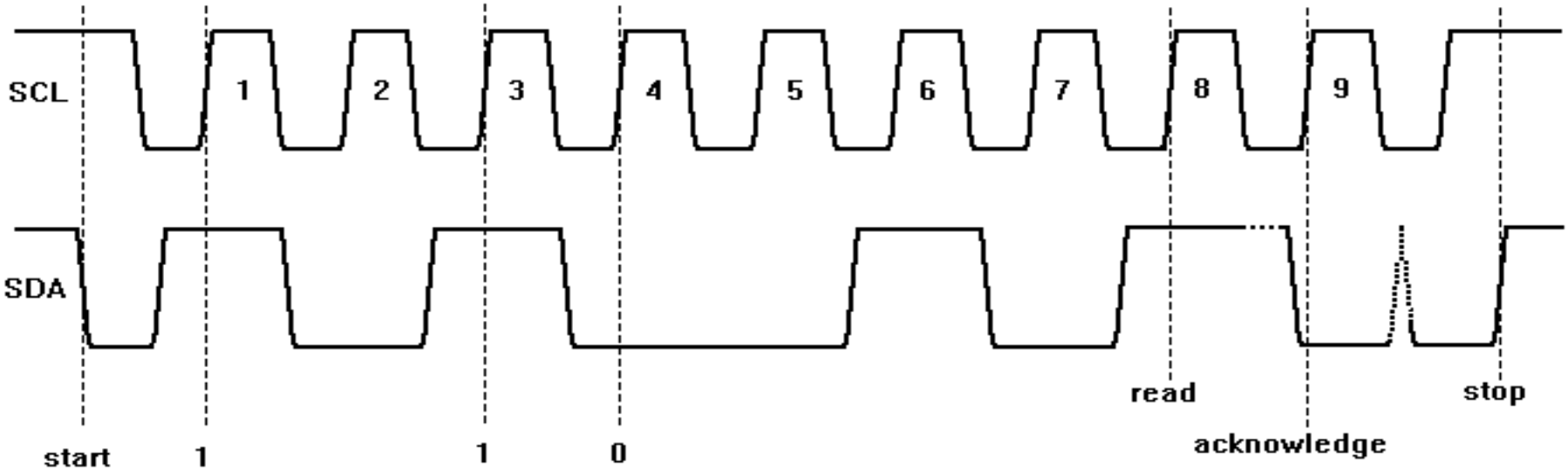
receiver → transmitter

< n data bytes > last data byte

S = Start condition
A = Acknowledge
P = Stop condition

R/W = read / write not
A = Not Acknowledge

I²C Bus Basics - Bus Operation



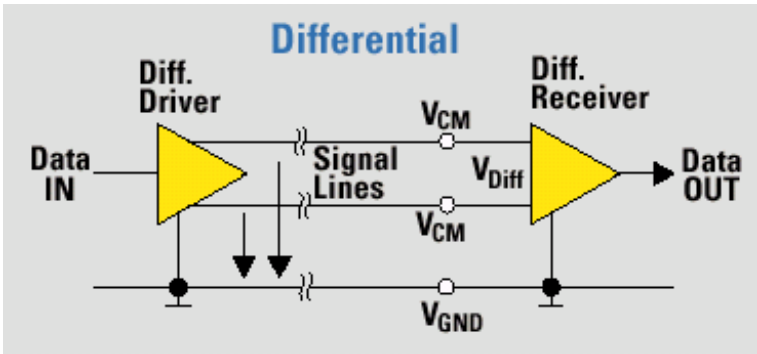
The SCL falling edge 'requests' data when reading, or 'advises' data coming when writing

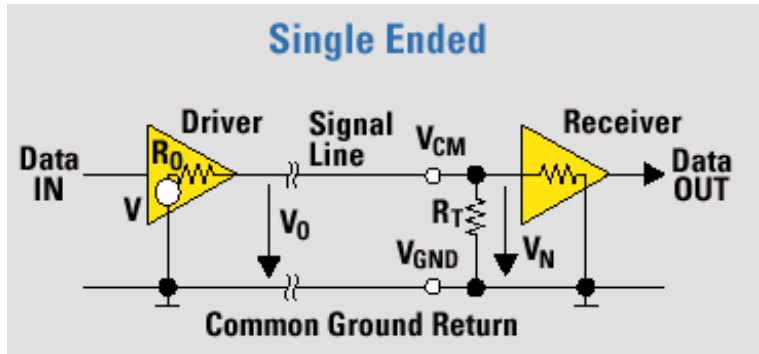
The SDA data changes during the SCL low and is used during or just after the SCL rising edge

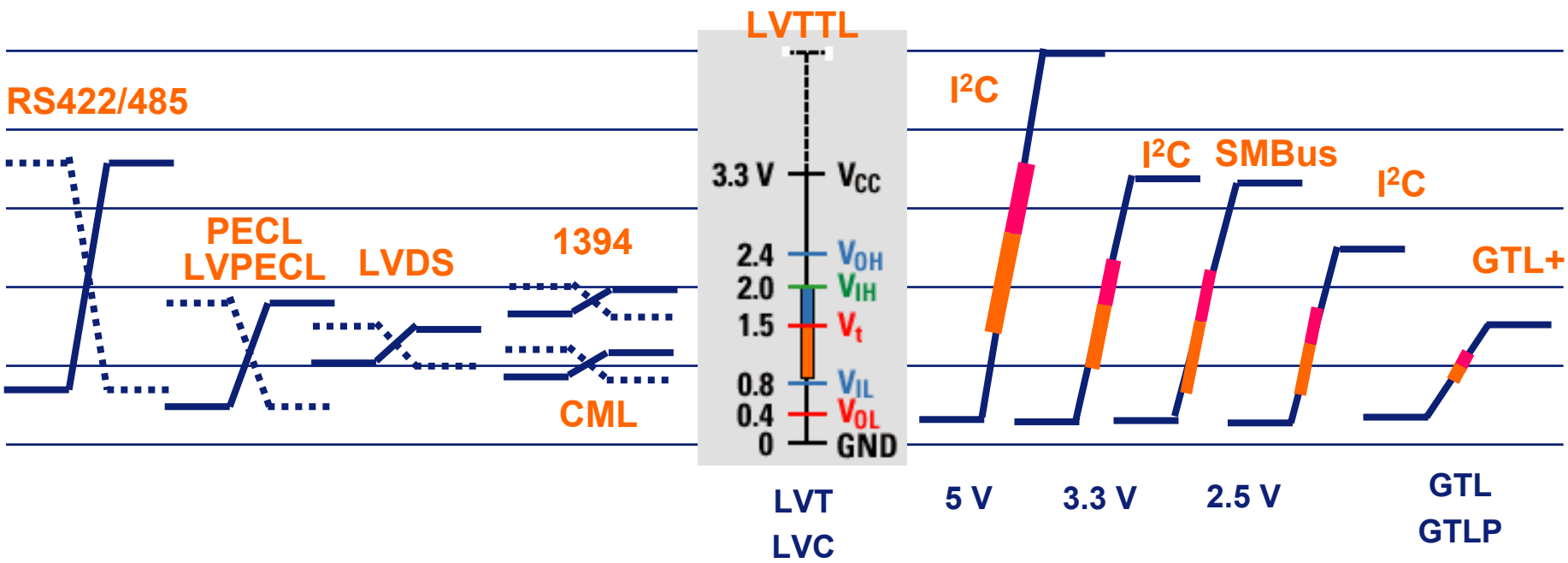
Typical bus communication waveforms

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

Typical Signaling Characteristics

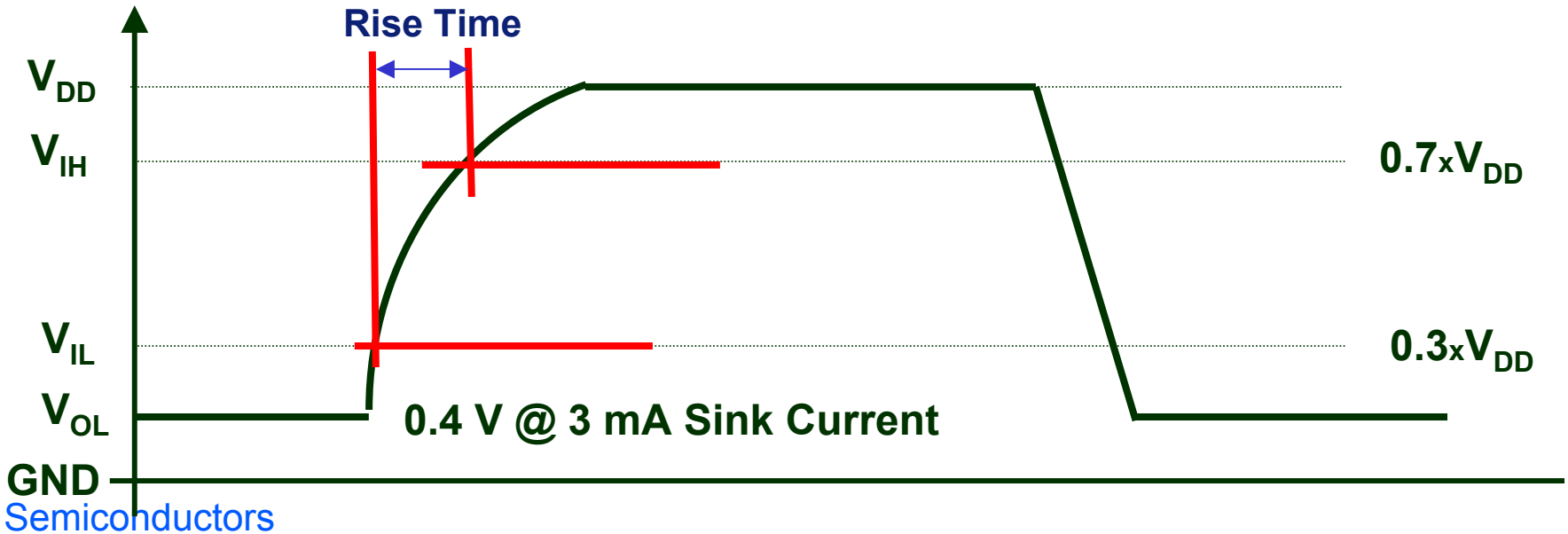






I²C by the numbers

	Standard-Mode	Fast-Mode	High-Speed-Mode	
Bit Rate (kbits/s)	0 to 100	0 to 400	0 to 1700	0 to 3400
Max Cap Load (pF)	400	400	400	100
Rise time (ns)	1000	300	160	80
Spike Filtered (ns)	N/A	50	10	
Address Bits	7 and 10	7 and 10	7 and 10	



I²C Signal Conversion

These microcontrollers have **I²C and UART (RS-232)** ports to allow conversion
- P87C6xxx2 family (661 has two byte oriented I²C interfaces)
- P87C55x
- P87LPC76x family
- P89C66x
- P89LPC932 and future LPC9xx products

These microcontrollers have **I²C and SPI** ports to allow conversion
- XA
- 87C51MX (future product)
- 89LPC9xx (future product)

These microcontrollers and USB devices allow a two device conversion between **I²C and USB**
- PDIUSBD12 + P89C66x -> 100 kHz I²C and USB1.1
- ISP1181 + P89C66x -> 100 kHz I²C and USB1.1
- ISP1581 + P89LPC932 -> 400 kHz I²C and USB2.0

These ucontrollers have **I²C and CAN** ports to allow conversion
- P87C591 - 8 bit solution
- PXA-C37 - 16 bit solution

Products from > www.semiconductors.philips.com/microcontrollers

Support > www.PhilipsMCU.com/products/standard/microcontrollers/support/feedback/

Device Overview

Philips I²C Logic Devices

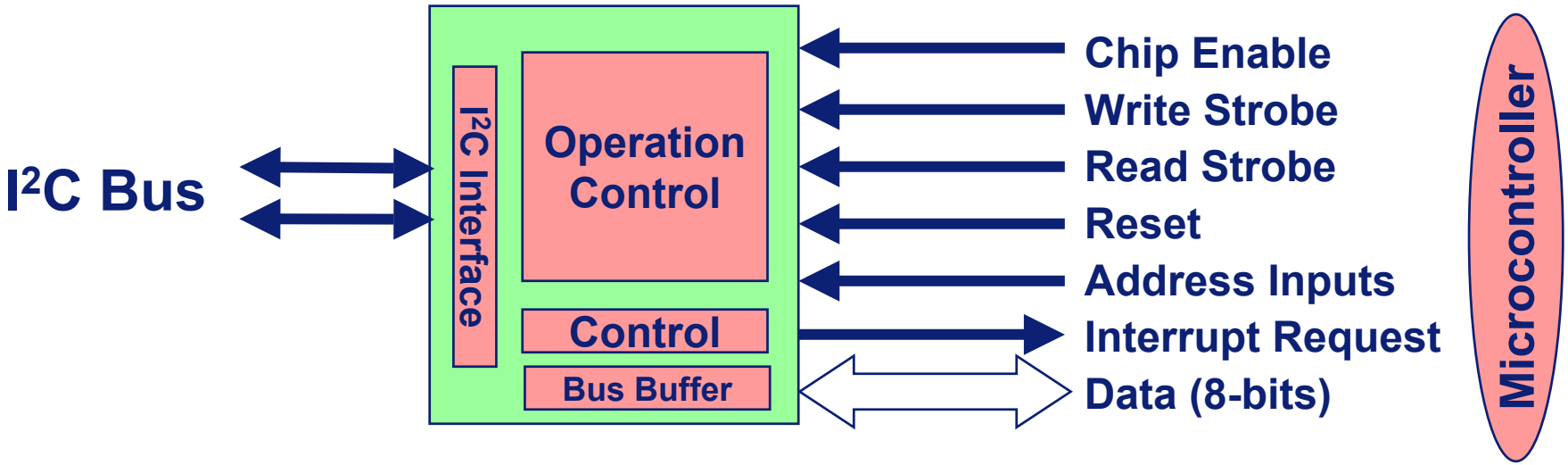
- Bus Controllers
- Temperature Sensors
- I/O Expanders
- LED Blinkers
- Serial EEPROMs
- DIP Switches
- Multiplexers and Switches
- Repeaters/Hubs/Extenders
- Segment Drivers
- Analog/Digital Converters

I²C Logic devices are broken down into 10 different categories

Philips offers over 63 different I²C Logic devices

Bus Controllers

Parallel Bus to I²C Bus Controller



FEATURES

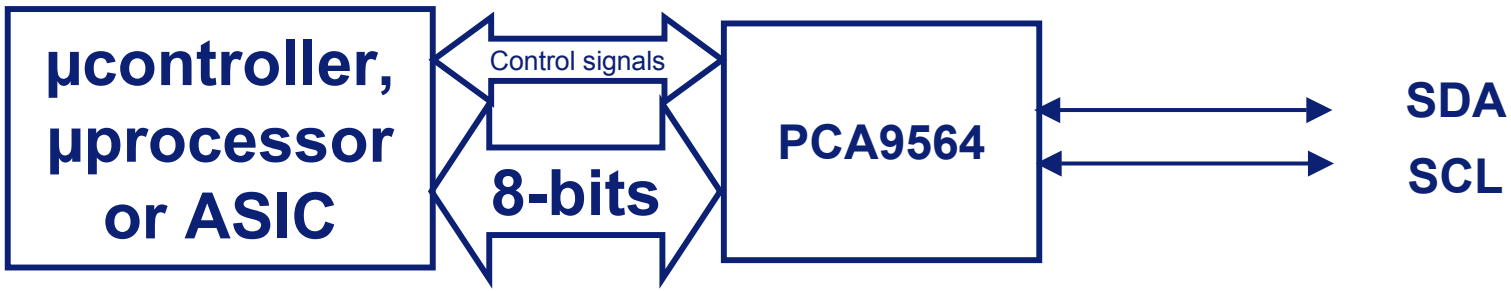
- Provides both master and slave functions.
- Controls all the I²C bus specific sequences, protocol, arbitration and timing
- Internal oscillator (PCA9564 only)
- Hardware Reset pin and Power On Reset \ (POR)

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	3 MHz - Slow
PCA9564	2.3 - 3.6V w/5V tolerance	320 kHz	Internal	50 MHz - Fast

Application – Add I²C Bus Port



- The PCA9564 converts 8-bit parellel data into a multiple master capable I²C port for microcontrollers, microprocessors, custom ASICs, DSPs, etc.., that need to interface with I²C or SMBus components.

Bus Controller vs Bit-banging

Hardware I^2C

Disadvantages: additional cost

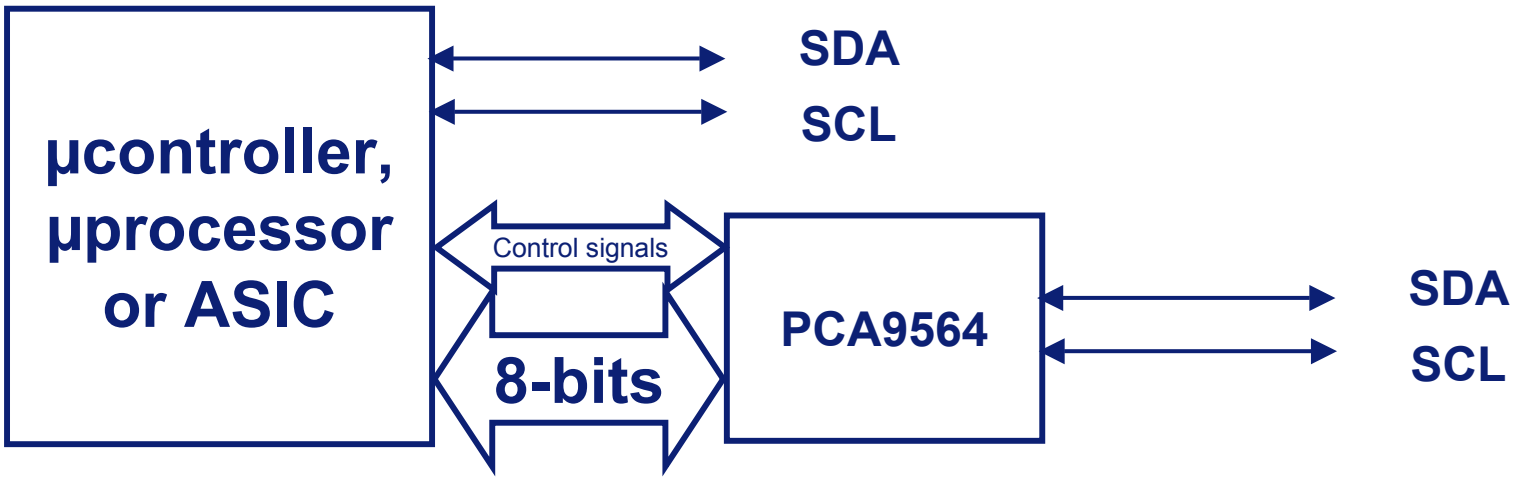
Advantages: frees up the micro to perform other tasks, multi-master capability, glitch filters, bus error detection and recovery, can easily be added to most microcontrollers, simple code (code for a hardware I^2C is relatively simple to write (to write a byte, just load the I2CDAT register with a byte and the hardware does the rest) but you may need to take into consideration all the different error conditions (such as lost arbitration, etc))

Bit-banging

Disadvantages: ties up the micro during the transmission and very difficult to use in a multi-master environment

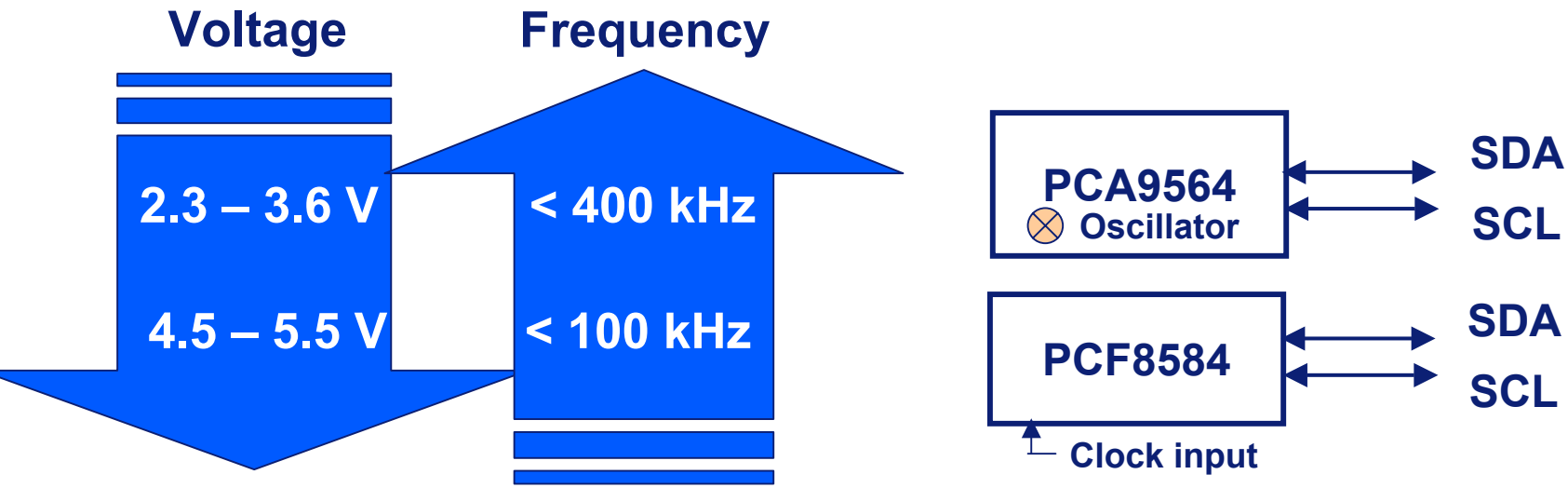
Advantages: inexpensive, can be incorporated into any micro and very little code required (code required for bit-banging an 80C51 micro is only about 50 bytes)

Application – Add additional I²C Bus Ports



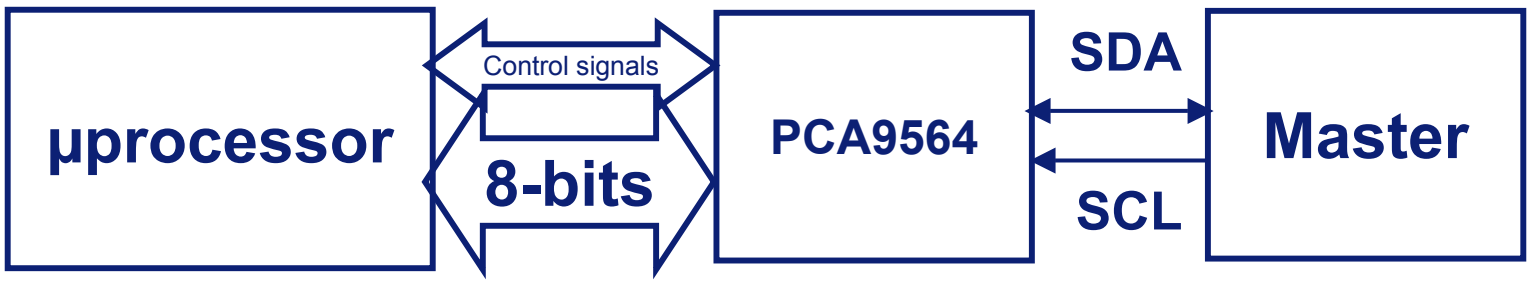
- The PCA9564 can be used to convert 8-bit parallel data into additional multiple master capable I²C port for microcontrollers, microprocessors, custom ASICs, DSPs, etc.., that already have an I²C port but need one or more additional I²C ports to interface with more I²C or SMBus components or components that cannot be located on the same bus (e.g., 100 kHz and 400 kHz slaves).

Application – Lower Voltage & Higher Frequency Migration Path for PCF8584



- The PCA9564 does the same type of parallel to serial conversion as the PCF8584. Although not footprint compatible, the PCA9564 provides improvements such as:
  - Operating at 3.3 V and 2.5 V voltage nodes
  - Allows interface with I^2C or SMBus components at speeds up to 400 kHz.
  - The built-in oscillator provides a cost effective solution since the external clock input is no longer required.
  - Parallel data can be exchanged at speeds up to 50 MHz allowing the use of faster processors. The PCA9564 is optimized for the Intel 8051 architecture.

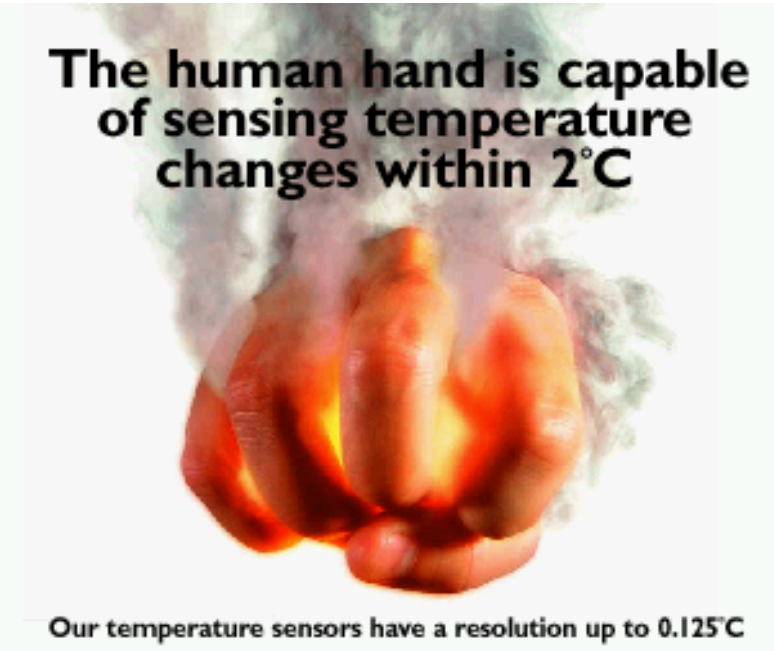
Application – Convert 8 bits of parallel data into I²C serial data stream

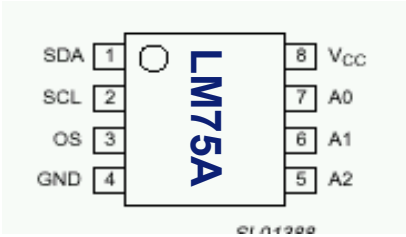


- Functioning as a slave transmitter, the PCA9564 can convert 8-bit parallel data into a two wire I²C data stream. This prevents having to run 8 traces across the entire width of the PC board.

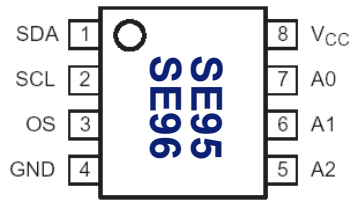
Temperature Sensors

I²C Temperature Sensors - Industrial





Digital Temperature Sensor and Thermal Watchdog™



Ultra High Accuracy Digital Temperature Sensor and Thermal Watchdog™

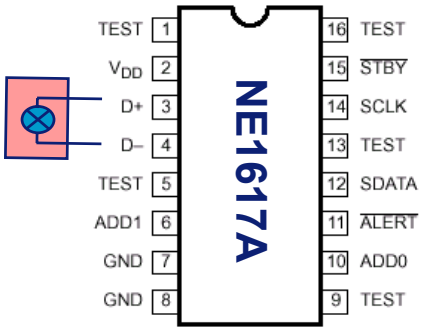
FEATURES
– Temperature range of – 55 to 125 °C
– Open drain interrupt output

KEY POINTS
– Sense temperature via I²C
– SE95 accurate to ± 1 °C from 0 to 100 °C
– SE96 accurate to ± 0.5 °C from 0 to 100 °C

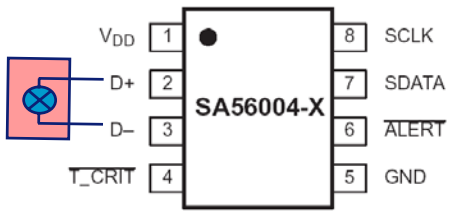
SE95 - Sampling

SE96 - Roadmap

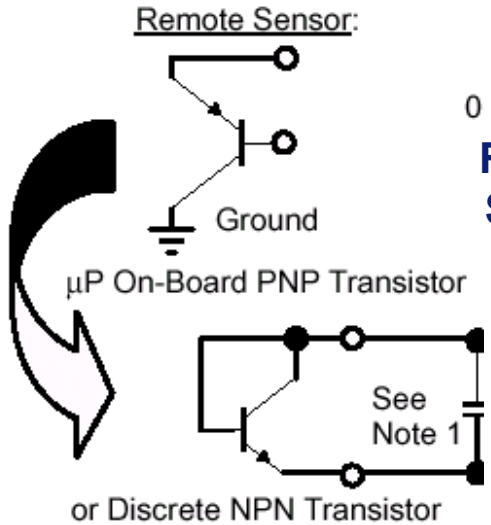
I²C Temperature Sensors - PC

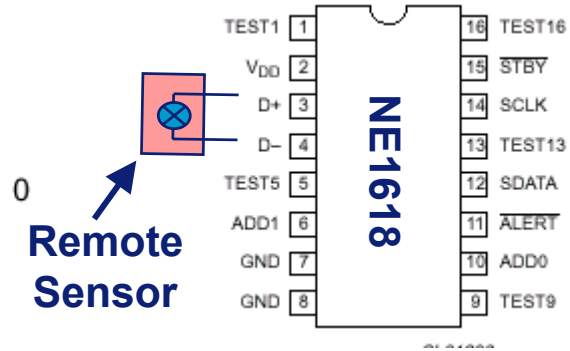


I²C Temperature Monitor

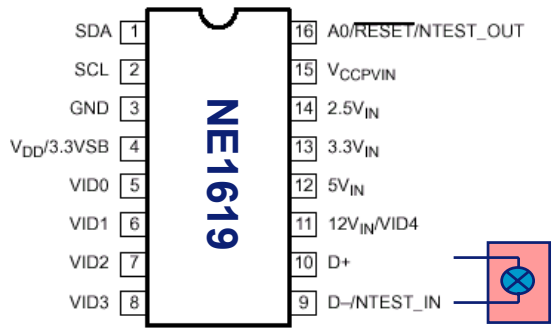


±1°C Accurate, Remote/Local Digital Temperature Sensor with Over Temperature Alarms





High Accuracy Temp Monitor



I²C Temperature and Voltage Monitor (Heceta4)

New!

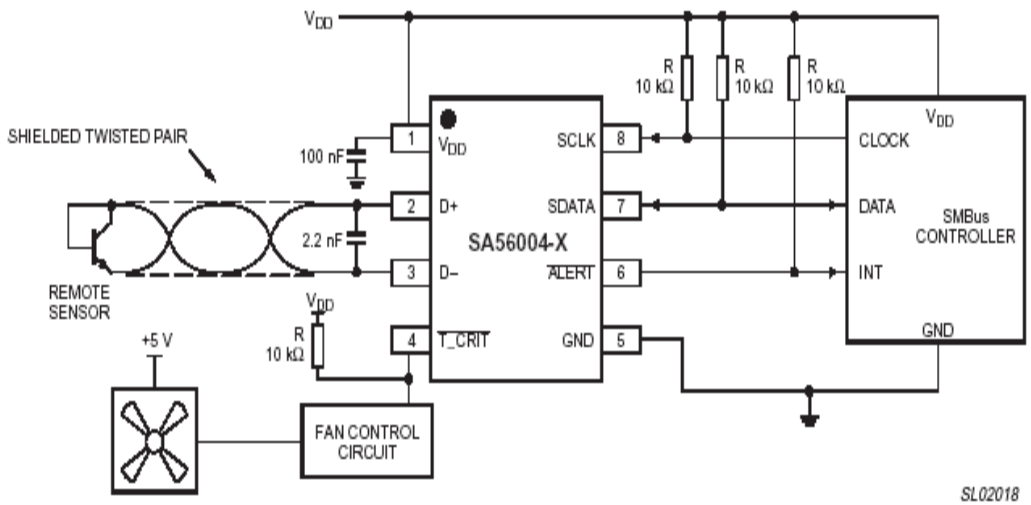
FEATURES
- High temperature accuracy
- SA56004 has eight address

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

SA56004 Application

APPLICATIONS

- System thermal management in laptops, desktops, servers and workstations
- Computers and office electronic equipment
- Electronic test equipment & instrumentation
- HVAC
- Industrial controllers and embedded systems

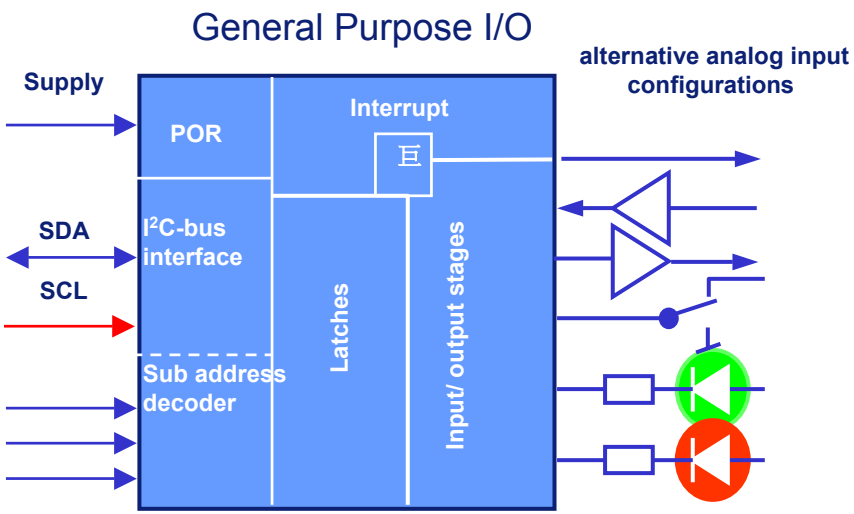


FEATURES

- On-chip local and remote microprocessor thermal diodes or diode connected transistors temperature sensing within ±1 °C
- Offset registers available for adjusting the remote temperature accuracy
- Programmable under/over temperature alarms: ALERT and T_CRIT
- SMBus 2.0 compatible interface, supports TIMEOUT and 100/400 kHz I^2C interface
- 11-bit, 0.125 °C resolution
- 8 different device addresses are available for server applications. The SA56004-ED/EDH with marking code ARW is address compatible with the National LM86, the MAX6657/8 and the ADM1032.

I/O Expanders

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	PCA9500/58	PCA9501
16	PCF8575/75C	-	-

Quasi Output I²C I/O Expanders - Registers

- **To program the outputs**

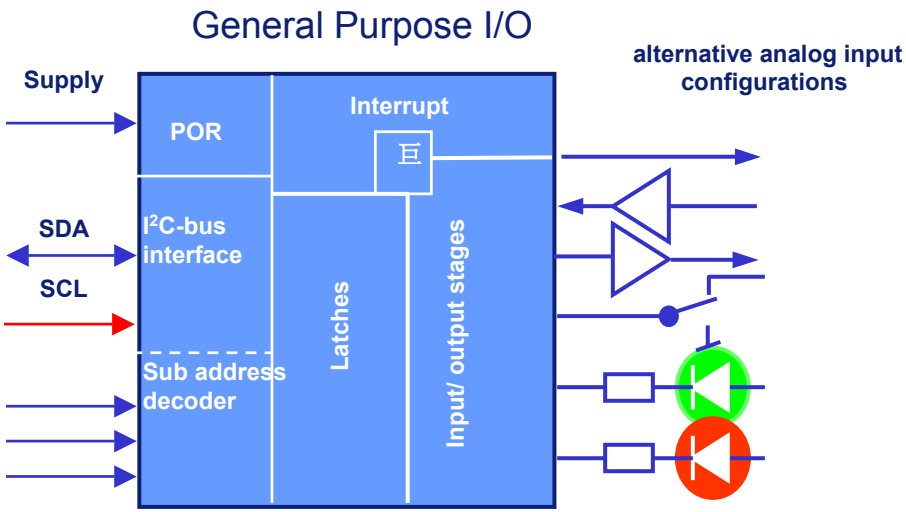
Multiple writes are possible during the same communication

- **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 (except PCF8575C); Only a current source to V_{DD} is active**
  - **Upper transistor is on for one clock cycle to provide strong pull-up and allow for faster rising edge rate**
  - **I/O's should be HIGH before using them as inputs**

Totem Pole Output I²C I/O Expanders



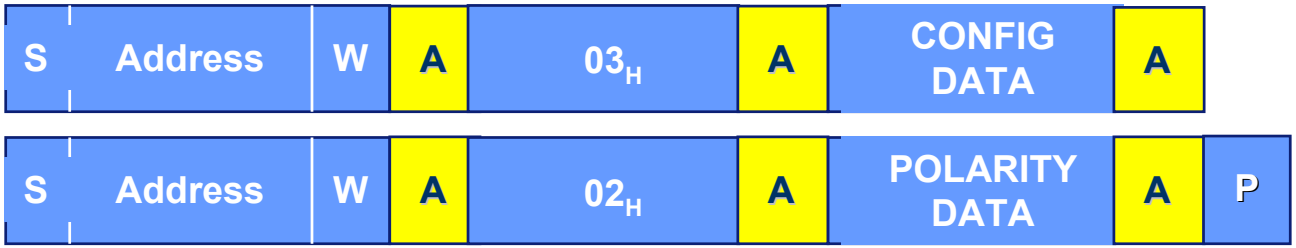
KEY POINTS

- 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	None	Reset	Interrupt	Interrupt and Reset
Totem Output (20-25 ma sink and 10 mA source)				
4	PCA9536			PCA9537
8		PCA9557	PCA9534/54/54A	PCA9538
16	-	-	PCA9535/55	PCA9539

Totem Output I²C I/O Expanders - Registers

- **To configure the device**

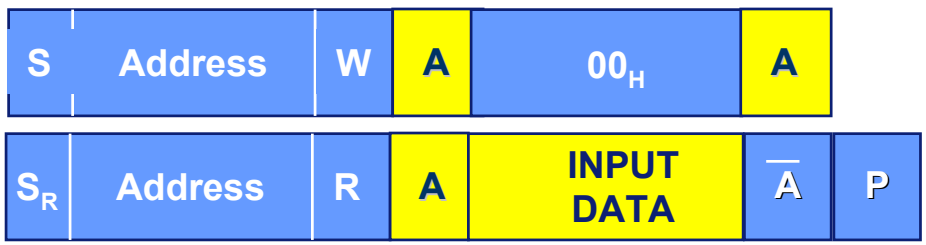


No need to access Configuration and Polarity registers once programmed

- **To program the outputs**

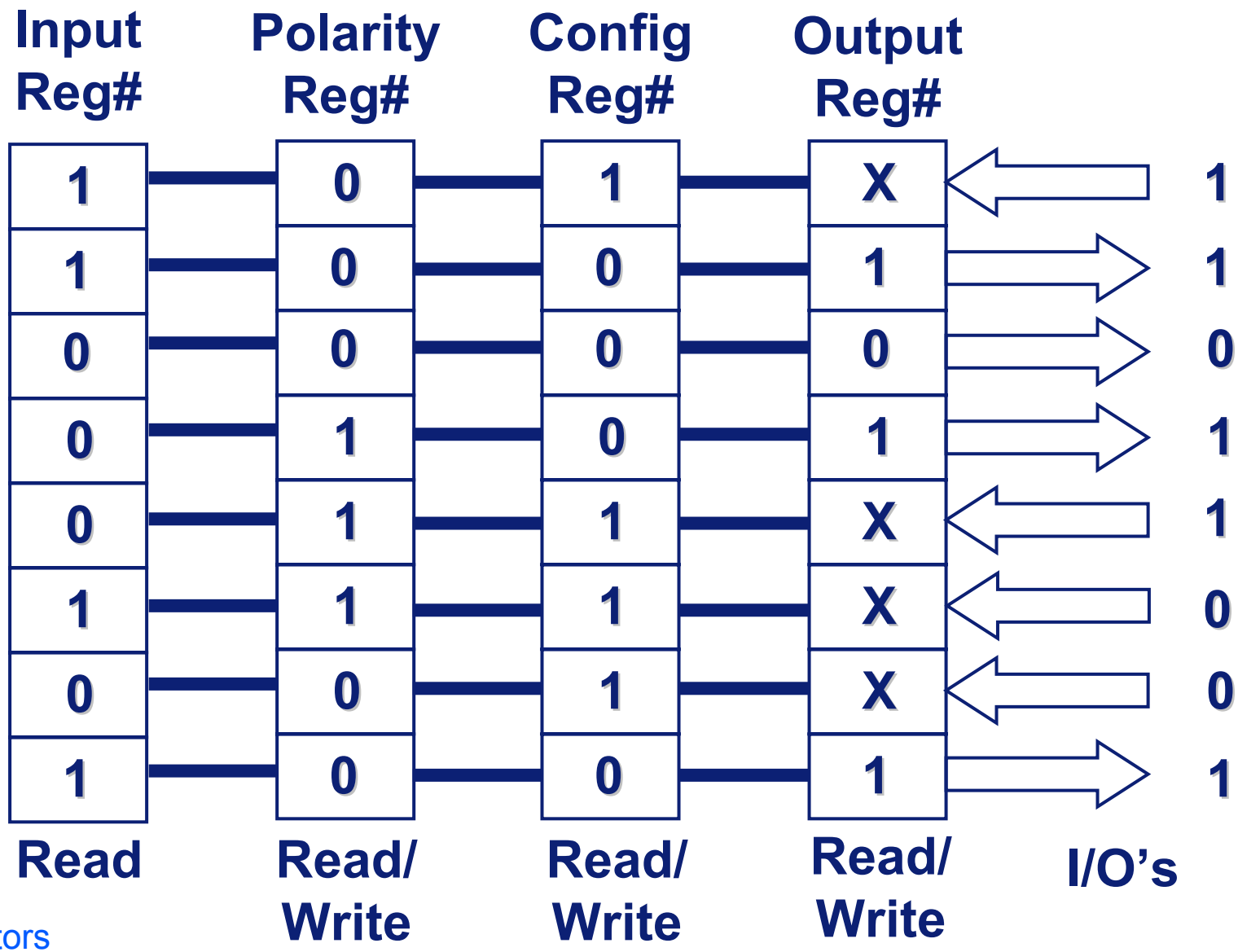
Multiple writes are possible during the same communication

- **To read input values**

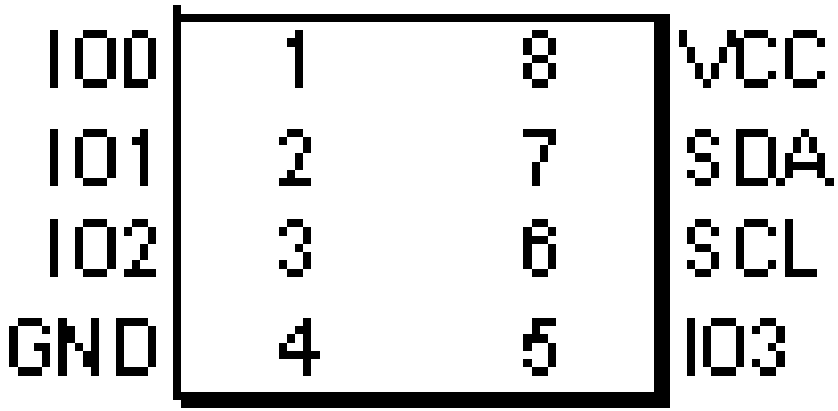


Multiple reads are possible during the same communication

Totem Pole Output I²C I/O Expanders - Example



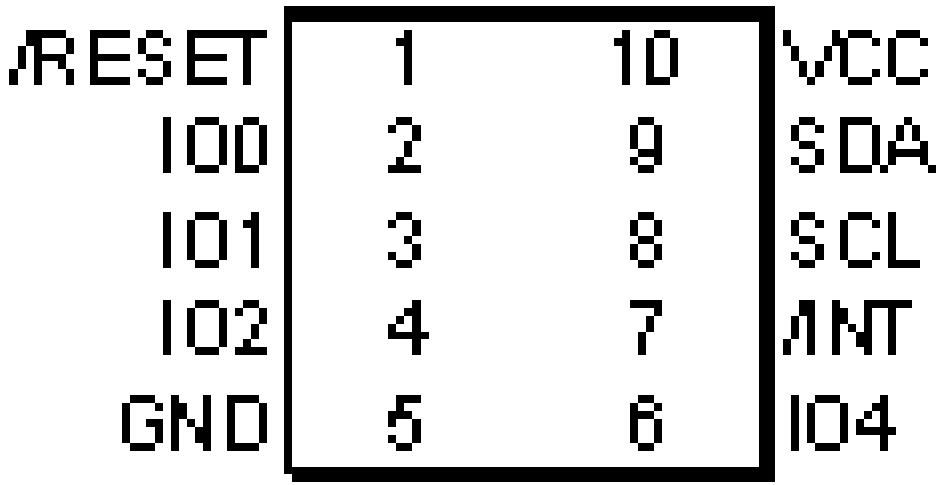
4-bit GPIO



- Similar to the PCA9554 but only 4 bits in an 8 pin SO or TSSOP package
- Fixed I²C address of 1000001R/W

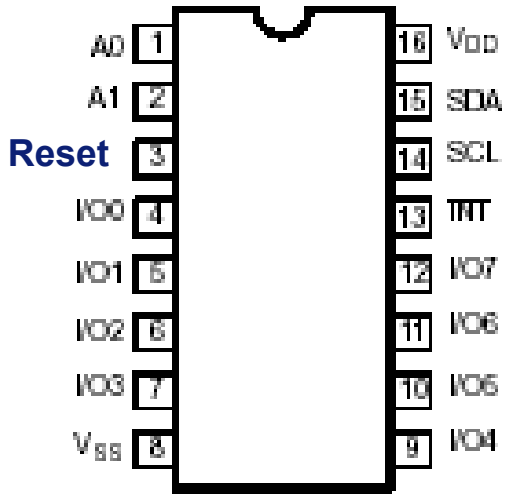
- **PCA9536 4-Bit I²C GPIO**

4-bit GPIO with Interrupt and Reset

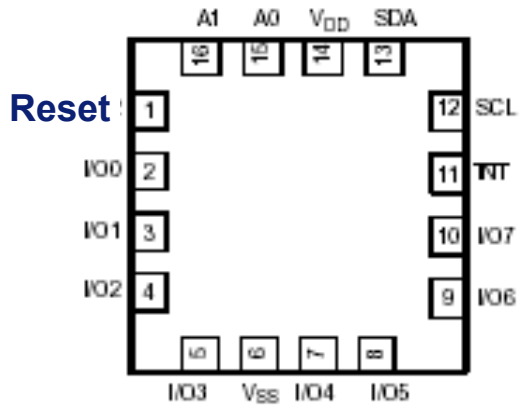


- Similar to the PCA9538 but only 4 bits of GPIO in an 10 pin TSSOP package
- Fixed I²C address of 1001001R/W
  - **PCA9537 4-Bit I²C GPIO with Interrupt and Reset**

8-bit GPIO with Interrupt and Reset



SO or TSSOP

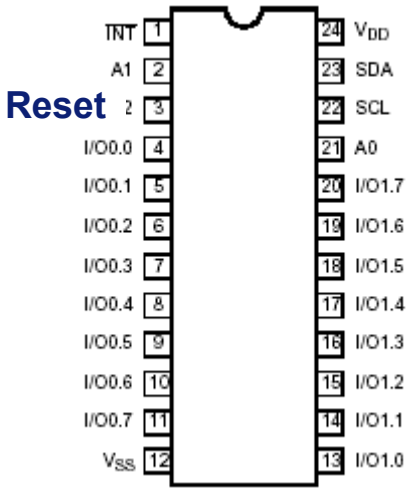


HVQFN

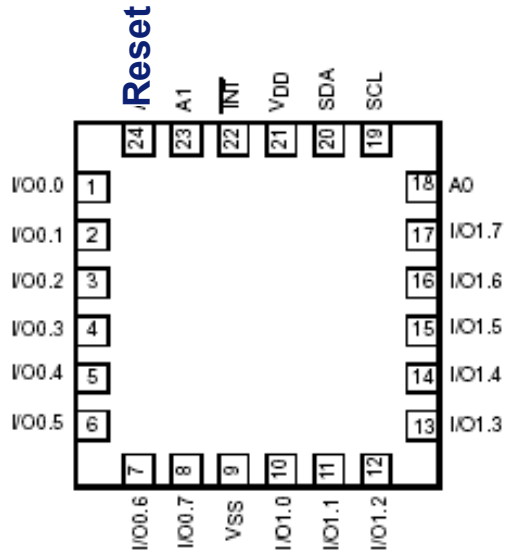
- Based on PCA9534 die with a metal mask option to tie A2 high internally and bring out the POR circuit to the hardware reset pin.
- Polling for input changes is not required since Interrupt output signals master.
- Reset pin is needed for higher bus reliability to allow all devices to be reset should the bus hang up.

- **PCA9538 8-Bit GPIO with Interrupt and Reset**

16-bit GPIO with Interrupt and Reset



SO and TSSOP



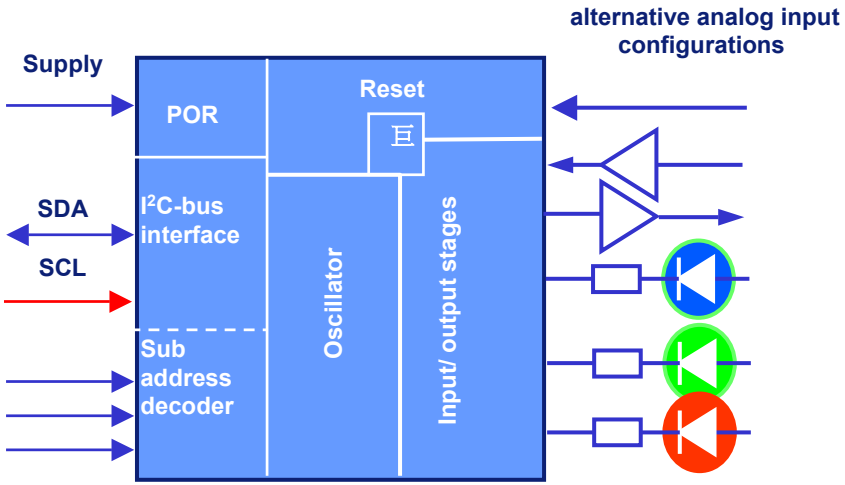
HVQFN

- Based on PCA9535 die with metal mask option to tie A2 high internally and bring out the POR circuit to the hardware reset pin.
- Polling for input changes is not required since Interrupt output signals master.
- Reset pin is needed for higher bus reliability to allow all devices to be reset should the bus hang up.

- **PCA9539 16-Bit GPIO with Interrupt and Reset**

LED Blinkers

I²C LED Dimmers/Blinkers



# of Outputs	Reset and POR
2	PCA9530/50
4	PCA9533/53
8	PCA9531/51
16	PCA9532/52

Application Note AN264

KEY POINTS

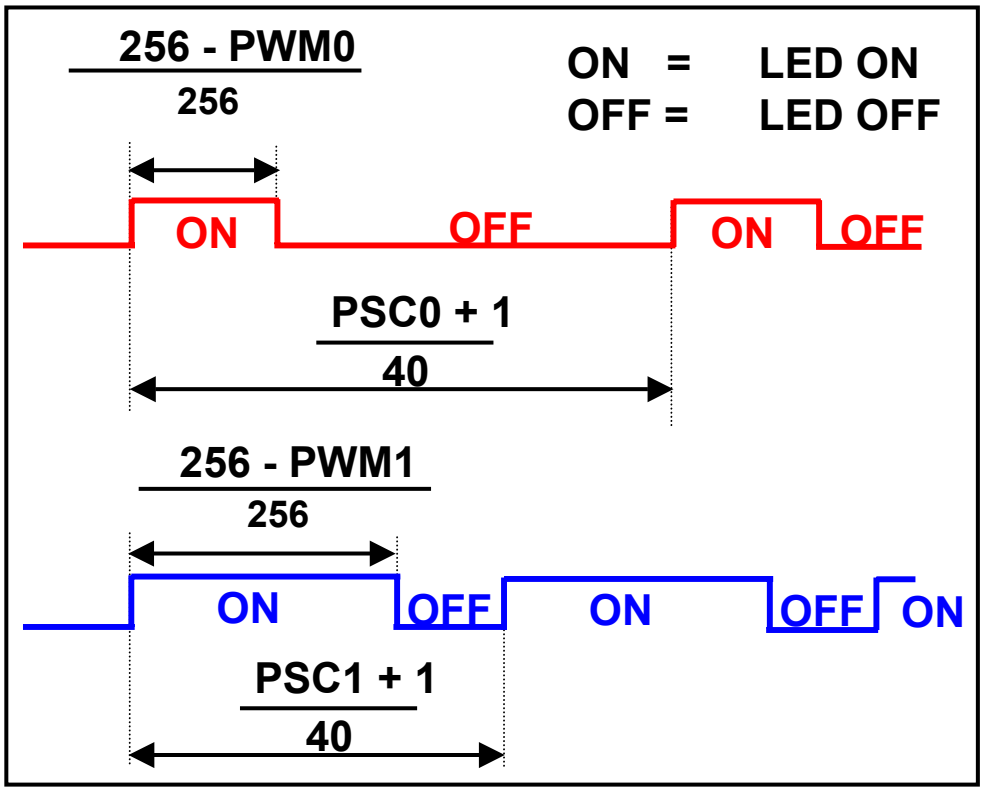
- I²C/SMBus is not tied up by sending repeated transmissions to turn LEDs on and then off to “blink” LEDs.
- Frees up the micro’s timer
- Continues to blink LEDs even when no longer connected to bus master
- Can be used to cycle relays and timers
- Higher frequency rate allows LEDs to be dimmed by varying the duty cycle for Red/Green/Blue color mixing applications.

FEATURES

- 25 mA open drain outputs
- Internal oscillator (+/- 15%)
- Two user definable blink rates and duty cycles adjustable between 160 Hz and 1.6 seconds (3x Dimmers) or 40 Hz and 6.4 seconds (5x Blinkers) in 256 steps
- Unused pins can be used for normal GPIO
- Hardware Reset pin and Power On Reset (POR)

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)

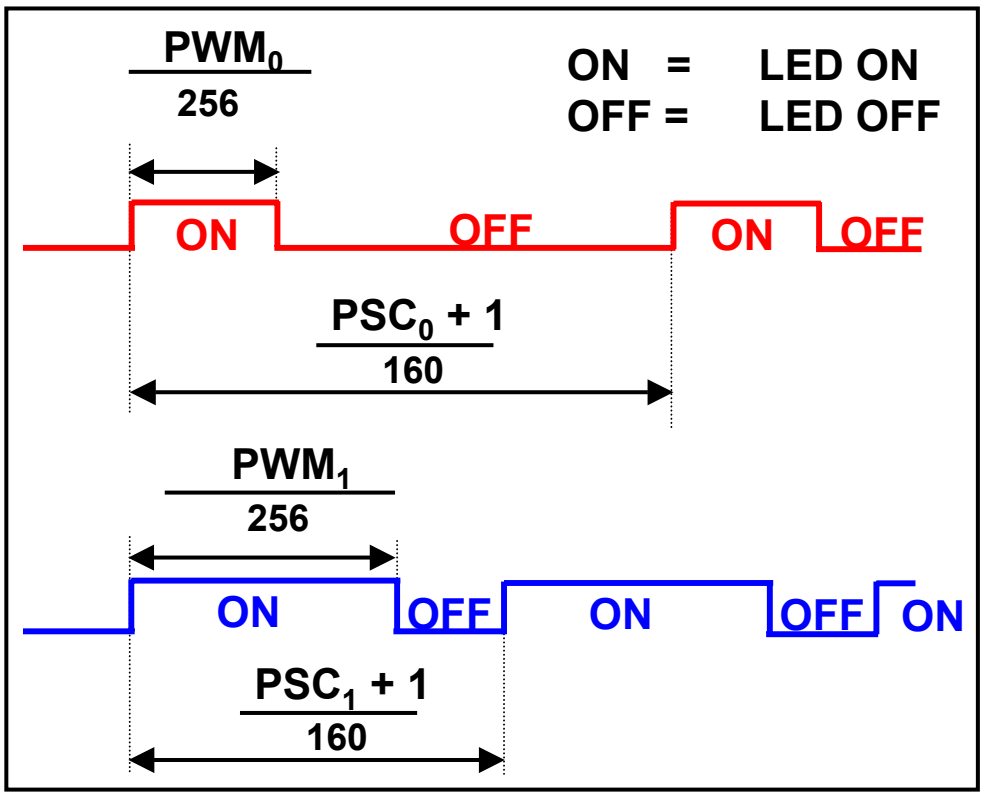
LED Selector

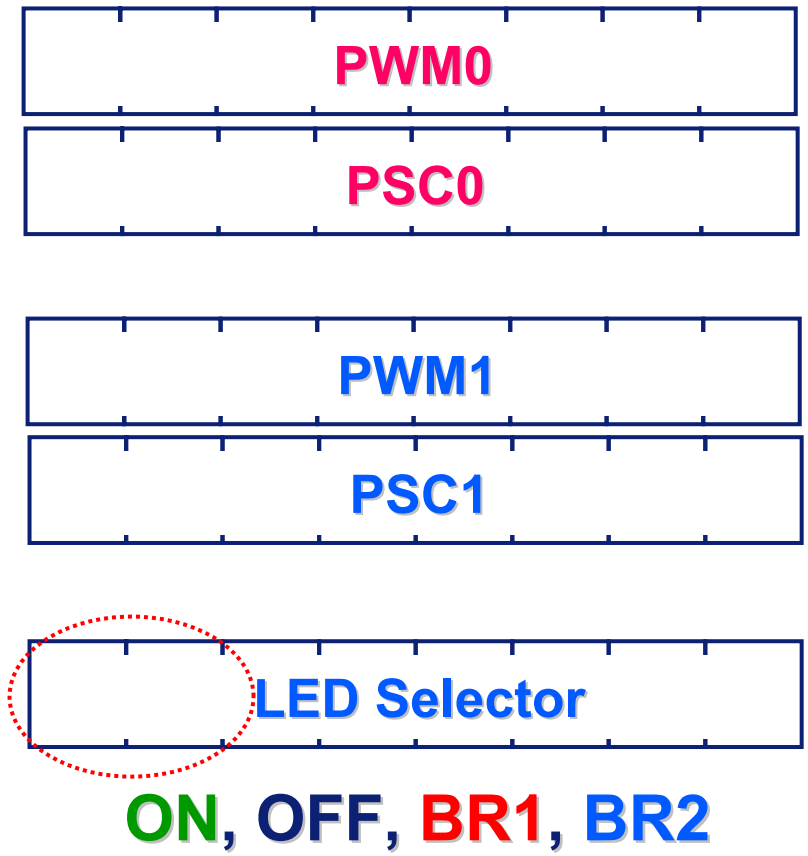
ON, OFF, BR1, BR2

PCA953x I²C LED Dimmers

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

State machine defaults to highest frequency at power on and duty cycle goes from 0% (off) to 99.6% (almost always on) for better dimming control.





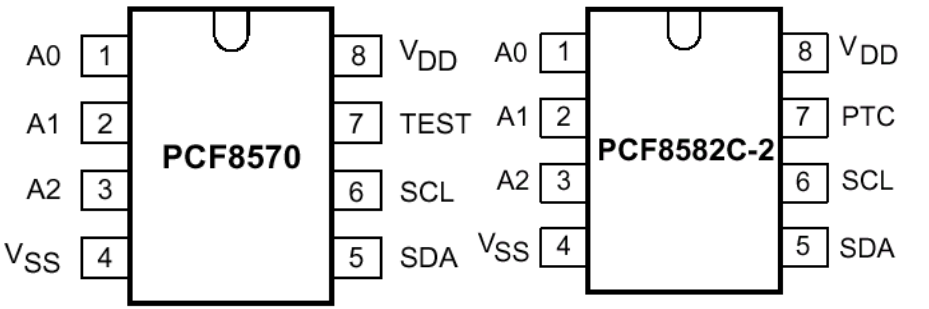
LED Dimmers/Blinkers vs Micros

Difference between using a LED Blinker/Dimmer or a micro:

- Easier software generation to control LEDs
  - ➢ Don't have to use micro timer
  - ➢ Don't have to continually send on and off command to blink or dim LEDs
- Frequency fixed by device, not dependant on processor clock frequency
- I^2C devices have higher sink current capability per bit and larger sink current capability per device

Serial EEPROMS

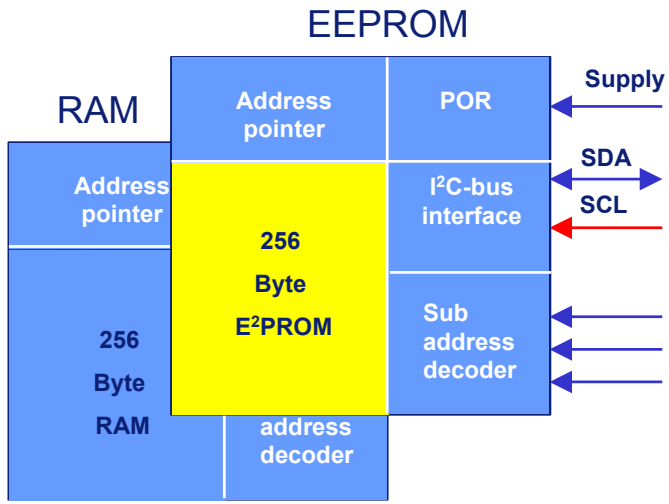
I²C Serial CMOS RAM/EEPROMs

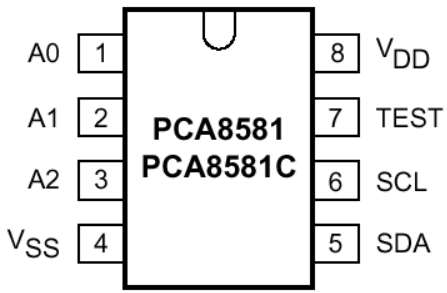


256 x 8-bit RAM

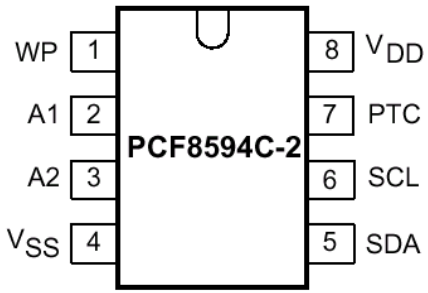
256 x 8-byte (2 kbit)

Also PCF85102C-2 and PCF85103C-2

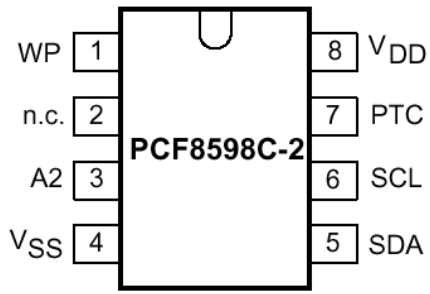




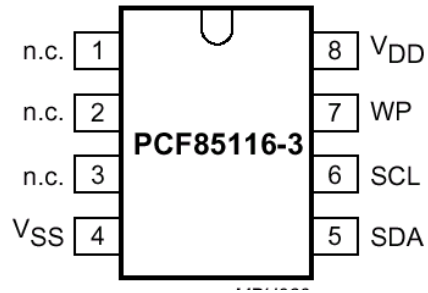
128 x 8-byte (1 kbit)



512 x 8-byte (4 kbit)



1024 x 8-byte (8 kbit)



2048 x 8-byte (16 kbit)

FEATURES

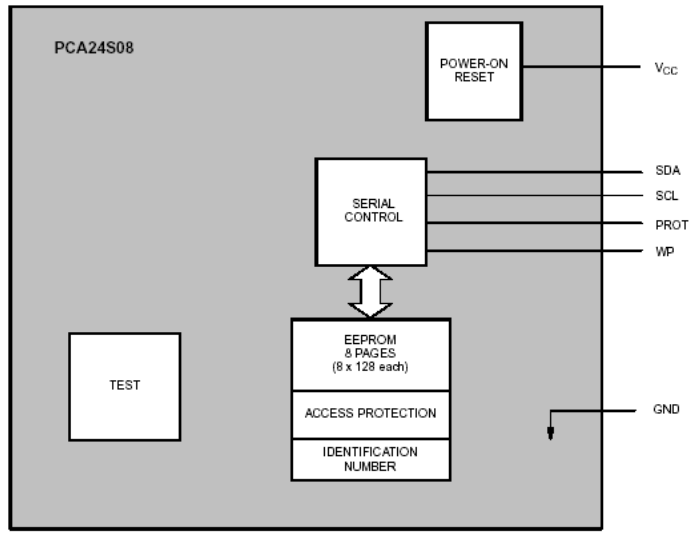
- Wide voltage range of 2.5 to 5.5V
- 1,000,000 read and write cycles
- 10 year data retention

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

1024 X 8 CMOS Security EEPROM

SYMBOL	NAME AND FUNCTION
NC	No connect
PROT	Protection input
GND	Ground
SDA	Serial data open drain I/O
SCL	Serial clock input
WP	Write protect input
V_{CC}	Supply voltage



FEATURES

- Nonvolatile memory - serial interface
- Compatible with a Standard 24C08 Serial EEPROM
- Programmable access protection to limit reads or writes
- Lock/unlock function
- Highly-reliable EEPROM memory
- 8 k bits (1 k bytes), organized as 8 blocks of 128 bytes
- 16-byte page write, 10 ms write time
- 10 years retention, 100 k write cycle endurance
- Operating temperature range - 40 to +85 °C
- Operating power supply voltage range of 2.5 V to 3.6 V
- Packages offered: SO8 and TSSOP8

DESCRIPTION

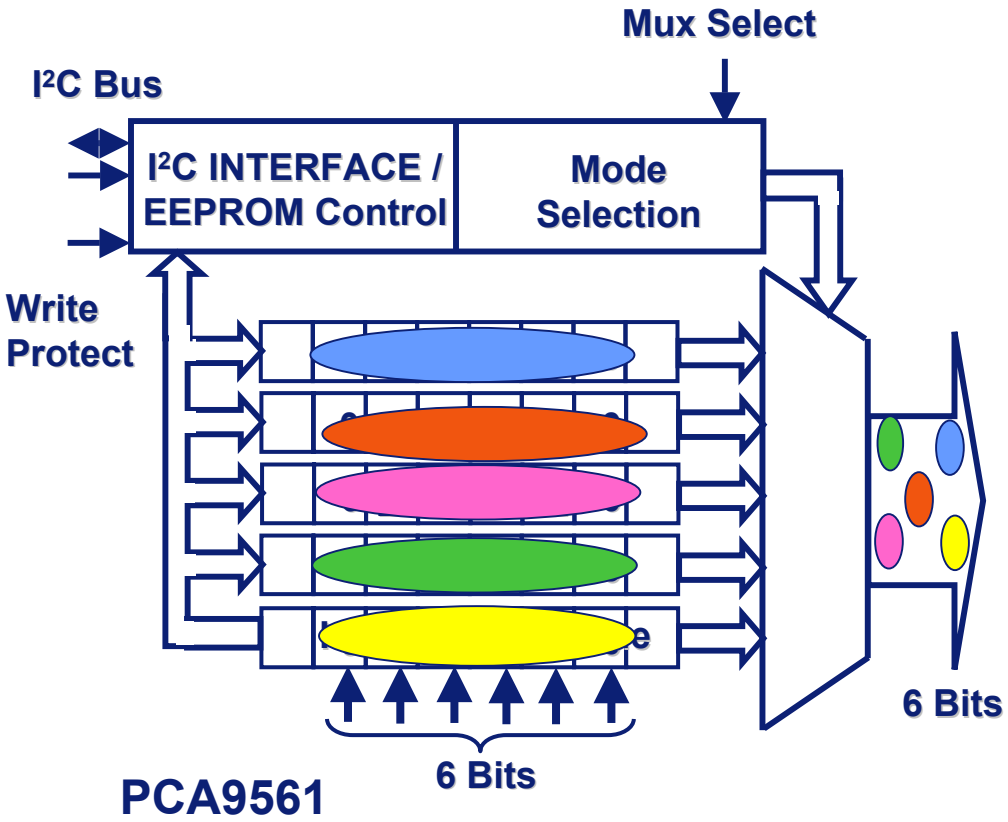
The PCA24S08 functions as a dual access EEPROM with a wired serial port used to access the memory. Access permissions are set from the serial interface side to isolate blocks of memory from improper access.

$10101B_2B_1.$ Only 1 device allowed per bus

PCA24S08 - 1024 X 8 CMOS EEPROM with access protection

DIP Switches

I²C DIP Switches



	# of Pins	# of Non Volatile Registers	# of Register Bits	# of Hardware Input Pins	# of Muxed Outputs	Non-Muxed Output
PCA8550	16	1	5	4	4	YES
PCA9558	28	1	6	5	5	YES
PCA9559	20	1	6	5	5	YES
PCA9560	20	2	6	5	5	YES
PCA9561	20	4	6	6	6	NO

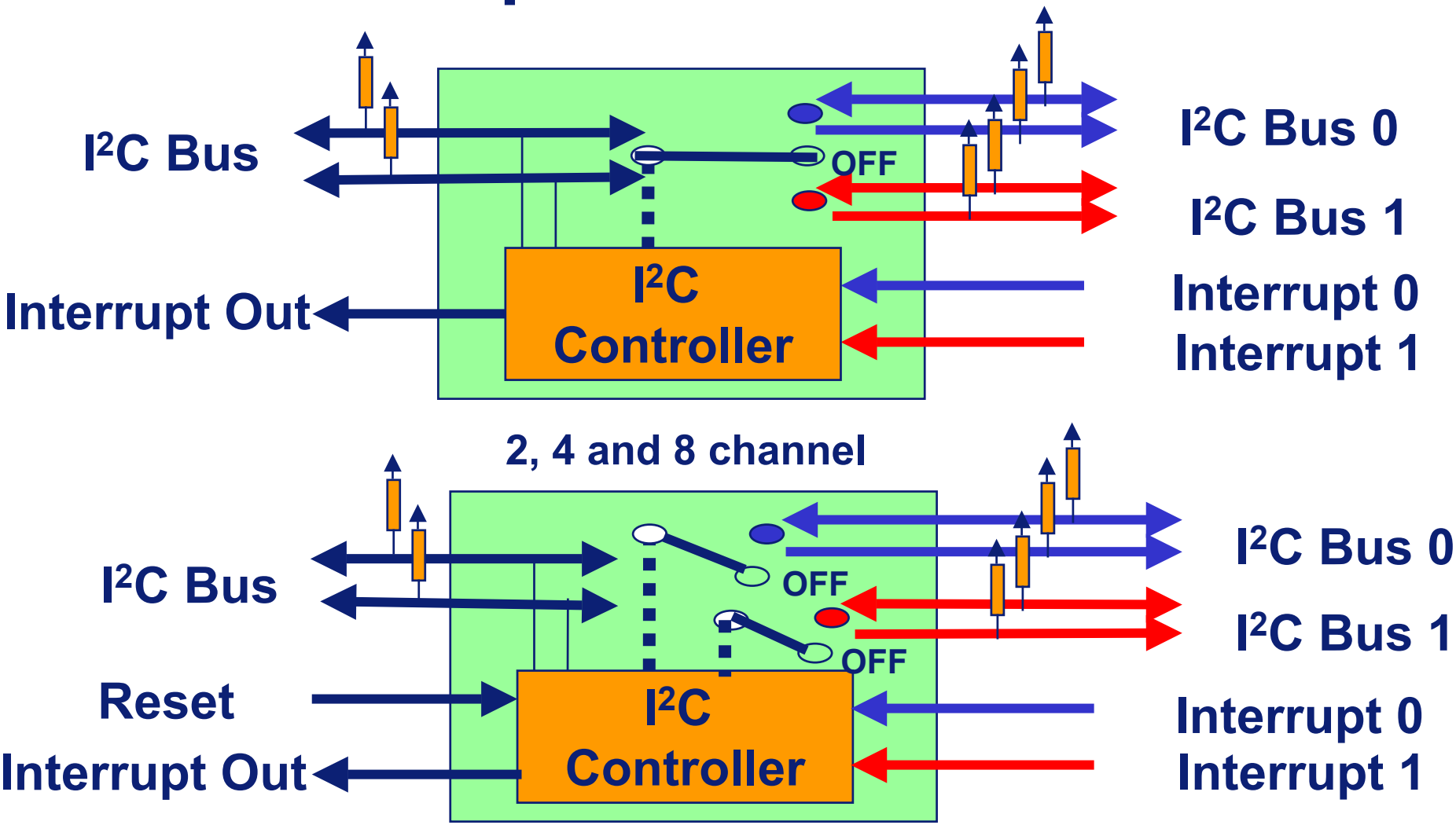
Application Note AN250

6 bit output value is dependant on the mux select pin position or command from I²C master

EEPROM 0 is default output

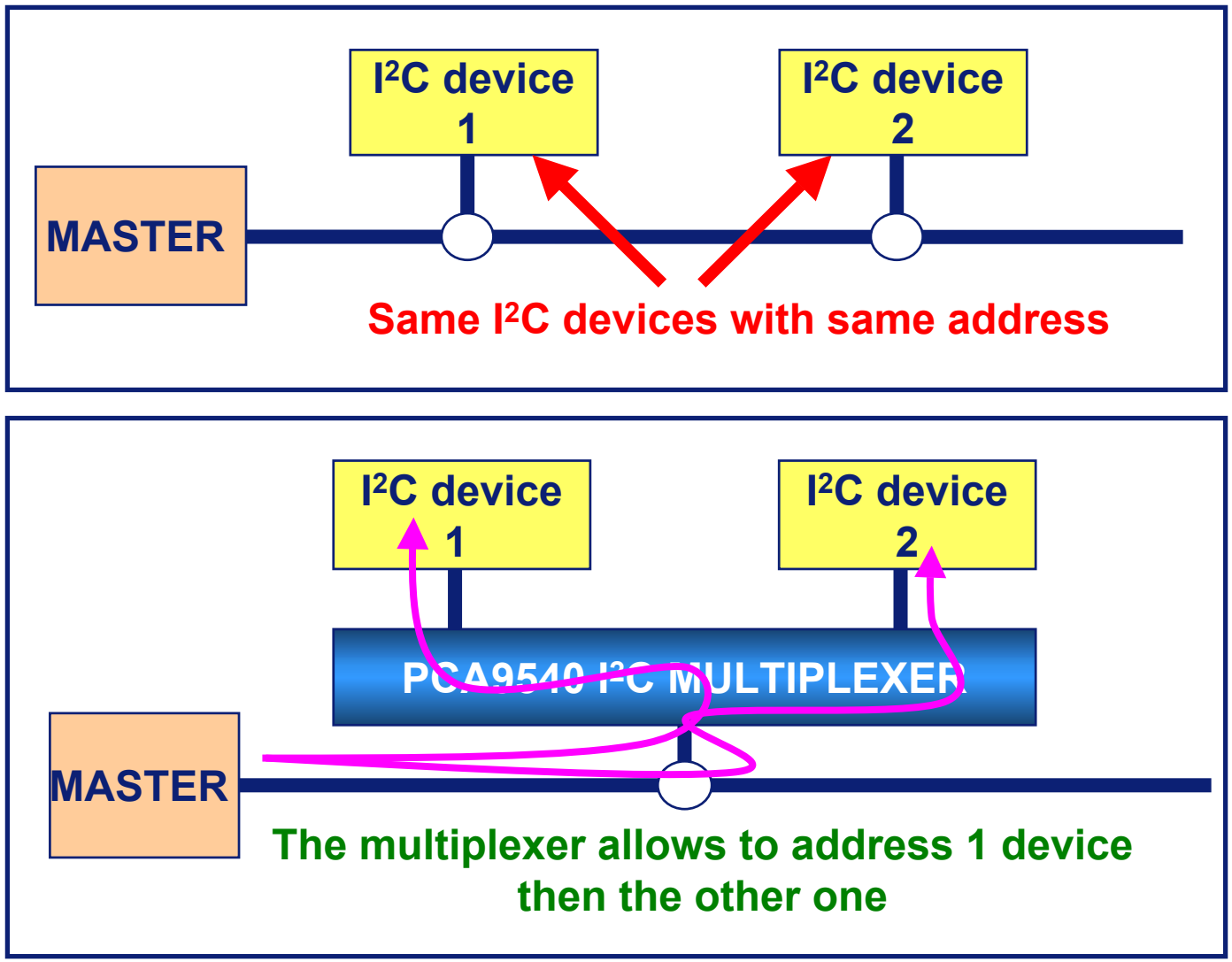
Multiplexers & Switches

I²C Multiplexers and Switches

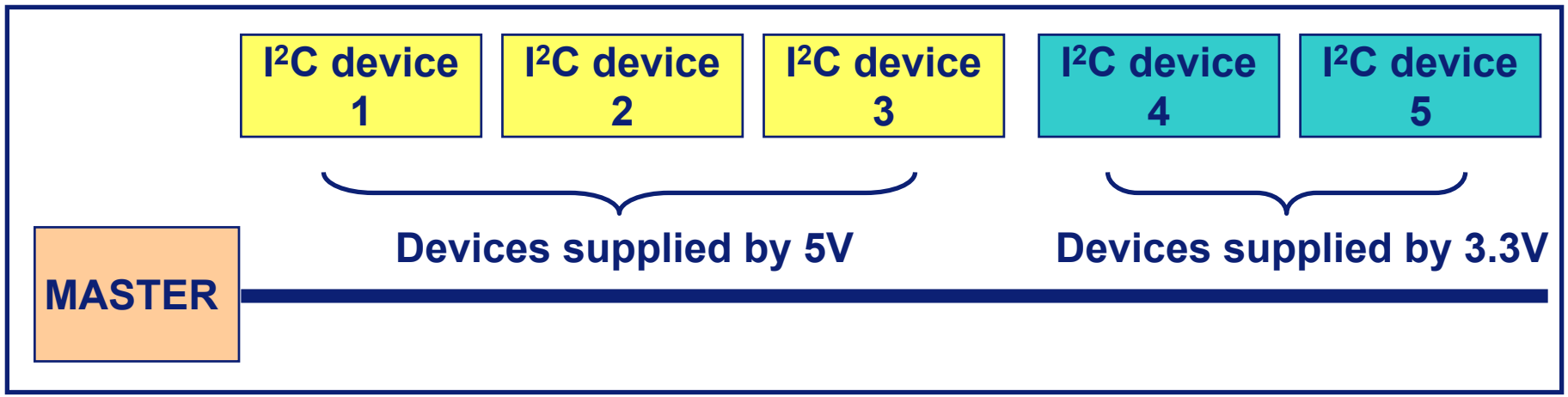


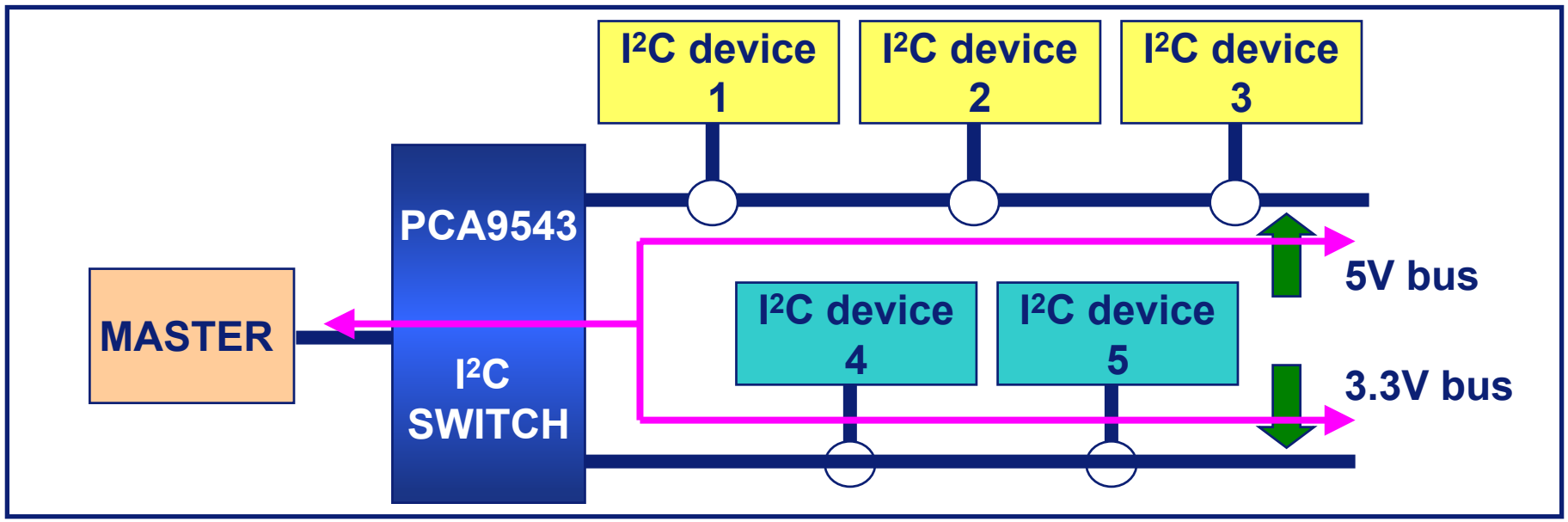
Application Note AN262

I²C Multiplexers: Address Deconflict

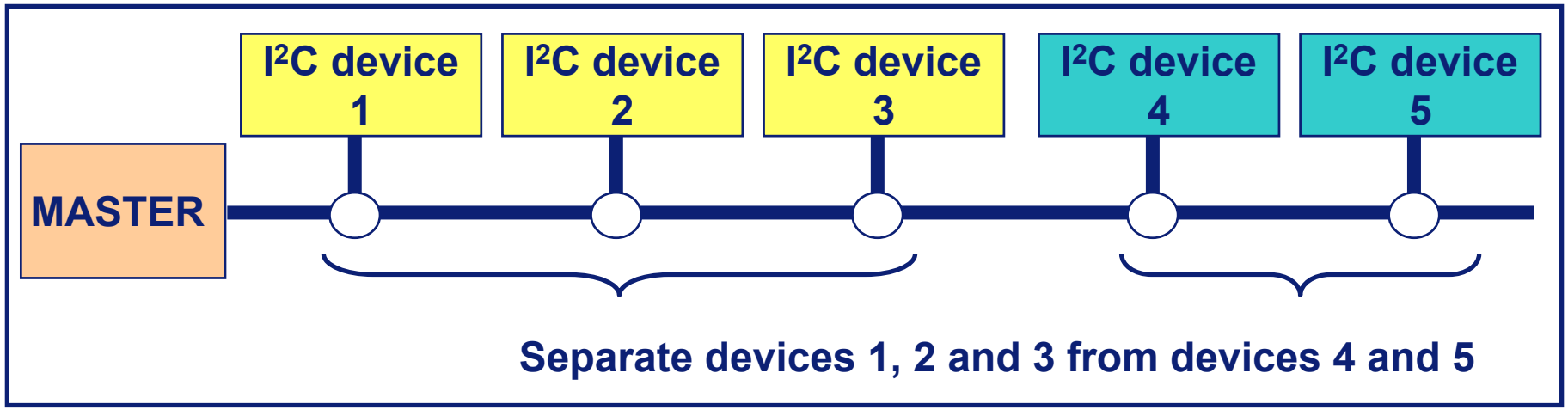


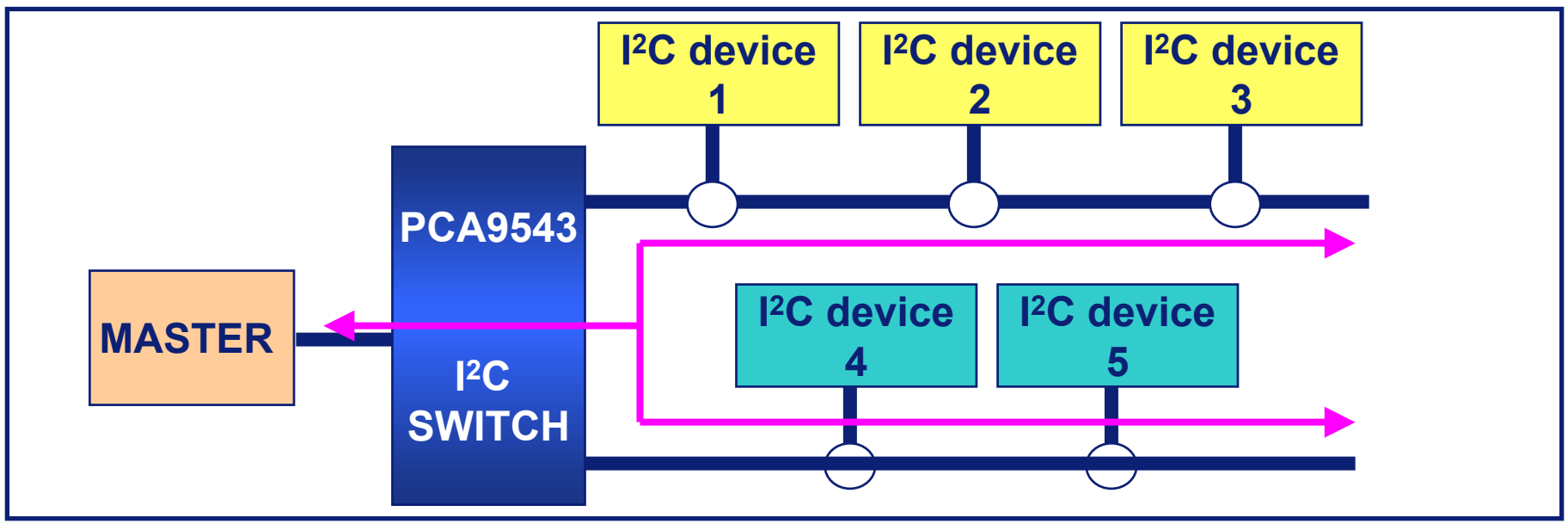
I²C Switches: Voltage Level Shifting





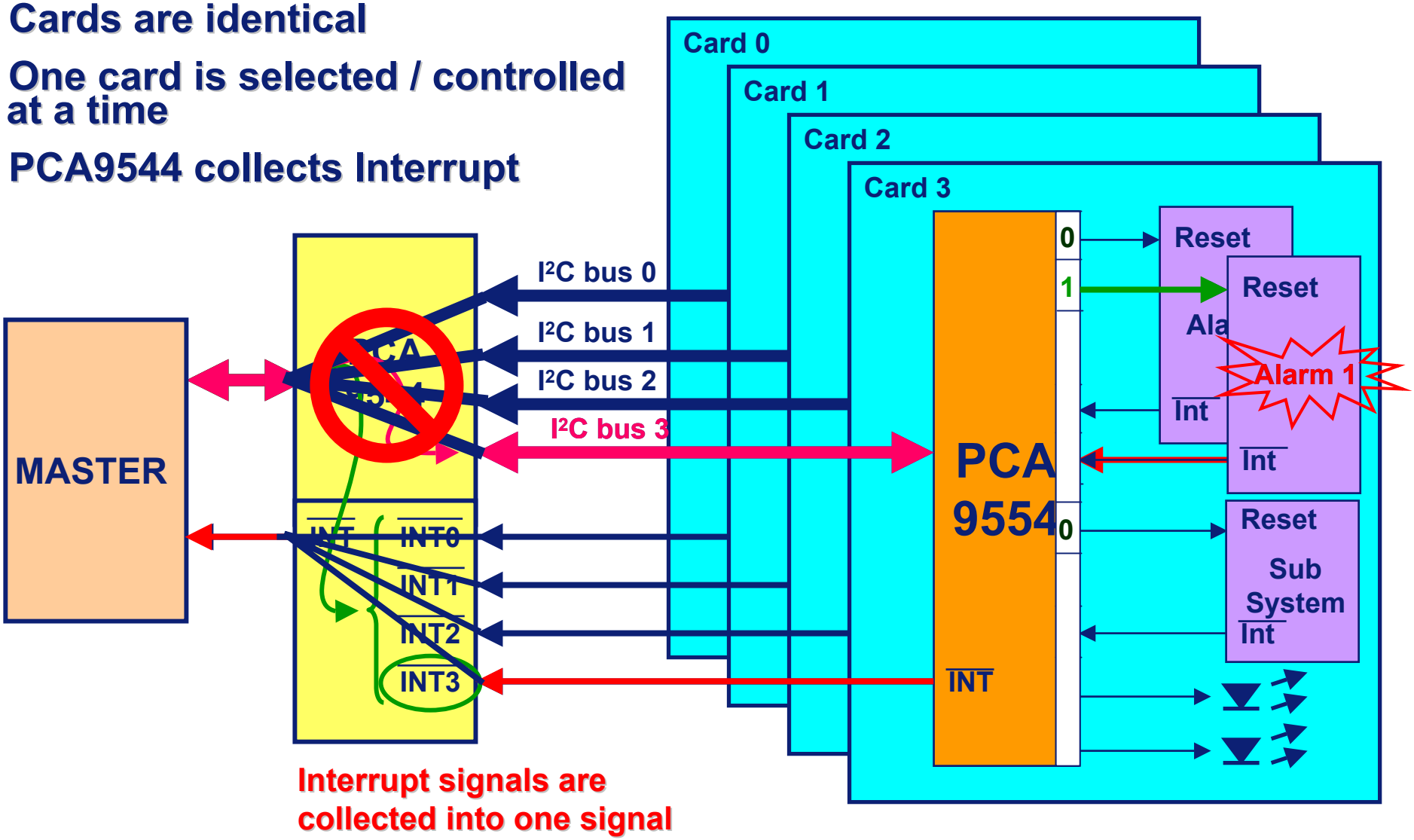
I²C Switches: Branch isolation





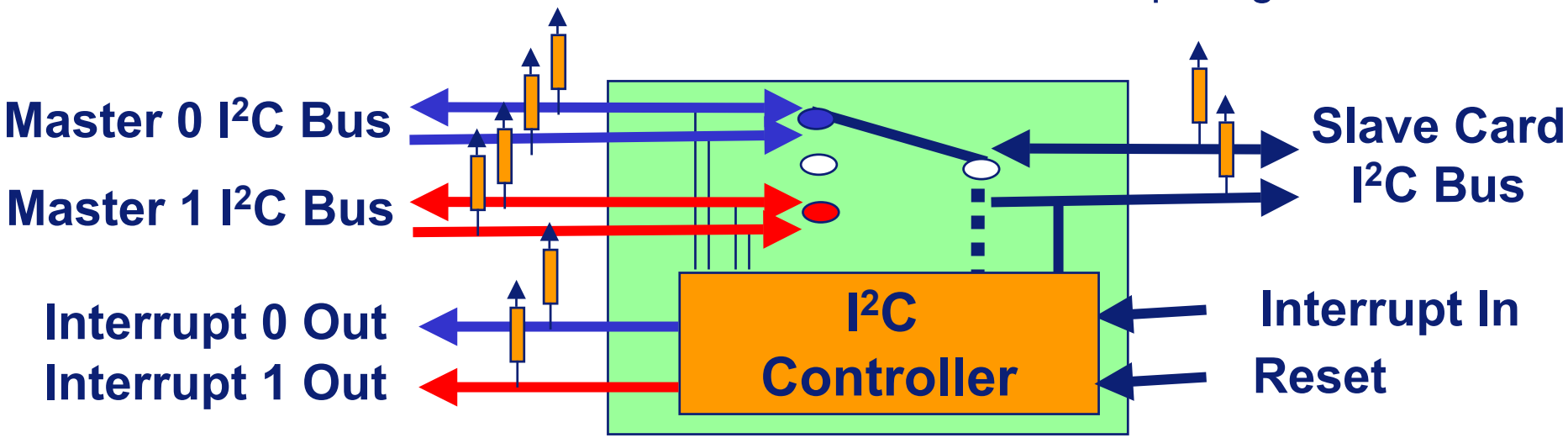
I²C Multiplexers: Multi-card Application

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



Interrupt signals are collected into one signal

2 to 1 I²C Master Selector w/Interrupt Logic and Reset

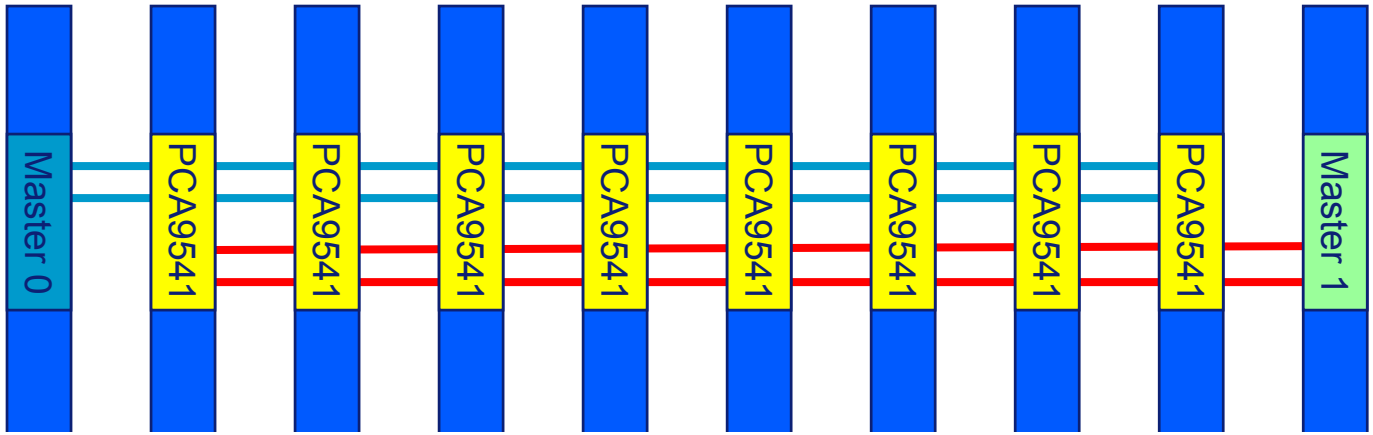


FEATURES
- Select one of two I²C masters to a single channel
- I²C/SMBus commands used to select channel
- Reset or Power On Reset (POR) resets state machine
- Interrupt outputs also report demultiplexer status
- Sends 9 clock pulses and stop condition to clear slave card prior to transferring master

KEY POINTS
- Allows primary and backup master to communicate to one downstream slave card.
- Arbitration circuit between bus masters
- Doesn't isolate bus capacitance
- Allows voltage translation between 1.8 V, 2.5 V, 3.3 V and 5 V
- Idle detect for live insertion protection

- **PCA9541/01 - defaults to channel 0 on start-up/reset**
- **PCA9541/02 - defaults to channel 0 on start-up/reset after stop condition**
- **PCA9541/03 – defaults to off on start-up/reset, master commands channel**

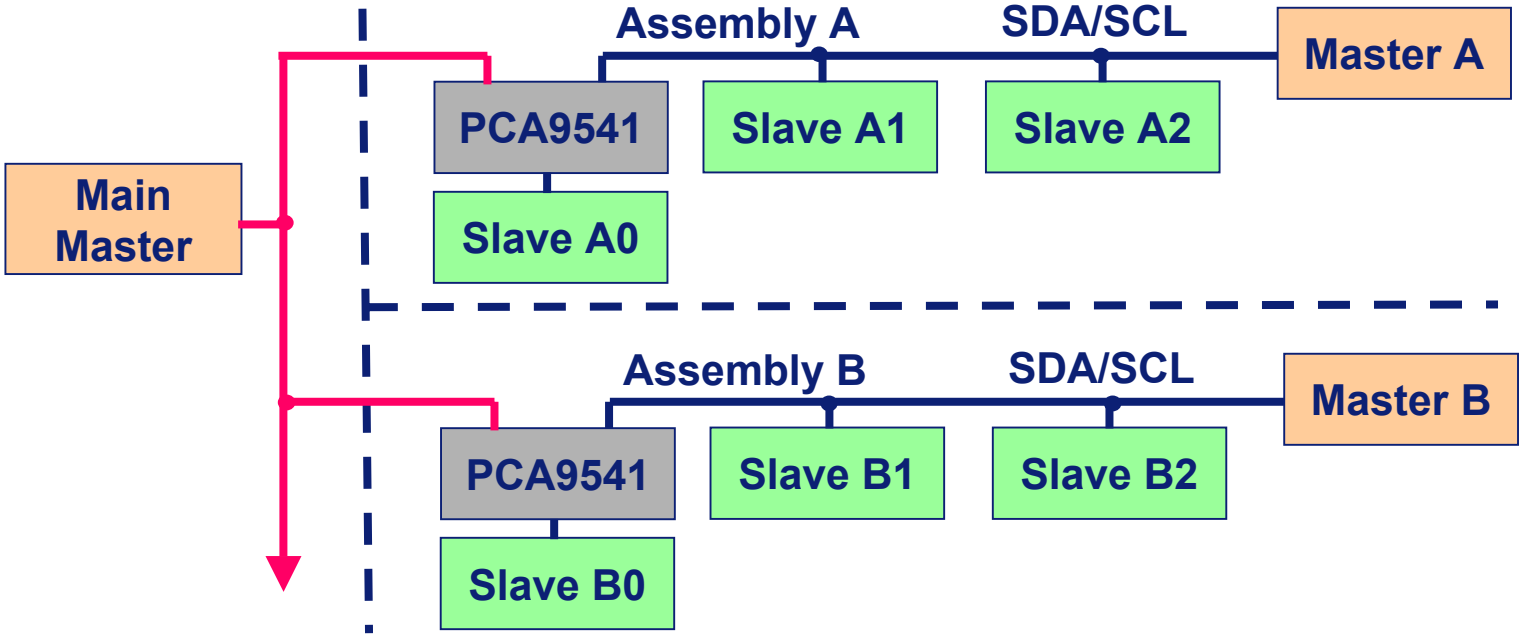
PCA9541 - Multi-Point Application



In a typical multi-point application, as shown in the diagram, the two masters (e.g., primary and back-up) are located on separate I^2C buses that connect to multiple downstream I^2C bus slave cards via a PCA9541 to provide high reliability of the I^2C bus.

This way one of the controller cards can fail or be removed from the system and control of the line cards is maintained. A bent pin or other hard failure is confined to one bus and control is maintained on the other bus. I^2C commands are sent via the primary or back-up master and either master at any time can gain control of the slave devices if the other master is disabled or removed from the system. The failed master is isolated from the system and will not affect communication between the on-line master and the slave devices located on the line cards.

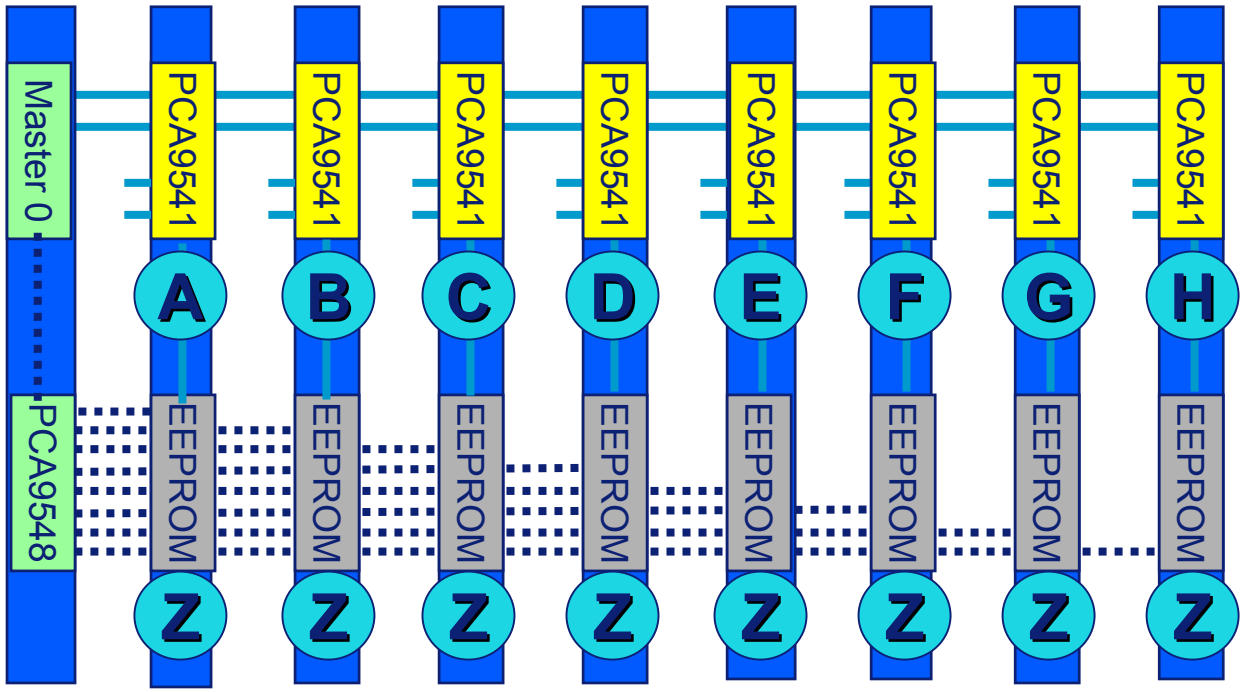
PCA9541 – Shared Resources



Some masters may not be multi-master capable or some masters may not work well together and continually lock up the bus. The PCA9541 can be used to separate the masters, but still allow shared access to slave devices, such as Field Replaceable Unit (FRU) EEPROMs or temperature sensors such as is represented by Slave A0 and Slave B0.

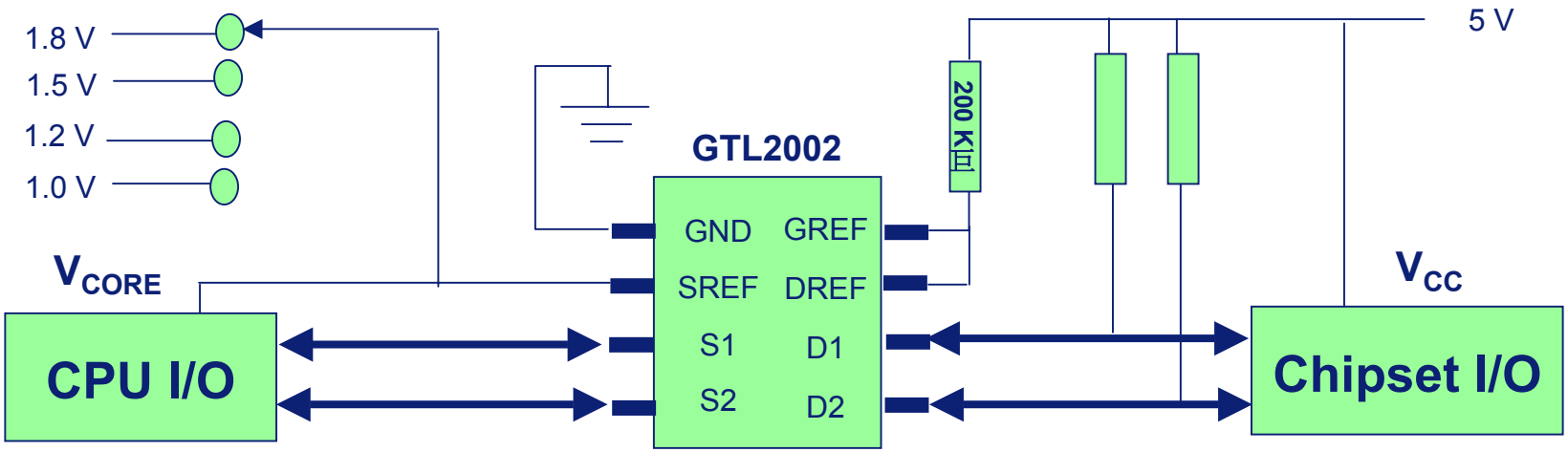
PCA9541 – Gatekeeper Multiplexer

- The PCA9541/03 acts as the gatekeeper to each card that have identically I²C addressed EEPROMs. The master turns each uniquely addressed PCA9541/03 on (master 0) and off, one at a time, to communicate with the EEPROMs.



- The alternative is to use a PCA9548 to 1 to 8 multiplexer on the master card and then run 8 I²C buses, one to each EEPROM card. You use the same number of card pins but have 8 times the number of traces on the backplane.

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
- Application Note AN10145

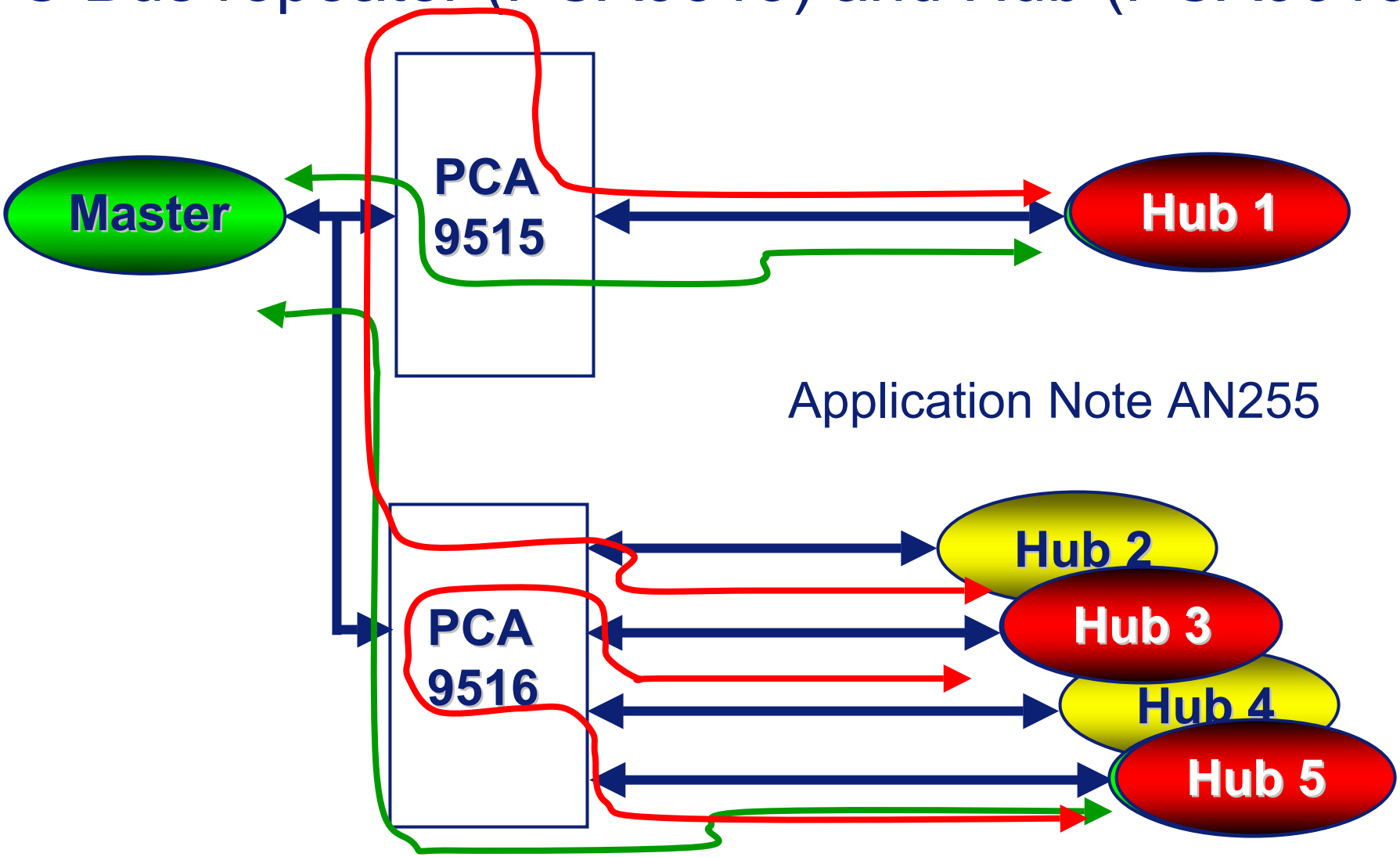
– **GTL2000 22-Bit**
– **GTL2002 2-Bit**
– **GTL2010 10-Bit**

I²C Multiplexers and Switches

Device	Multiplexer (In/Out)	Switch (In/Out)	Features			Packages				
			# of Addresses	Interrupt (In/Out)	Hardware RESET	Pin Count	SO (Narrow)	SO (Wide)	TSSOP	HVQFN
PCA9540	1-2		1			8	D		DP	
PCA9541	2-1		16	1-2	✓	16	D		PW	BS
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	BS
PCA9548		1-8	8		✓	24		D	PW	BS

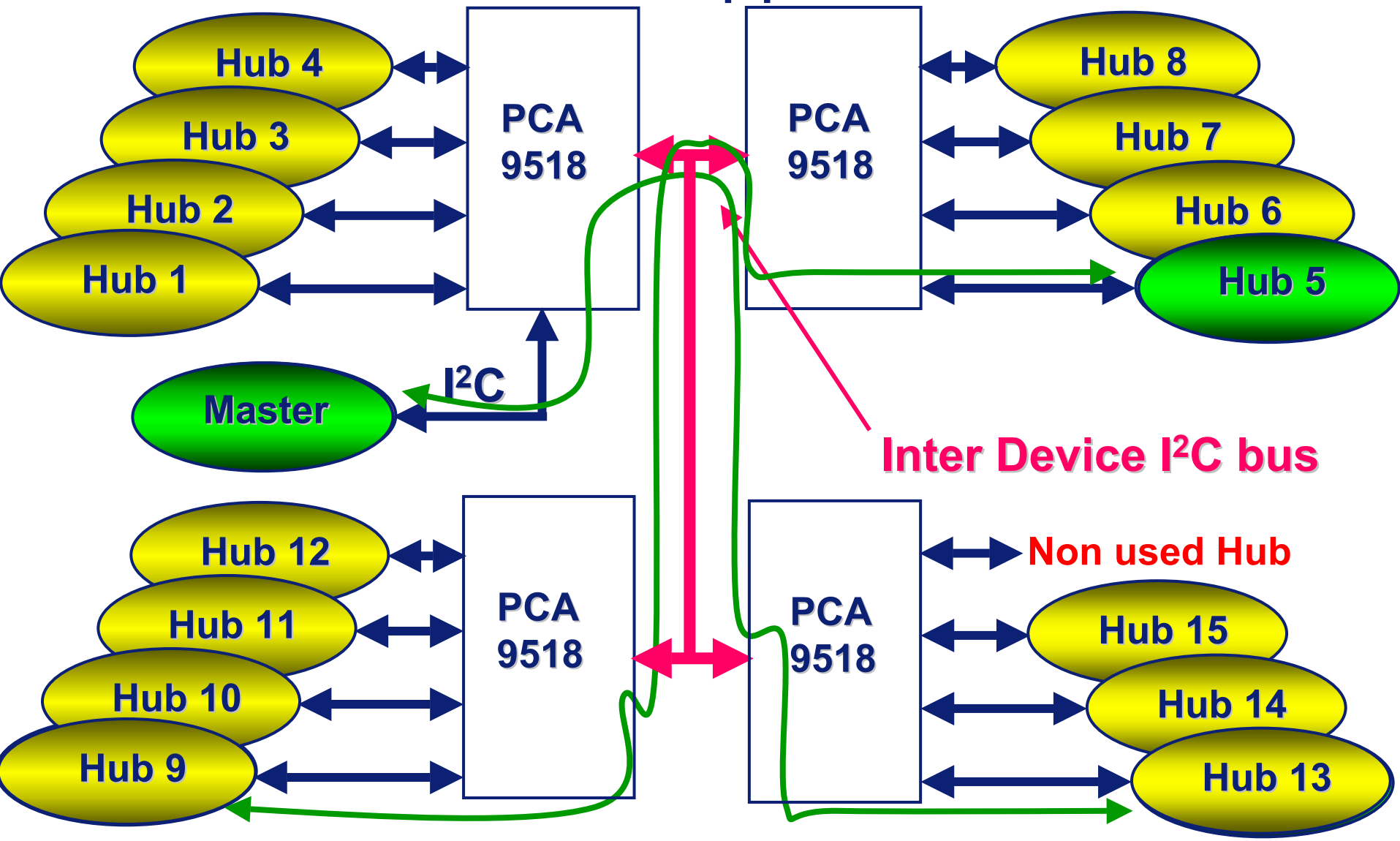
Bus Buffers

I²C Bus repeater (PCA9515) and Hub (PCA9516)



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

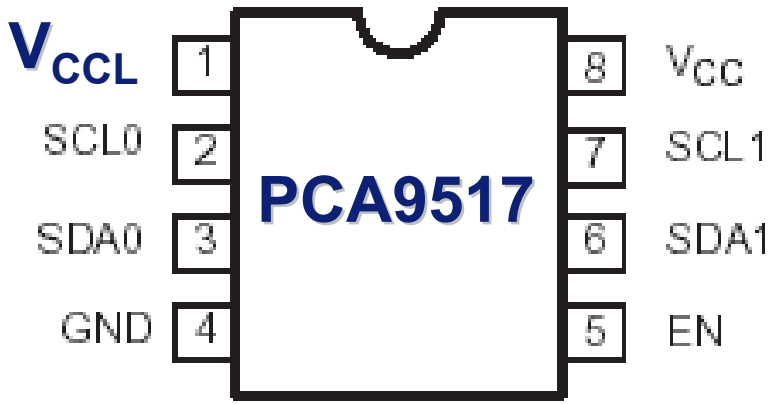


The PCA9518 was design to allow expansion to an unlimited number of segments of 400 pF each.

Level Translation I²C Bus Buffer

I²C or SMBus

0.9 to 5.5V

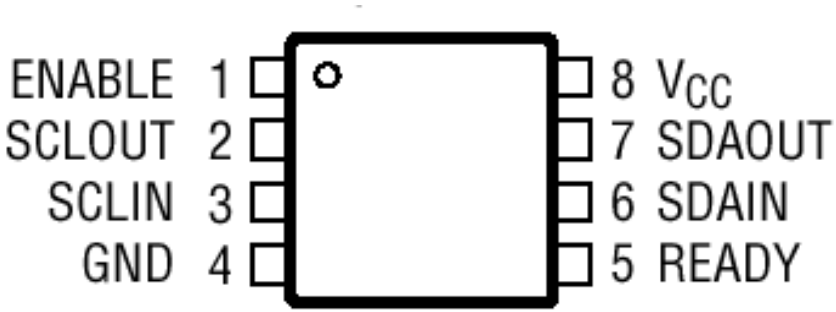


I²C or SMBus

3.3 to 5.5V

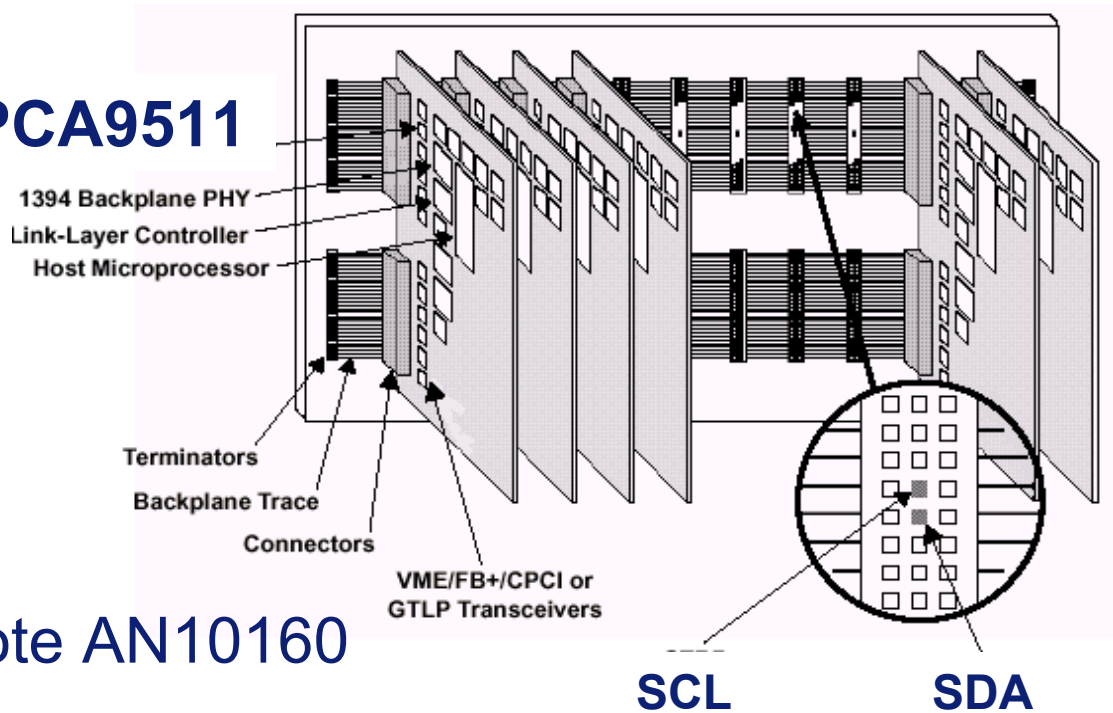
- **Isolates capacitance allowing 400pF on each side of the device**
- **Enable/disable pin allows isolation of bus**
- **Dual V_{CC}s allow voltage translation with optimum noise margin on the low voltage side**
- **Drop in replacement for the PCA9515**

I²C Hot Swap Bus Buffer



- Isolate capacitance
- Stop and Idle detect
- SDA/SCL Precharge
- Rise Time Accelerators

PCA9511



Application Note AN10160

I²C Hot Swap Bus Buffer

Feature	PCA9510	PCA9511	PCA9513	PCA9514		PCA9512
Alternate source to Linear Tech LTC4300-1ISM8	Similar	Yes	Similar	Similar		-
Alternate source to Linear Tech LTC4300-2ISM8	-	-	-	-		Yes
Idle Detect	Yes	Yes	Yes	Yes		Yes
High Impedance SDA, SCL pins for Vcc = 0V	Yes	Yes	Yes	Yes		Yes
Rise Time Accelerator Circuitry on all SDA and SCL lines	No	Yes	Yes	Yes		Yes
Rise Time Accelerator Circuitry Hardware Enable Pin	-	-	-	-		Yes
Rise Time Accelerator threshold 0.8 V vs 0.6 V improves noise margin	-	-	Yes	Yes		-
Low Icc chip disable < 1 uA	Yes	Yes	Yes	Yes		No
Ready Open Drain Output	Yes	Yes	Yes	Yes		No
Separate Vccs to support 5 V to 3.3 V level translation	-	-	-	-		
1V Precharge on all SDA and SCL Lines	bus side	Yes	No	No		Yes
92 uA Current Source on SCLIN and SDAIN for PICMG applications	-	-	Yes	-		-
Improve acknowledge and clock stretching behavior	Yes	Yes	Yes	Yes		Yes

Intelligent Platform Management Interface

- Intel initiative in conjunction with hp, NEC and Dell to standardize the maintenance and monitoring of non hot swap server applications.
- Consists of three specifications:
  - Intelligent Platform Management Interface (IPMI) for software extensions
  - Intelligent Platform Management Bus (IPMB) for intra-chassis (in side the box) extensions and is I^2C based
  - Inter Chassis Management Bus (ICMB) for inter-chassis (outside of the box) extensions
- Needed since as the complexity of systems increase, MTBF decreases
- Defines a standardized, abstracted, message-based interface to intelligent platform management hardware.
- Defines standardized records for describing platform management devices and their characteristics.
- Provides a self monitoring capability increasing reliability of the systems
- More information – www.intel.com/design/servers/ipmi/ipmi.htm

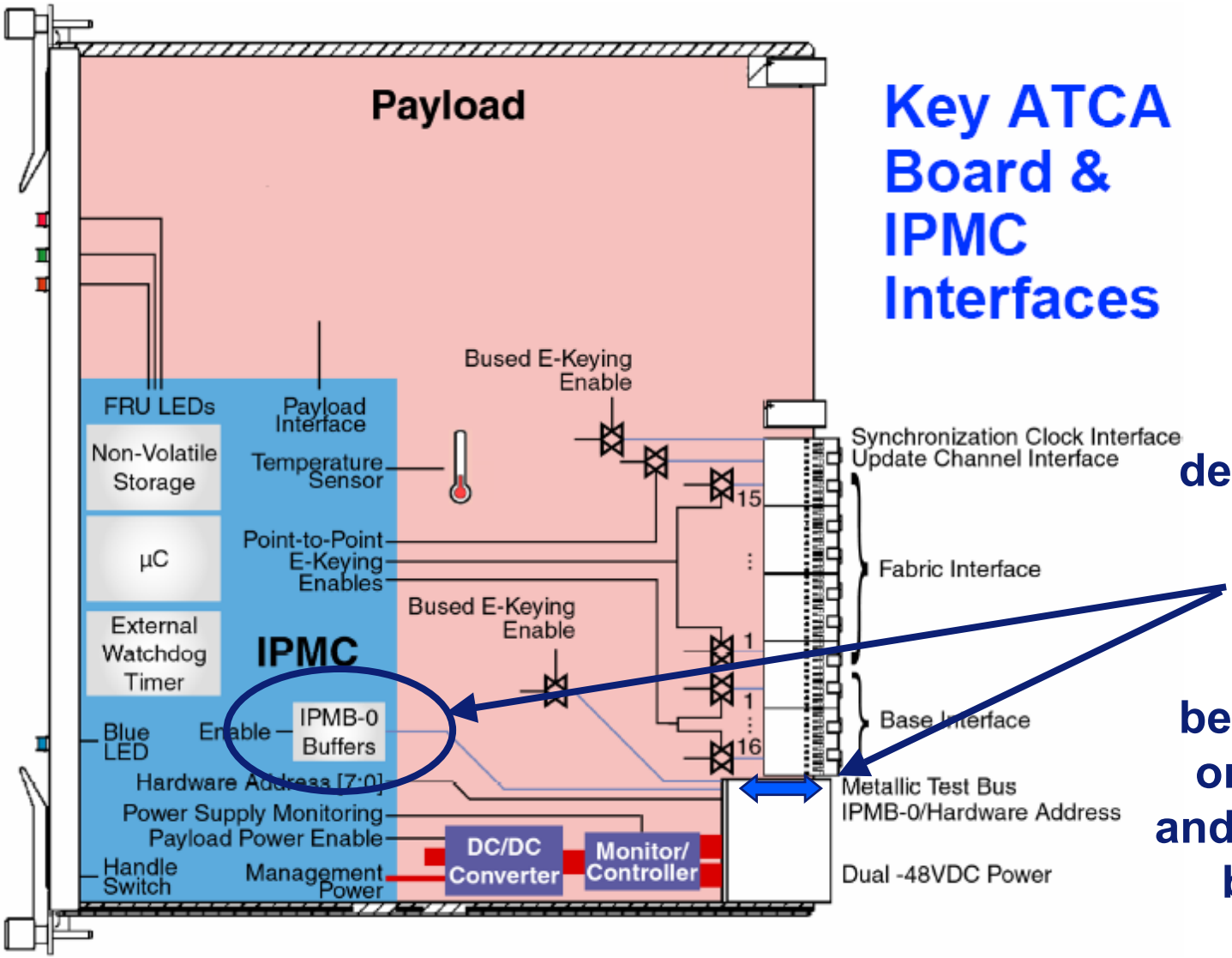
CompactPCI, AdvancedTCA and VME use IPMI

Known as	Specification	Based on	Comments
cPCI	PICMG 2.0	NA	No IPMB
cPCI	PICMG 2.9	IPMI 1.5	Single hot swap IPMB optional
AdvancedTCA	PICMG 3.x	IPMI 1.5	Dual redundant hot swap IPMB mandatory

- IPMI is used as the basis for the management and monitoring of these hot swap telecom applications
  - PICMG 2.0: CompactPCI Core
  - PICMG 2.9: System Management
  - PICMG 3.0: AdvancedTCA Core
    - 3.1 Ethernet Star (1000BX and XAUI)
    - 3.2 InfiniBand® Star & Mesh
    - 3.3 StarFabric
    - 3.4 PCI Express
  - VME will use PICMG 2.9 specifications
- AdvancedTCA tutorial > http://www.picmg.org/advancedTCA_Tutorial_0503.stm

These systems will use the PCA9510/11/12/13/14 to help buffer capacitance and provide hot swap protection.

Bus Buffers used on every ATCA board!

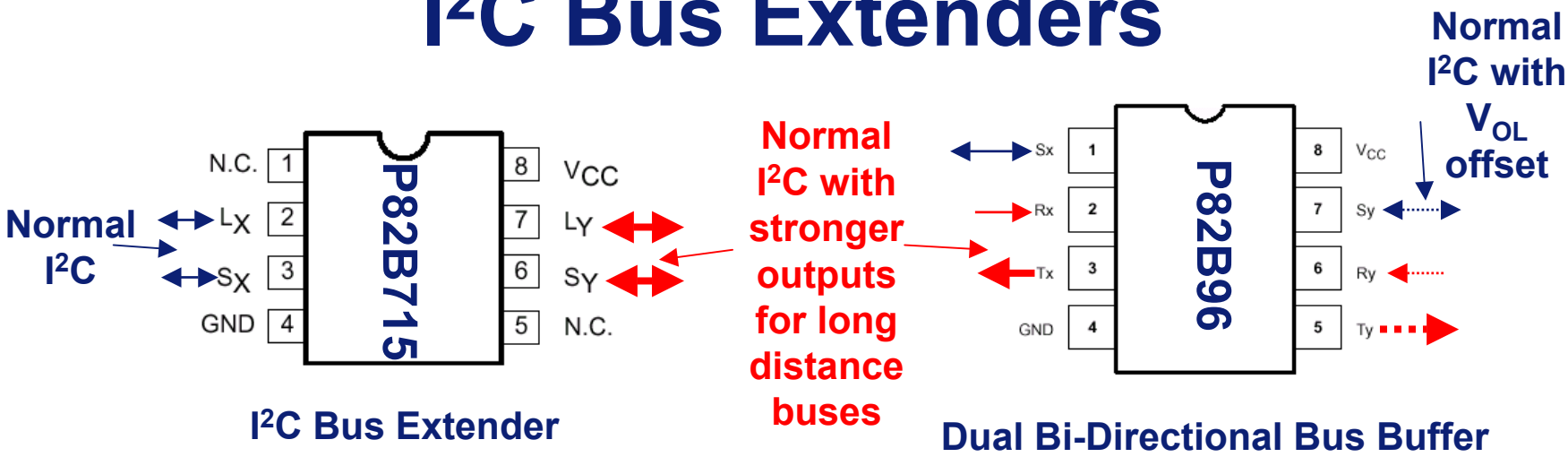


Key ATCA Board & IPMC Interfaces

PCA951x devices buffer

between IPMC on the board and IPMB on the backplane

I²C Bus Extenders



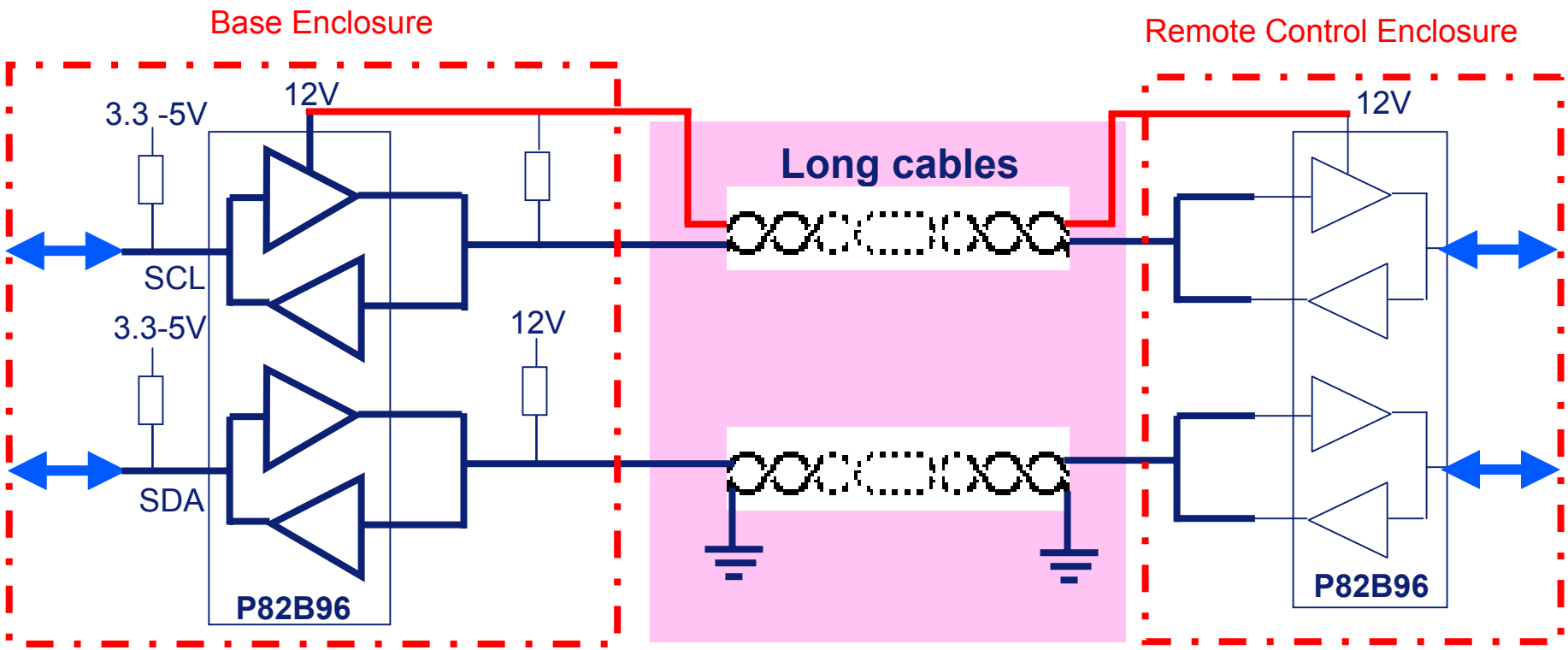
I²C Bus Extender

Dual Bi-Directional Bus Buffer

KEY POINTS

- High drive outputs are used to extend the reach of the I²C bus and exceed the 400 pF/system limit. Can be used in 400 kHz systems.
- Possible distances range from 50 meters at 85 kHz to 1km at 31 kHz over twisted-pair phone cable.
- P82B96 has split high drive outputs allowing differential transmission or Opto-isolation of the I²C Bus.
- The 715 doesn't isolate capacitance beyond 3000 pF but doesn't use offset V_{OL} like the 96 so it is better for V_{OL} sensitive applications.
- See Application Note AN255 for more details.

Driving I²C bus signals long distances

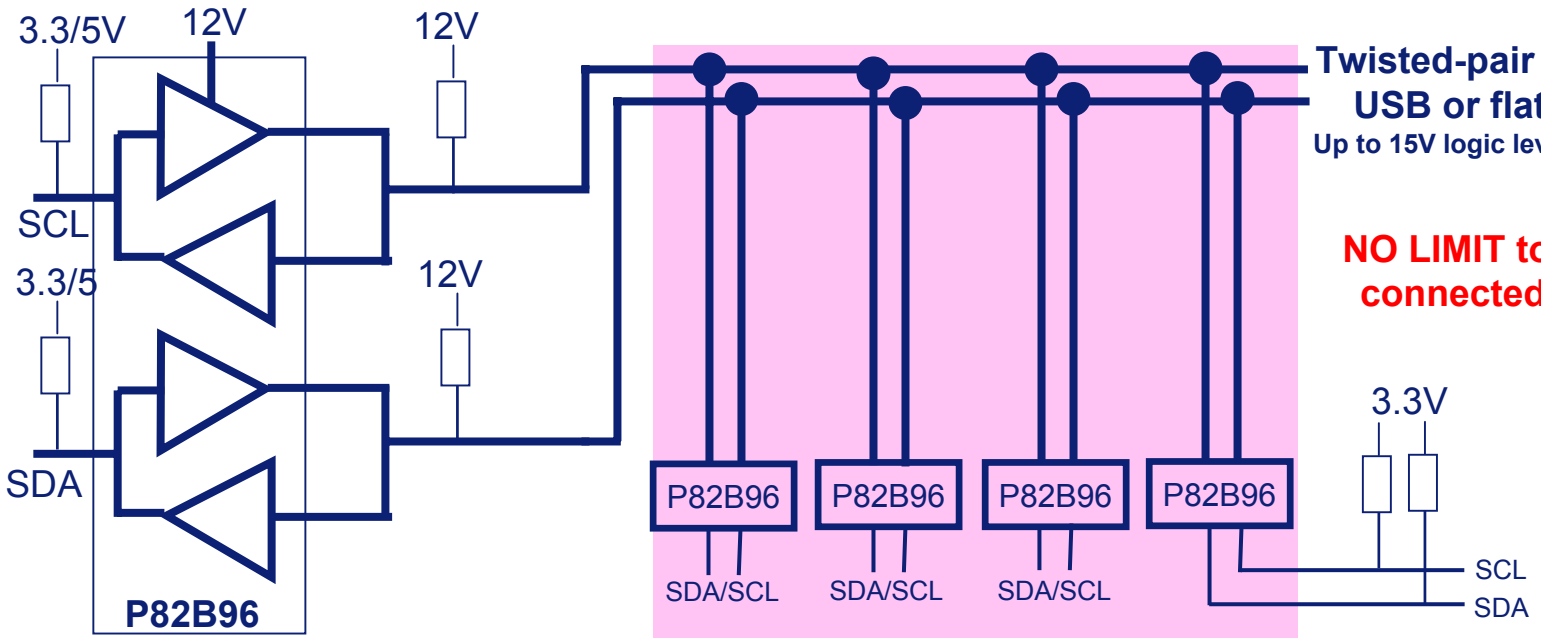


- Normal I²C logic levels (3.3 or 5 V)
- I²C currents (3mA)

- 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!

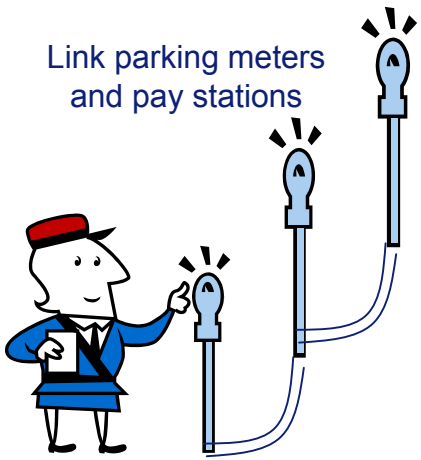


Twisted-pair telephone wires, USB or flat ribbon cables

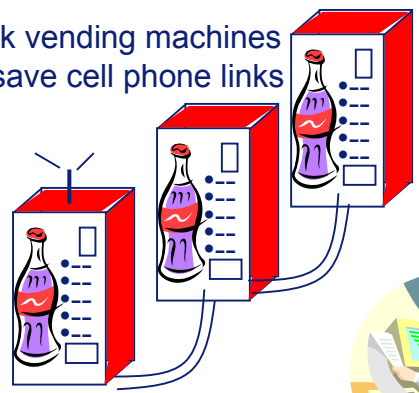
Up to 15V logic levels, Include V_{CC} & GND

NO LIMIT to the number of connected bus devices !

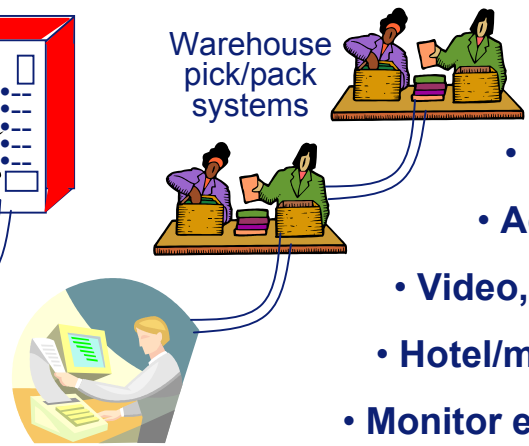
Link parking meters and pay stations



Link vending machines to save cell phone links

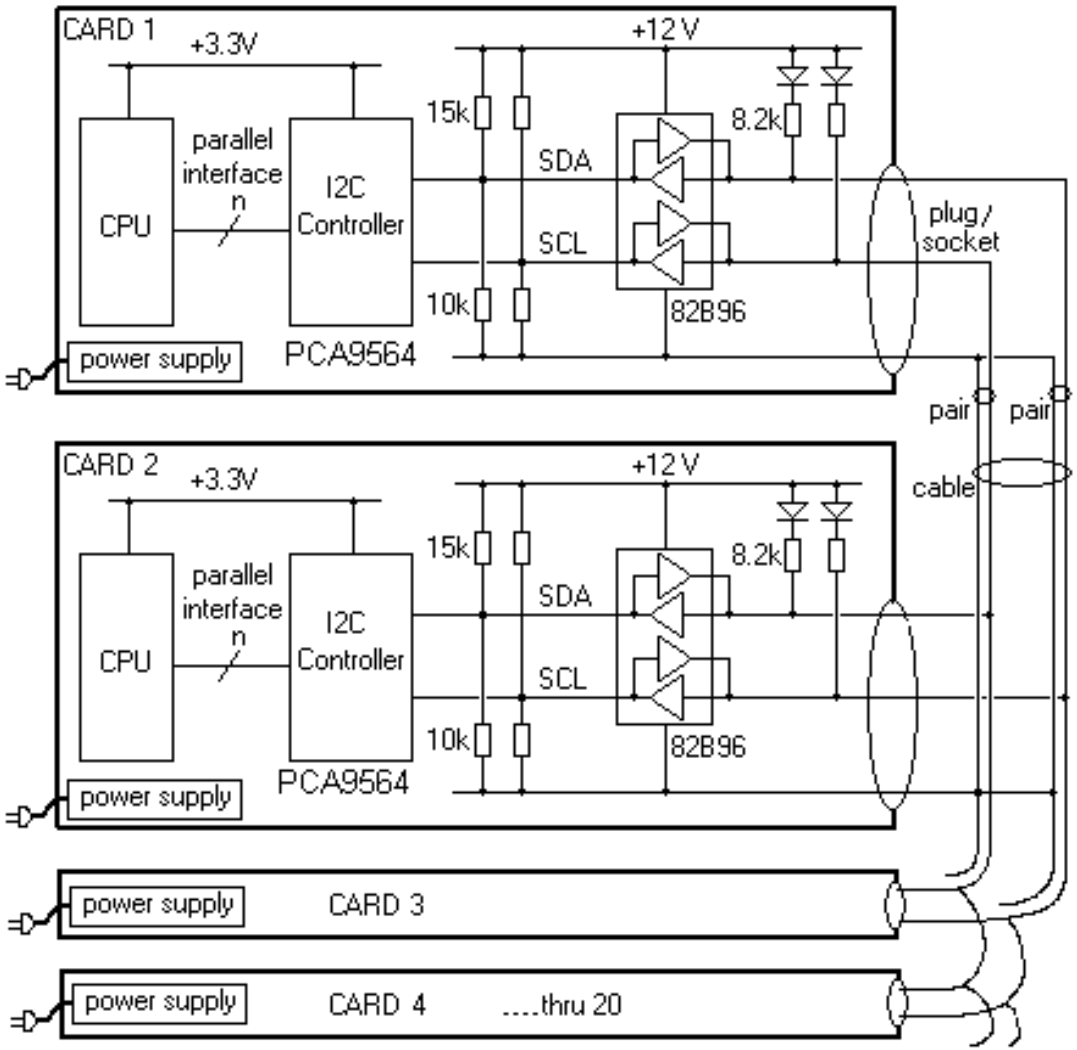


Warehouse pick/pack systems



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

Changing I²C bus signals for multi-point applications!

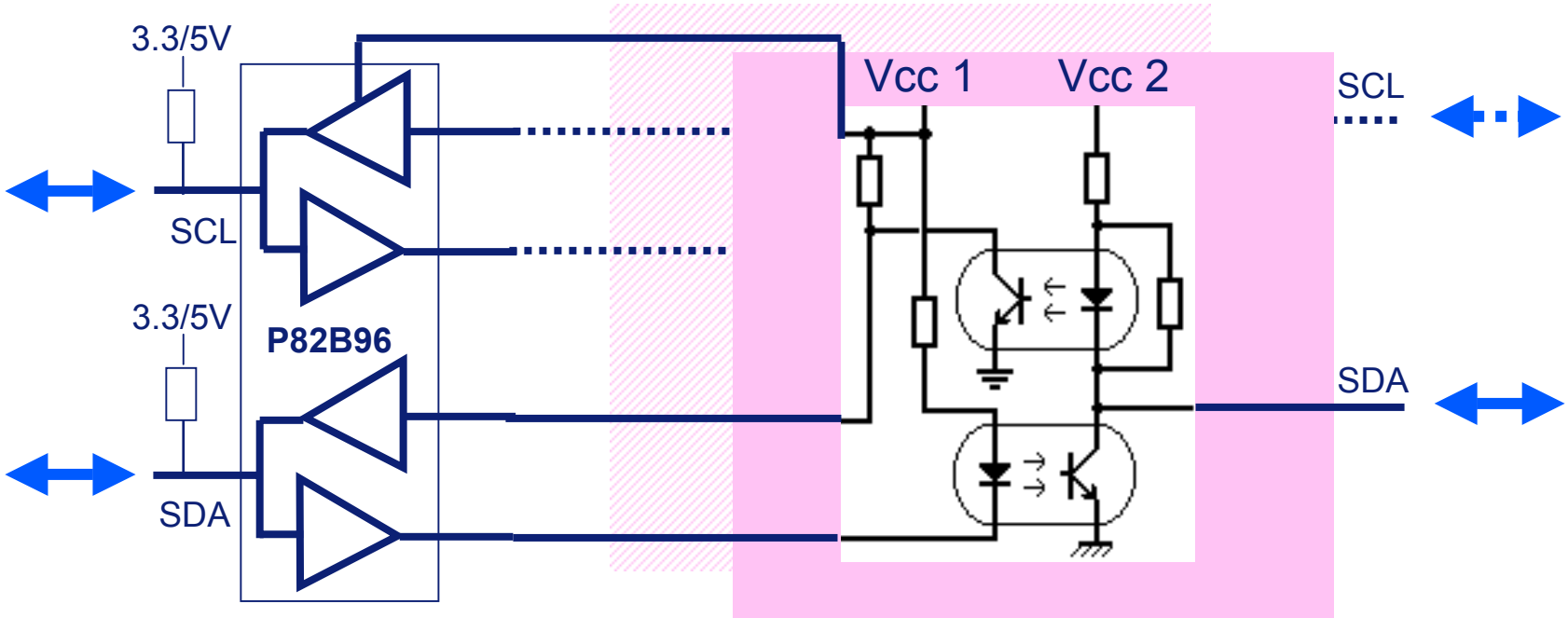


Twisted-pair telephone wires, USB or flat ribbon cables
Up to 15V logic levels, Include V_{CC} & GND

NO LIMIT to the number of connected bus devices !

Connect servers together

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**

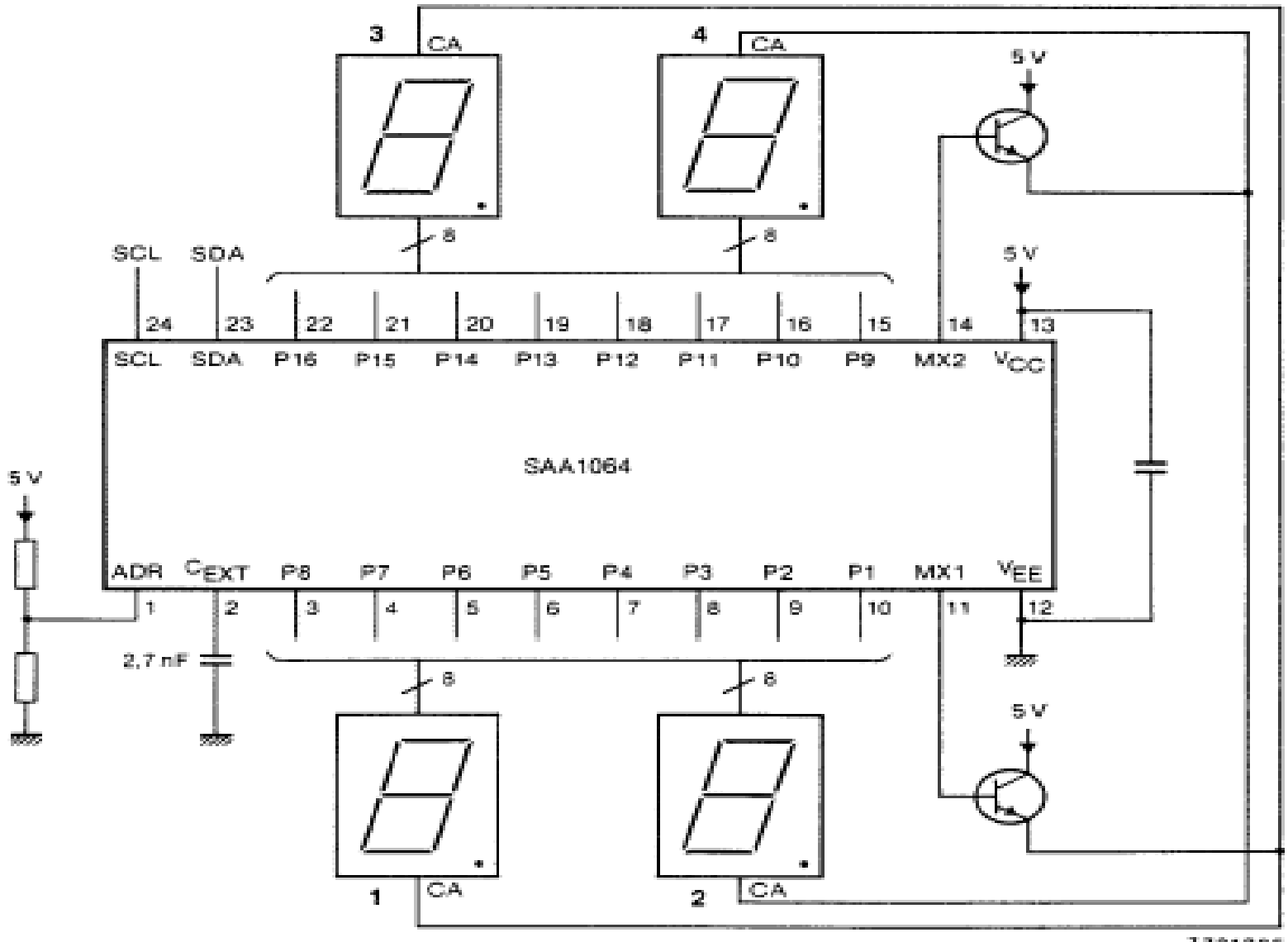
I²C Bus Buffers

Product	Usage					
	Bus Buffer	Long Distance Bus	Bus Isolation/ Multiplexing	Voltage Translation	Multi-Point Distribution	Opto-Electrical Isolation
P82B715	3000pF	✓✓✓			✓✓✓	
P82B96	4000pF	✓✓✓	✓	✓✓✓	✓✓✓	✓✓✓
PCA9511	800pF	✓	✓✓	✓	✓✓✓	
PCA9512	800pF	✓	✓	✓✓	✓✓✓	
PCA9513	800pF	✓	✓✓	✓	✓✓✓	
PCA9514	800pF	✓	✓✓	✓	✓✓✓	
PCA9515	800pF		✓✓	✓		
PCA9516	2000pF		✓✓✓	✓		
PCA9518	2000pF x n		✓✓✓	✓		

Usage Legend: ✓ = Good, ✓✓ = Better, ✓✓✓ = Best

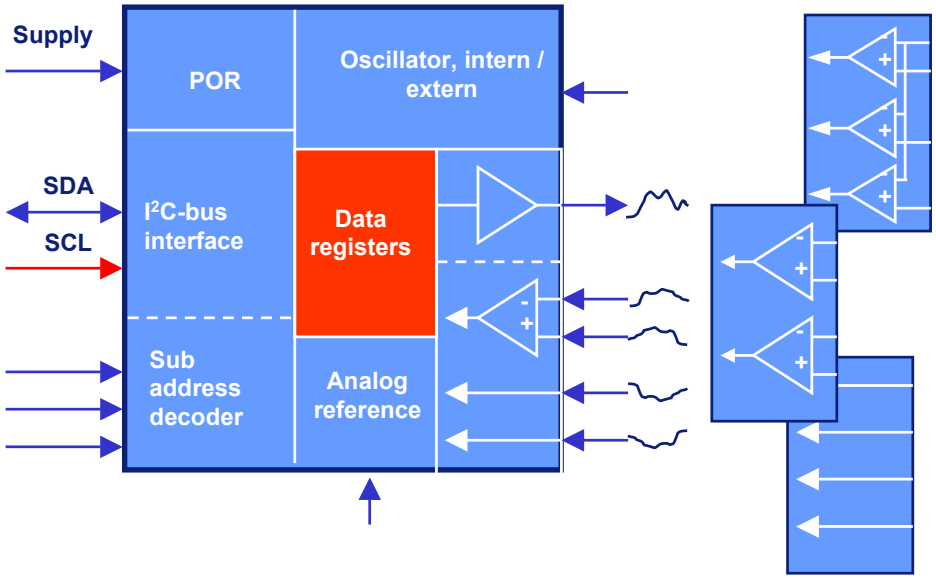
Segment Drivers

SAA1064 Driving Four 7 Segment plus Decimal



A/D Converters

Analog to Digital Converter



KEY POINTS

- Converts signals from digital to analog and analog to digital

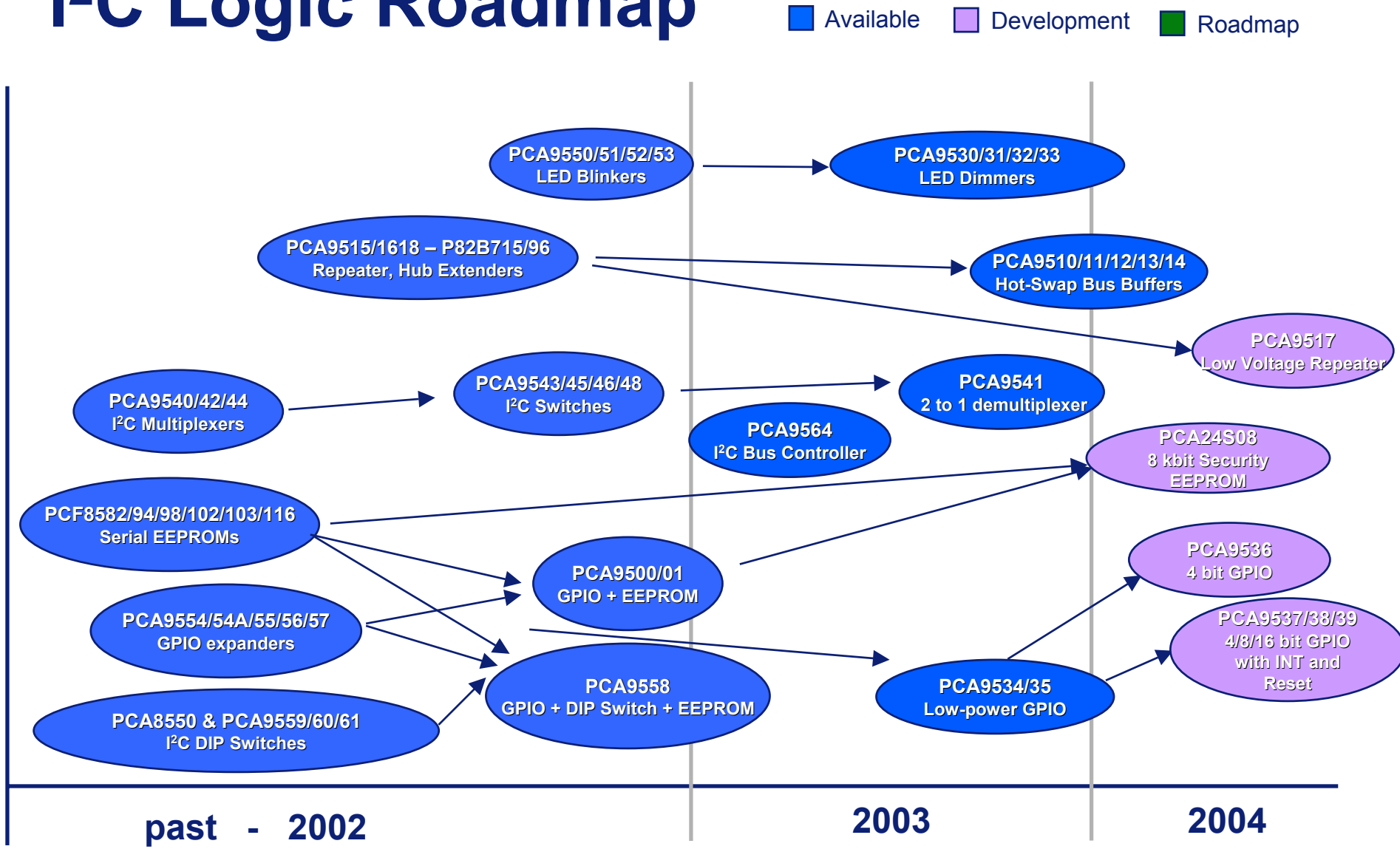
FEATURES

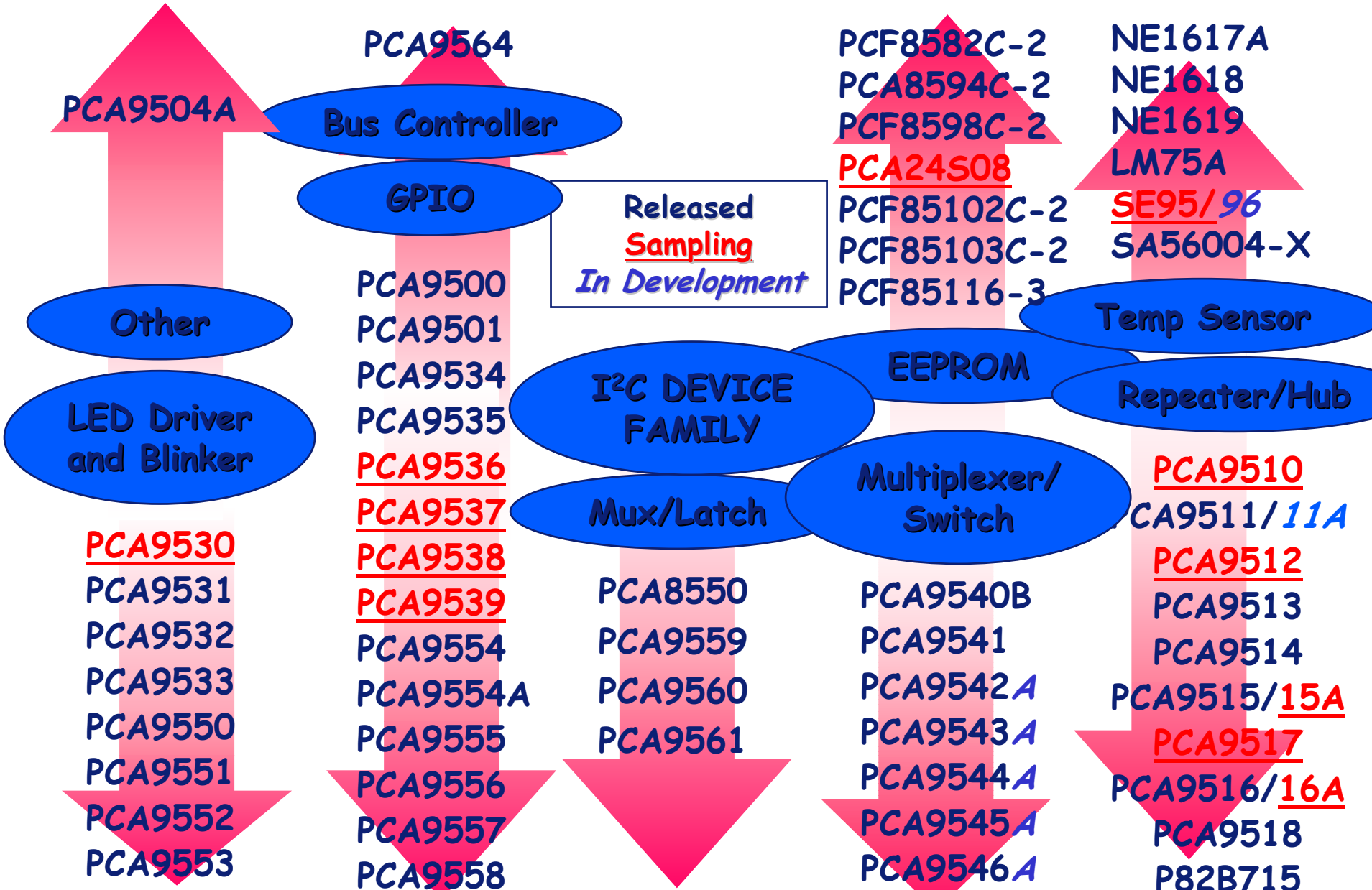
- 4 channel A to D
- 1 channel D to A
- Internal oscillator
- Power On Reset (POR)

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

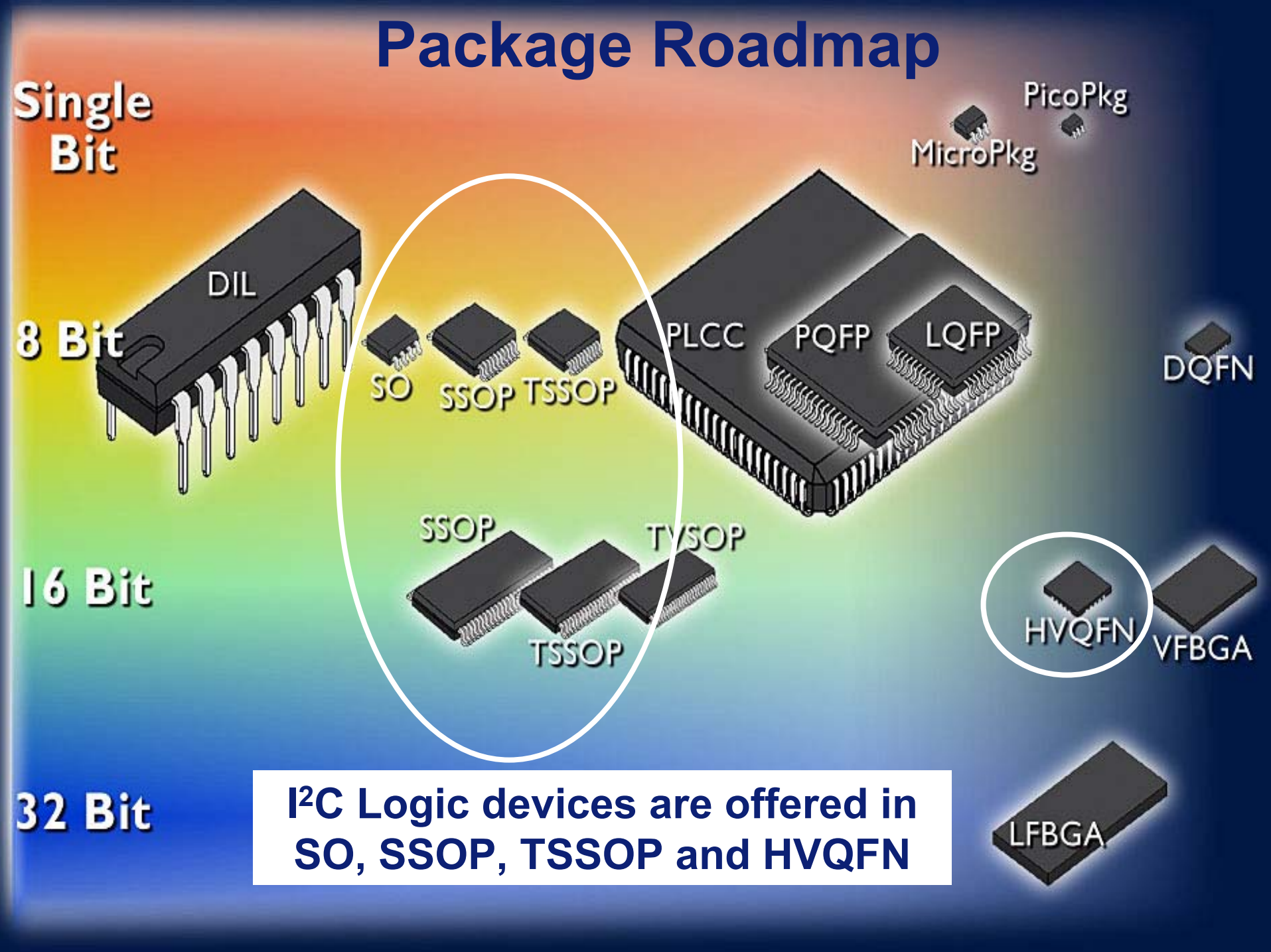
Roadmap

I²C Logic Roadmap



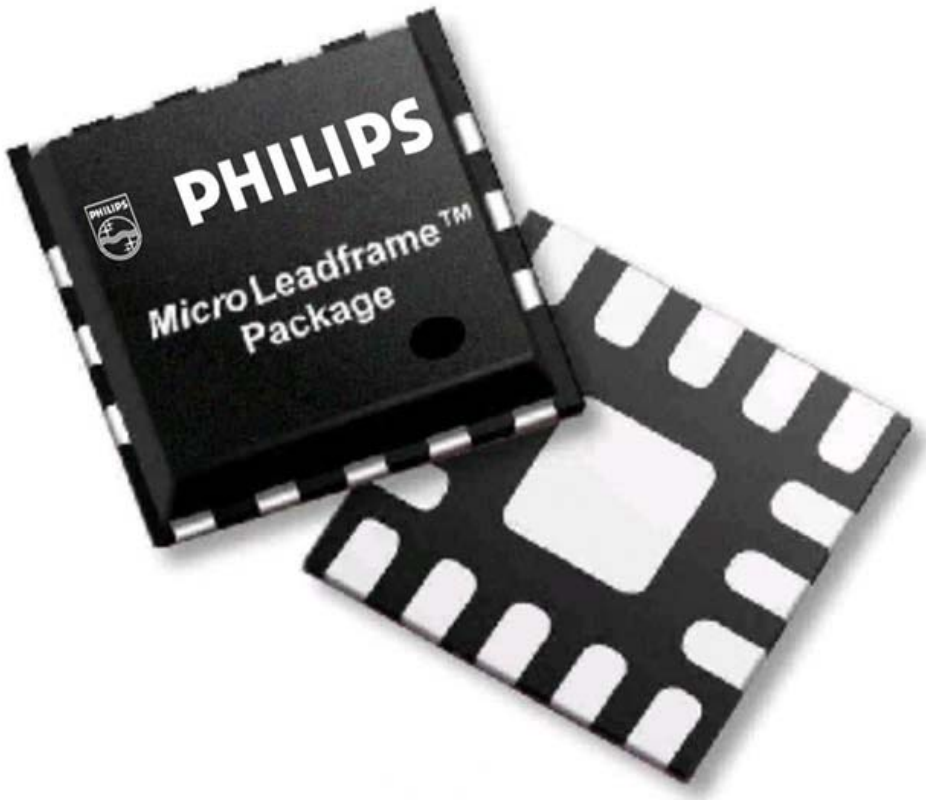

PCA9504A
PCA9564
Bus Controller
GPIO
Released
Sampling
In Development
PCF8582C-2
PCA8594C-2
PCF8598C-2
PCA24S08
PCF85102C-2
PCF85103C-2
PCF85116-3
NE1617A
NE1618
NE1619
LM75A
SE95/96
SA56004-X
Other
LED Driver and Blinker
I²C DEVICE FAMILY
EEPROM
Temp Sensor
Repeater/Hub
Mux/Latch
Multiplexer/ Switch
PCA9530
PCA9531
PCA9532
PCA9533
PCA9550
PCA9551
PCA9552
PCA9553
PCA9500
PCA9501
PCA9534
PCA9535
PCA9536
PCA9537
PCA9538
PCA9539
PCA9554
PCA9554A
PCA9555
PCA9556
PCA9557
PCA9558
PCA8550
PCA9559
PCA9560
PCA9561
PCA9540B
PCA9541
PCA9542A
PCA9543A
PCA9544A
PCA9545A
PCA9546A
PCA9548A
PCA9510
PCA9511/11A
PCA9512
PCA9513
PCA9514
PCA9515/15A
PCA9517
PCA9516/16A
PCA9518
P82B715
P82B96

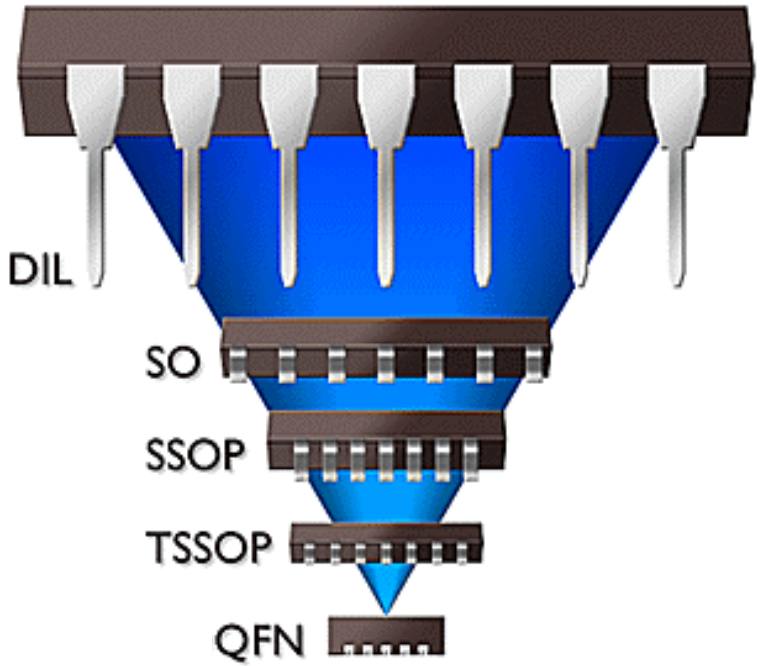
Package Roadmap



I²C Logic devices are offered in SO, SSOP, TSSOP and HVQFN

MLP/HVQFN

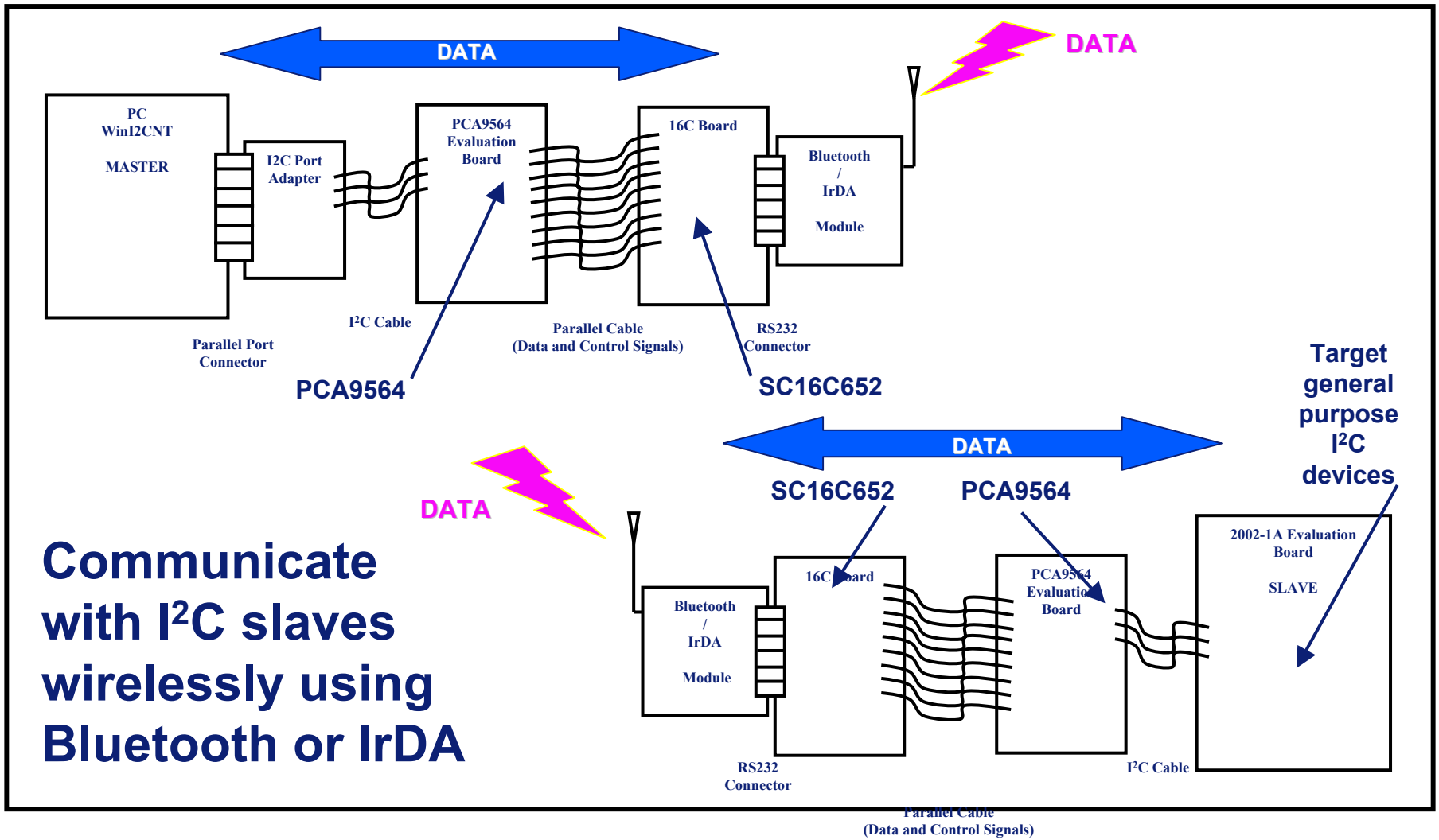




New Heat Sink Very Thin Quad Flat pack No Lead Packages are 75% Smaller than TSSOP

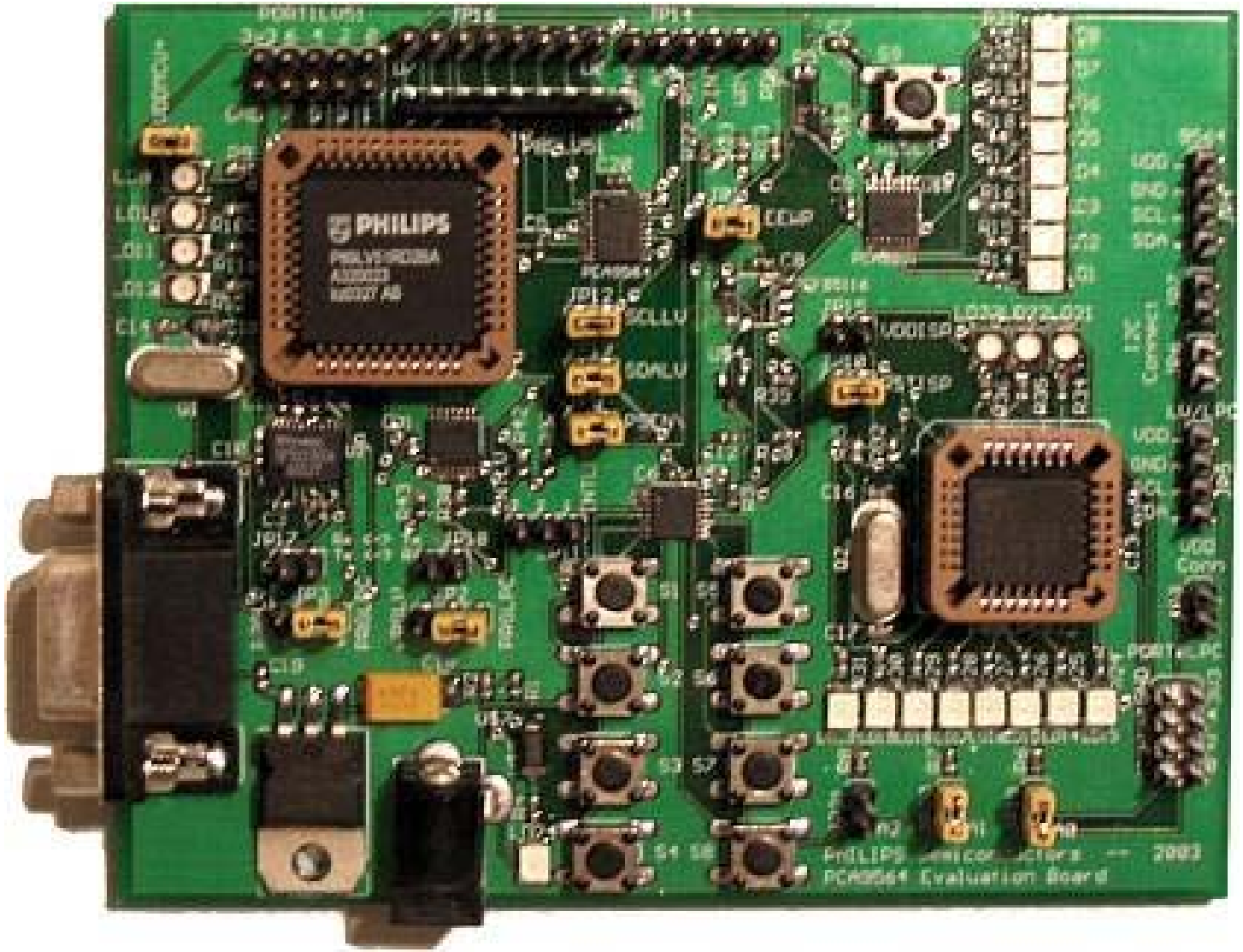
Support Material

Combined I²C and UART Demo Board

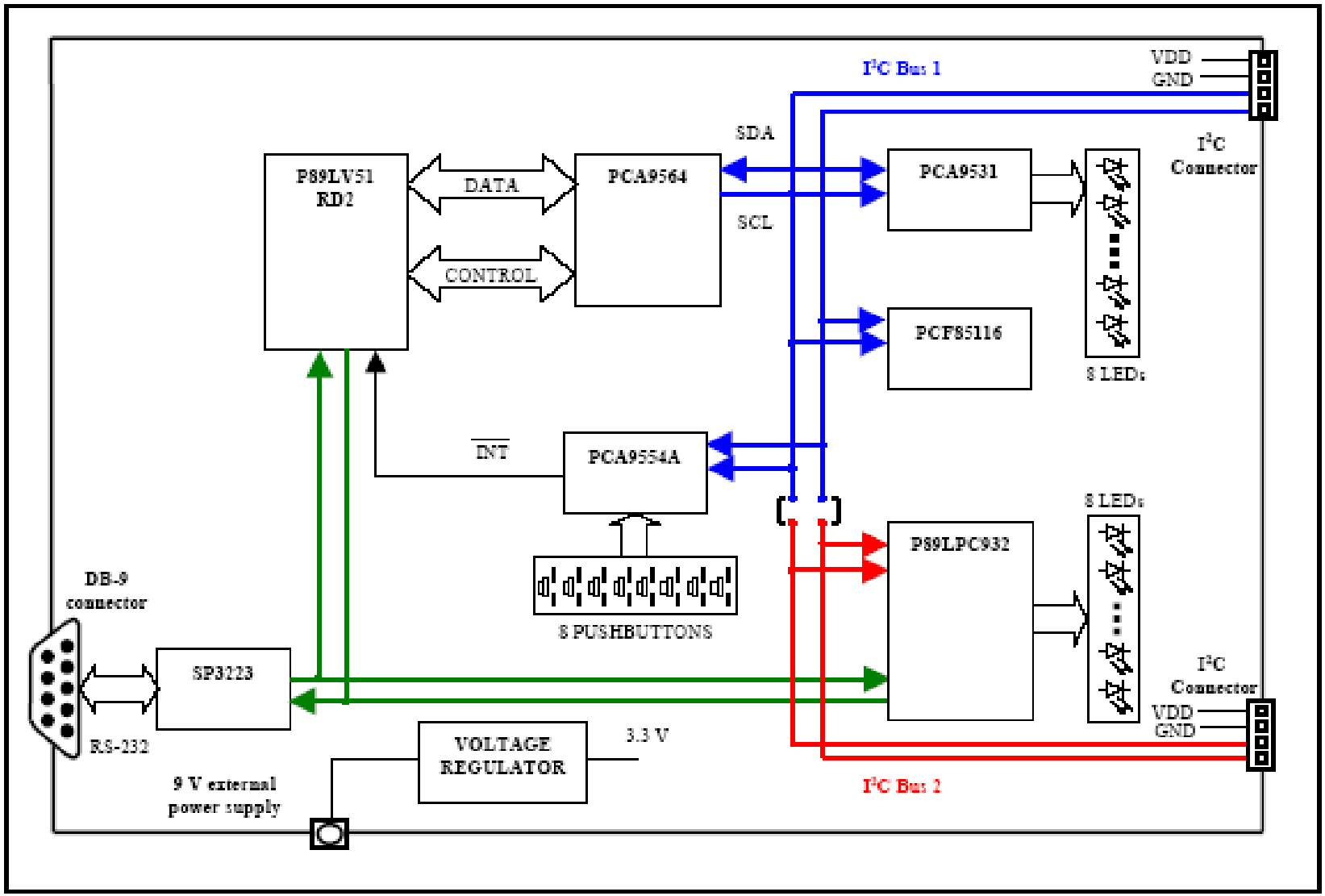


Communicate with I²C slaves wirelessly using Bluetooth or IrDA

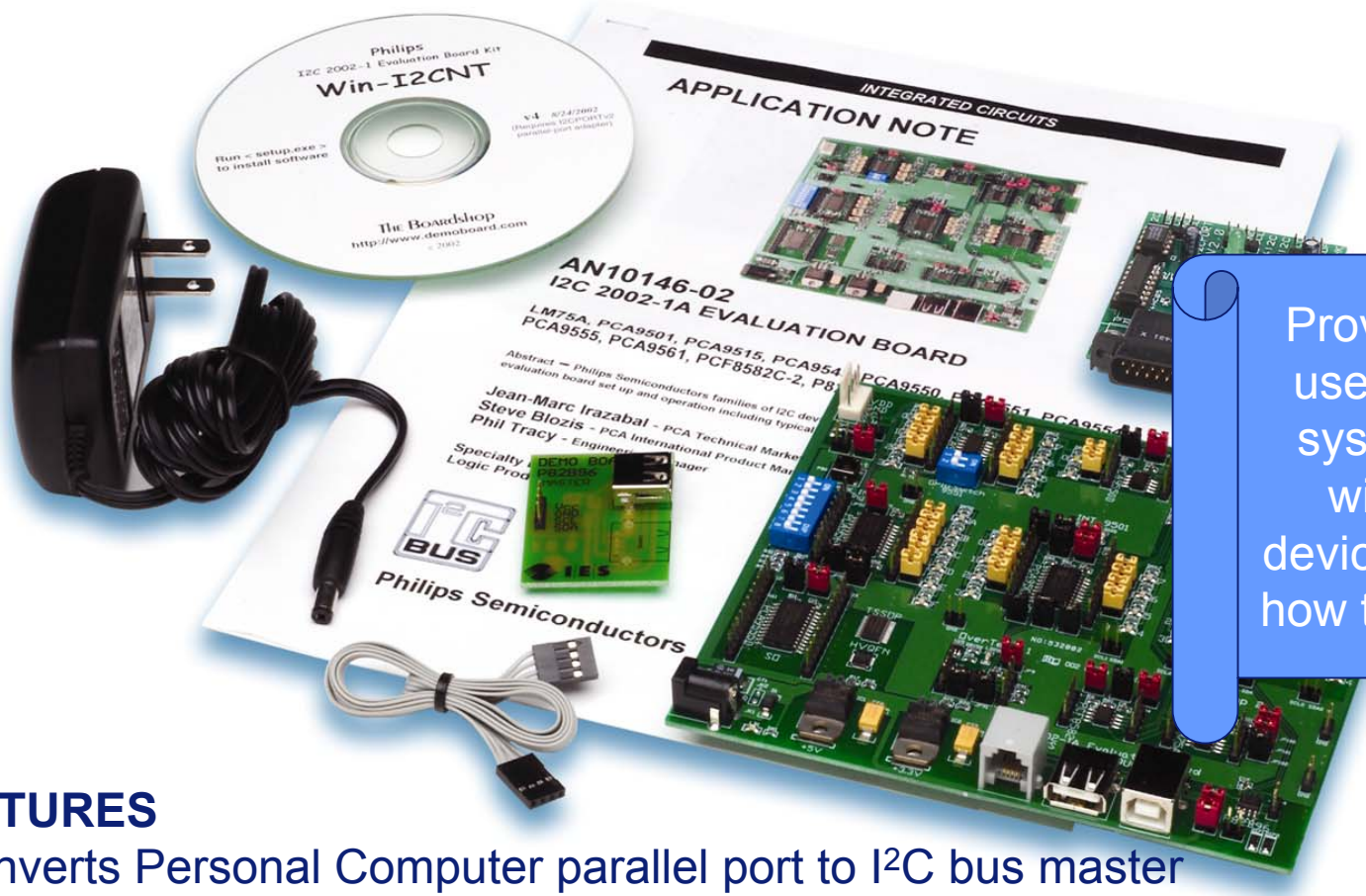
PCA9564 Demo Board Picture



PCA9564 Demo Board Layout



I2C 2002-1A Evaluation Board Kit



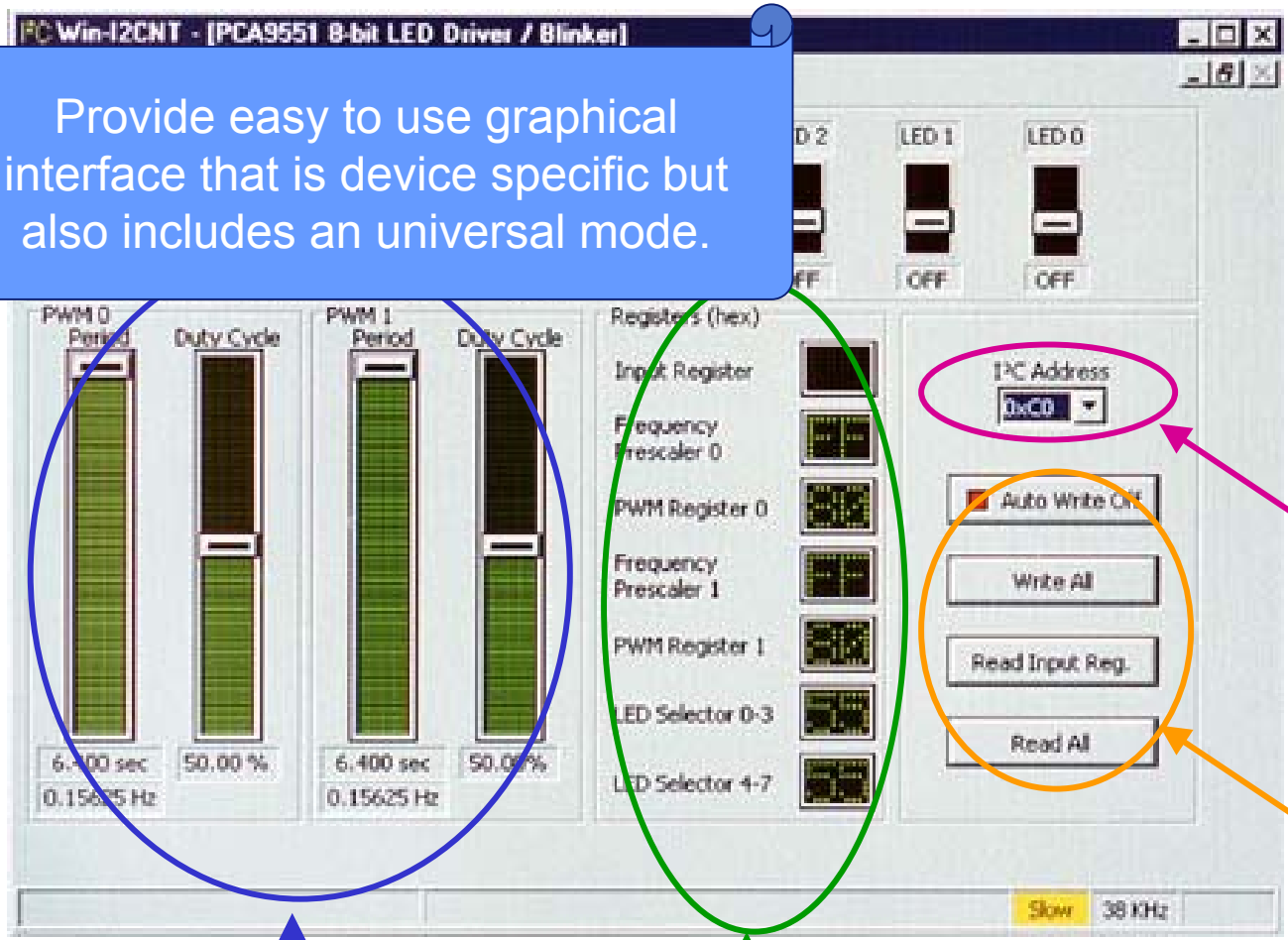
Provide easy to use, PC based system to play with the I²C devices and learn how they operate.

FEATURES

- Converts Personal Computer parallel port to I²C bus master
- Simple to use graphical interface for I²C commands with new expert mode
- Win-I2CNT software compatible with Windows 95, 98, ME, NT, XP and 2000
- Order kits at www.demoboard.com
- Support tools > http://www.semiconductors.philips.com/buses/i2c/tools/index.html

PCA9551 LED Blinkers Win-I2CNT Interface Screen

Provide easy to use graphical interface that is device specific but also includes an universal mode.



Select LEDs mode

Device address CC for PCA9551

Write and Read Registers

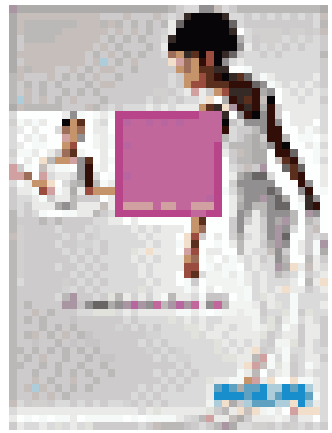
Select blinking options

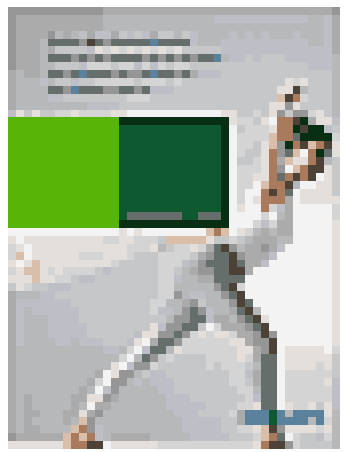
Register information

I²C Product Flyers and Selection Guides

Provide overview of all the devices to

2003 I²C Selection Guide	Order Number: 9397 750 10591
2003 CBT Selection Guide	Order Number: 9397 750 10336
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
P82B96	Order Number: 9397 750 09084





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

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

Provide easy to access to all the up to date data sheets, application notes and modeling tools.

www.philipslogic.com/i2c or
www.semiconductors.philips.com/i2c

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
AN444 P82B715 I²C Bus Buffer
AN460 Introducing the P82B96 I²C Bus Buffer
AN262 PCA954X Multiplexers and Switches
AN264 I²C Devices for LED Display Control
AN469 I²C I/O Port Selection
AN10145 Bi-Directional Voltage Translators
AN10146 I²C 2002-1A Evaluation Board
AN10148 PCA9564 Bus Controller
AN10149 PCA9564 Eval Board
AN10160 I²C Hot Swap Bus Buffers ** (Jun)
AN10216 I²C Manual

Provide in-depth technical support to make it easier to design in the device.

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

I²C Sample Kit

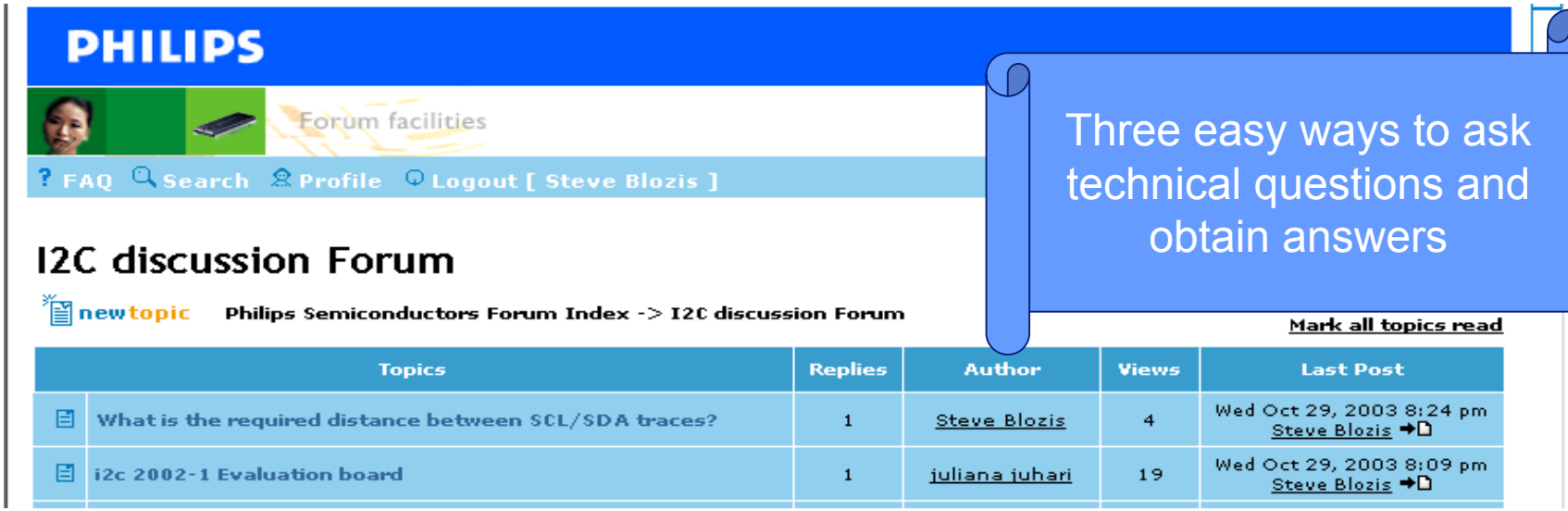
The I²C Sample Kit consists of eight different I²C devices in tape inserted into the I²C Sample Kit box with an informative insert.

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

Provide small quantity of free samples to make it easy to assemble and test your system.

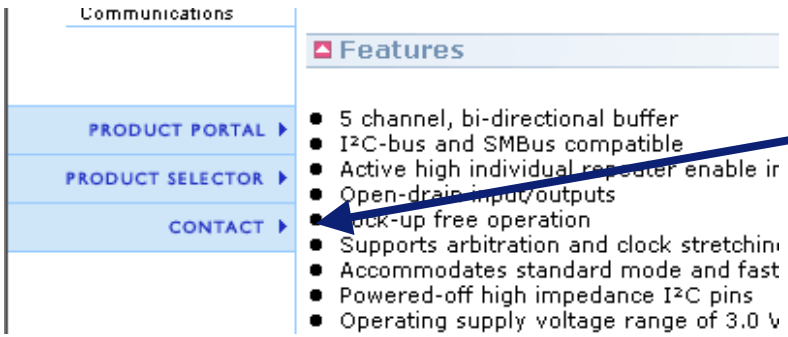
Request I²C Sample Kit or individual samples from your Philips Sales Representative or directly from I2C.Support at philips.com

Easy Access to I²C Technical Help



Three easy ways to ask technical questions and obtain answers

Access from > www.semiconductors.philips.com/buses/i2c/



CONTACT link on every Product Information Page

Send e-mail directly to I2C.Support at philips.com

www.semiconductors.philips.com/i2c

www.philipslogic.com/i2c