I^2C Overview

2H 2003
Agenda

• What is I\textsuperscript{2}C and why would you be interested in using the I\textsuperscript{2}C bus?

• What new I\textsuperscript{2}C devices are there and what are the typical applications?

• How are we going to help you design-in these devices?
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.

General Purpose Logic

Data Transfer Rate (Mbps)

Backplane Length (meters)

Cable Length (meters)
I²C Bus Basics - Address and Data

The master always sends the SCL (clock) signal.

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.

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

Write data

<table>
<thead>
<tr>
<th>S</th>
<th>slave address</th>
<th>W</th>
<th>A</th>
<th>data</th>
<th>A</th>
<th>data</th>
<th>A</th>
<th>P</th>
</tr>
</thead>
</table>

Read data

<table>
<thead>
<tr>
<th>S</th>
<th>slave address</th>
<th>R</th>
<th>A</th>
<th>data</th>
<th>A</th>
<th>data</th>
<th>A</th>
<th>P</th>
</tr>
</thead>
</table>

S = Start condition
A = Acknowledge
P = Stop condition

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

Semiconductors
Typical Signaling Characteristics

**Differential**
- Diff. Driver
- Signal Lines
- V_CM
- V_DIFF
- Data IN
- V_GND
- Data OUT

**Single Ended**
- Driver
- Signal Line
- V_CM
- V_GND
- Receiver
- V_N
- Common Ground Return

**Signaling Standards**
- RS422/485
- PECL
- LVPECL
- LVDS
- 1394
- CML
- LVTTL
- I^2C
- I^2C SMBus
- GTL+
- GTL
- GTLP

**Voltage Levels**
- LVT, LVC
- 5 V
- 3.3 V
- 2.5 V

**Semiconductors**
### I²C by the numbers

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

![Graph of I²C waveforms](image)

- **Rise Time**: 
  - 
  - 
  - 

- **0.7xV_DD**: 
  - 

- **0.3xV_DD**: 
  - 

- **0.4 V @ 3 mA Sink Current**: 
  -
I²C Bus Basics - Bus Operation

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 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 (100 pF/meter)
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
  - Industrial
  - Telecom
  - Automotive
  - Consumer

• Used in many types of applications:
  - PC
  - DVD
  - Printers
  - Set Top Boxes
  - Cell Phones
  - PDA

• Adopted by a lot of leading High-Tech companies
  - Intel
  - IBM
  - Nokia
  - Cisco
  - Compaq
  - HP

• Life of products: designed to stay in the market several years
I²C Designer Benefits

- No need to design bus interfaces because the I²C-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
I²C Product Characteristics

• Package Offerings
  Typically SO, TSSOP and HVQFN packages
• Frequency Range
  Older devices 100 kHz operation
  Newer devices operating up to 400 kHz
  Graphic devices up to 3.4 MHz
• Operating Supply Voltage Range
  2.5 to 5.5 V or 2.8 to 5.5 V
  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
  Some 0 to +70 ºC
• Hardware address pins
  Typically three \((A_0, A_1, A_2)\) 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
**I²C Patent and Legal Information**

- The I²C bus is protected by patents held by Philips. Licensed IC manufacturers that sell devices incorporating the technology already have secured the rights to use these devices, relieving the burden from the purchaser.

- A license is required for implementing an I²C interface on a chip (IC, ASIC, FPGA, etc). It is Philips's position that all chips that can talk to the I²C bus must be licensed. It doesn’t matter how this interface is implemented. The licensed manufacturer may use its own know how, purchased IP cores, or whatever.

- This also applies to FPGAs. However, since the FPGAs are programmed by the user, the user is considered a company that builds an I²C-IC and would need to obtain the license from Philips.

- Apply for a license or text of the Philips I²C Standard License Agreement
  - US and Canadian companies: contact Mr. Piotrowski (I2C.Support at philips.com)
  - All other companies: contact Mr. Hesselmann (I2C.Support at philips.com)
Agenda

• What is I²C and why would you be interested in using the I²C bus?

• What new I²C devices are there and what are the typical applications?

• How are we going to help you design-in these devices?
Philips Semiconductors I\(^2\)C Devices Overview

- TV Reception
- Radio Reception
- Audio Processing
- SMART Card Interface
- 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

I\(^2\)C devices are broken down into 14 different categories

Philips offers over 400 different I\(^2\)C devices
TV Reception

The SAA56xx family of microcontrollers are a derivative of the Philips industry-standard 80C51 microcontroller and are intended for use as the central control mechanism in a television receiver. They provide control functions for the television system, OSD and incorporate an integrated Data Capture and display function for either Teletext or Closed Caption.

Additional features over the SAA55xx family have been included, e.g. 100/120 Hz (2H/2V only) display timing modes, two page operation (50/60 Hz mode for 16:9, 4:3), higher frequency microcontroller, increased character storage, more 80C51 peripherals and a larger Display memory. For CC operation, only a 50/60 Hz display option is available.

Byte level I²C-bus up to 400 kHz dual port I/O
The TEA6845H is a single IC with car radio tuner for AM and FM intended for microcontroller tuning with the I²C-bus. It provides the following functions:

- AM double conversion receiver for LW, MW and SW (31 m, 41 m and 49 m bands) with IF1 = 10.7 MHz and IF2 = 450 kHz
- FM single conversion receiver with integrated image rejection for IF = 10.7 MHz capable of selecting US FM, US weather, Europe FM, East Europe FM and Japan FM bands.
The SAA7740H is a function-specific digital signal processor. The device is capable of performing processing for listening-environments such as equalization, hall-effects, reverberation, surround-sound and digital volume/balance control. The SAA7740H can also be reconfigured (in a dual and quad filter mode) so that it can be used as a digital filter with programmable characteristics.

The SAA7740H realizes most functions directly in hardware. The flexibility exists in the possibility to download function parameters, correction coefficients and various configurations from a host microcontroller. The parameters can be passed in real time and all functions can be switched on simultaneously. The SAA7740H accepts 2 digital stereo signals in the I2S-bus format at audio sampling frequency (fast) and provides 2 digital stereo outputs.
SMART Card Interface - TDA8003

- Power off switch
- Vddi (1.5 to 6V) (reference for µC signals)
- Vddp (2.5 to 6V)
- Asynchronous cards (3&5V) only
- Supply / Supervisor Power on reset
- Step-up converter
- Security / protections
- Vgen.
- Buffer
- Buffer
- Buffer
- Sequence
- VCC
- RST
- I/O
- CLK
- Card presence
- Possibility to cascade 4 ICs
- Off mode
- IRQ
- I/O (µC)
- I2C bus (control/status)
- Clock generator
- Clock in
- I2C sub-addresses
- Possibility to cascade 4 ICs
SMART Card Interface - OM5926HN

- Reference voltage from the Host
- Power off switch
- Supply/Supervisor Power on reset
- Step-up converter
- Clock generator
- Sequencer
  - Security / protections
  - Vgen.
  - Buffer
  - Buffer
  - Buffer

- Vddi (1.5 to 6V) (reference for μC signals)
- Vddp (2.5 to 6V)
- 40000 clock cycles counter for ATR sequence
- Asynchronous cards (3&5V) only

- Clock in
- I2C bus (control/status)
- I/O (μC)
- Off mode
- I/O
- Clk
- Vcc
- RST

- Vddi (1.5 to 6V) (reference for μC signals)
- Vddp (2.5 to 6V)
SMART Card - Telecom Terminal Application

Single Slot application

ISO UART
Single chip baseband
TDA8003 or OM5926
SIM/WIM card

or

Single chip baseband
RS232
TDA8029
SIM/WIM or banking card

Dual slot application

ISO UART
Single chip baseband
TDA8003 or OM5926
SIM card

or

Single chip baseband
RS232
TDA8029
Banking card
SMART Card Interface - TDA8023

- VDD (2.7 to 6.5V)
- VDDP (2.7 to 6.5V)
- Supply / Supervisor
- Power on reset
- DC/DC Converter
- Inductive or capacitive
- Security / protections
- Sequencer
- I2C Interface
- Clocks counters
- Adjust supervisor Threshold (opt)
- POFF
- I/O (µC)
- CLKIN
- INT
- SDA
- SCL
- VDDI (1.5 to 6.5V)
SMART Card Interface - TDA8020

AVDD = 2.7V to 6V

- Supply /Supervisor Power on reset
- I²C bus Control & Status
- Level shifters
- Internal oscillator
- Step-up converter
- Clock circuit
- Sequencer

Connections:
- SCL
- SDA
- IRQ
- A0
- A1
- CLKBIN1
- CLKBIN2
- I/O µC1
- I/O µC2
- V_DD(I.8 to 6.5V)
- CGND1
- CLKB1
- CLKB2
- Card presence1
- Card presence2
- VCC1
- RST1
- Buffer
- V generation
- Buffer
- I/O1
- CLK1
- CGND2
- VCC2
- RST2
- Buffer
- Clock circuit
- I/O µC2
- CLK2
DTMF/Modem/Musical Tone Generators

- Modem and musical tone generation
- Telephone tone dialing
  - DTMF > Dual Tone Multiple Frequency
- Low baud rate modem
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 LCD Display and Segment Drivers

**LCD Character Driver**
- PCF2104 LCD controller/driver
- PCF2113x LCD controllers/drivers
- PCF2116x LCD controller/drivers
- PCF2119x LCD controllers/drivers

**LCD Graphic Black/White Driver**
- OM6217 67 x 96 pixel matrix LCD driver
- PCF8531 34 x 128 pixel matrix driver
- PCF8535 65 x 133 pixel matrix driver
- PCF8548 65 x 102 pixels matrix LCD driver
- PCF8811M 80 x 128 pixels matrix LCD driver
- PCF8811 80 x 128 pixels matrix LCD driver
- PCF8813 67 x 102 pixels matrix LCD driver
- PCF8814 65 x 96 pixels matrix LCD driver

**LCD Graphic Gray Scale Driver**
- PCF8820 67 x 101 Grey-scale/ECB color dot matrix LCD driver
- OM6208 65 x 96 Grey-scale/ECB color dot matrix LCD driver

**LCD Segment Driver**
- OM4085 Universal LCD driver for low multiplex rates
- PCF8533 Universal LCD driver for low multiplex rates
- PCF8566 Universal LCD driver for low multiplex rates
- PCF8576C Universal LCD driver for low multiplex rates
- PCF8576D Universal LCD driver for low multiplex rates
- PCF8577C Universal LCD driver for low multiplex rates
- PCF8578 LCD row/column driver for dot matrix graphic displays
- PCF8579 LCD column driver for dot matrix graphic displays

**LED Segment Driver**
- SAA1064 4-digit LED-driver with I²C-Bus interface
The RTC is used to provide absolute timing to devices on the I²C Bus. The latest RTC is the PCF8565 which is the automotive temp range version of the PCF8563 low current consumption RTC. The PCF8583 has 240 bytes 'scratchpad' RAM integrated with the RTC.

- PCA8565  Real time clock/calendar
- PCF8563  Real time clock/calendar
- PCF8573  Clock/calendar with serial I/O
- PCF8583  Clock/calendar with 240 x 8-bit RAM
- PCF8593  Low power clock/calendar
I\textsuperscript{2}C Controlled Clock Generation

PCK2023 CK408 (66/100/133/200MHz) Spread Spectrum Differential System Clock Generator

The PCK2023 is a clock synthesizer/driver for a Pentium IV and other similar processors. The PCK2023 has three differential pair CPU current source outputs. There are ten PCI clock outputs running at 33 MHz and two 48 MHz clocks. There are six 3V66 outputs. Finally, there is one 3.3 V reference clock at 14.318 MHz. All clock outputs meet Intel’s drive strength, rise/fall times, jitter, accuracy, and skew requirements.

I\textsuperscript{2}C is used to turn options on/off, control edge rate, enable/disable I/O and switch clock input.

Supports platforms based on the Intel CK408 clock specification for the Almador (Intel 830) and Brookdale (Intel 845) chipsets.
I\textsuperscript{2}C Controlled Clock Distribution

The PCK2001/2 are a LVTTL fanout buffers used for 133/100 MHz CPU, 66/33 MHz PCI, 14.318 MHz REF, or 133/100/66 MHz SDRAM clock distribution.

18 outputs are used to support up to 4 SDRAM DIMMS commonly found in desktop, workstation or server applications.

10 outputs of the mobile (M) version support 2 SDRAM DIMMS in notebook applications.

6 outputs of the registered (R) version support up to 4 registered SDRAM DIMMs commonly found in server applications.

I\textsuperscript{2}C is used to turn each individual I/O on/off

- **PCK2001** 14.318-167MHz I\textsuperscript{2}C 1:18 SDRAM Clock Buffer
- **PCK2001M** 14.318-167MHz I\textsuperscript{2}C 1:10 SDRAM Clock Buffer
- **PCK2001R** 14.318-133MHz I\textsuperscript{2}C 1:6 SDRAM Clock Buffer
- **PCK2002** 0-300MHz I\textsuperscript{2}C 1:18 SDRAM Clock Buffer
- **PCK2002M** 0-300MHz I\textsuperscript{2}C 1:10 SDRAM Clock Buffer
I²C Controlled Zero-Delay Clock Distribution

PCK2057 DDR Memory Clock Driver

• Optimized for clock distribution in DDR (Double Data Rate) SDRAM applications supporting DDR 200/266/300/333
• 1:10 differential clock distribution
• Jitter < 100 ps
• HCSL to SSTL_2 input conversion
• 2.5 V and 3.3 V I²C support @ 100 kHz
• Test mode enables output buffers while enabling PLL
• Spread spectrum tolerant clock input
• 48-pin plastic TSSOP packaging
• Form, fit, and function compatible with CDCV850

Clocking Solution for ServerWorks Grand Champion™ System I/O Switch
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

<table>
<thead>
<tr>
<th># of Outputs</th>
<th>Interrupt</th>
<th>2Kbit EEPROM</th>
<th>Interrupt and 2Kbit EEPROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quasi Output (20-25 ma sink and 100 uA source)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>PCF8574/74A</td>
<td>PCA9500/58</td>
<td>PCA9501</td>
</tr>
<tr>
<td>16</td>
<td>PCF8575/75C</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Application Note AN469
Quasi Output I²C I/O Expanders - Registers

• To program the outputs

To read input values

• Important to know

– At power-up, all the I/O’s are HIGH (except PCF8575C); Only a current source to VDD 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
**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

### General Purpose I/O

<table>
<thead>
<tr>
<th># of Outputs</th>
<th>Reset</th>
<th>Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Output (20-25 mA sink and 10 mA source)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>PCA9556/57</td>
<td>PCA9534/54/54A</td>
</tr>
<tr>
<td>16</td>
<td>-</td>
<td>PCA9535/55</td>
</tr>
</tbody>
</table>

*Application Note AN469*
### True Output I²C I/O Expanders - Registers

**To configure the device**

- No need to access Configuration and Polarity registers once programmed.

<table>
<thead>
<tr>
<th>S</th>
<th>Address</th>
<th>W</th>
<th>03H</th>
<th>A</th>
<th>CONFIG DATA</th>
<th>A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>S</th>
<th>Address</th>
<th>W</th>
<th>02H</th>
<th>A</th>
<th>POLARITY DATA</th>
<th>A</th>
<th>P</th>
</tr>
</thead>
</table>

**To program the outputs**

- Multiple writes are possible during the same communication.

<table>
<thead>
<tr>
<th>S</th>
<th>Address</th>
<th>W</th>
<th>01H</th>
<th>A</th>
<th>OUTPUT DATA</th>
<th>A</th>
<th>P</th>
</tr>
</thead>
</table>

**To read input values**

- Multiple reads are possible during the same communication.

<table>
<thead>
<tr>
<th>S</th>
<th>Address</th>
<th>W</th>
<th>00H</th>
<th>A</th>
</tr>
</thead>
</table>

| S_R | Address | R | INPUT DATA | A | P |
### True Output \( I^2C \) I/O Expanders - Example

<table>
<thead>
<tr>
<th>Input Reg#</th>
<th>Polarity Reg#</th>
<th>Config Reg#</th>
<th>Output Reg#</th>
<th>I/O’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>0</td>
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<td>0</td>
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<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
I²C LED Dimmers/Blinkers

**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)

**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.

<table>
<thead>
<tr>
<th># of Outputs</th>
<th>Reset and POR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>PCA9530/50</td>
</tr>
<tr>
<td>4</td>
<td>PCA9533/53</td>
</tr>
<tr>
<td>8</td>
<td>PCA9531/51</td>
</tr>
<tr>
<td>16</td>
<td>PCA9532/52</td>
</tr>
</tbody>
</table>

Application Note AN264
PCA953x I²C LED Dimmers

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.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Duty Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 Hz</td>
<td>0%</td>
</tr>
<tr>
<td>1.6 s</td>
<td>99.6%</td>
</tr>
</tbody>
</table>

ON = LED ON
OFF = LED OFF

ON, OFF, BR1, BR2
PCA955x I²C LED Blinkers

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Duty Cycle</th>
<th>0 (00_H)</th>
<th>255 (FF_H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 Hz</td>
<td>100 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.4 s</td>
<td>0.4 %</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Input Register(s)

PWM0 (ON Time)

PSC0 (Frequency)

PWM1 (ON Time)

PSC1 (Frequency)

LED Selector

ON, OFF, BR1, BR2

ON = LED ON
OFF = LED OFF

256 - PWM0
256

256 - PWM1
256

PSC0 + 1
40

PSC1 + 1
40

Semiconductors
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 internal processor clock frequency
- I²C devices have higher sink current capability per bit and larger sink current capability per device
I²C DIP Switches

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

EEPROM 0 is default output

Application Note AN250
I²C Multiplexers and Switches

Application Note AN262
I\textsuperscript{2}C Multiplexers: Address Deconflict

Same I\textsuperscript{2}C devices with same address

The multiplexer allows to address 1 device then the other one
I²C Switches: Voltage Level Shifting

Devices supplied by 5V

I²C device 1
I²C device 2
I²C device 3
I²C device 4
I²C device 5

Devices supplied by 3.3V

PCA9543

5V bus
3.3V bus

I²C device 1
I²C device 2
I²C device 3
I²C device 4
I²C device 5

MASTER
I²C Switches: Branch isolation

Separate devices 1, 2 and 3 from devices 4 and 5

Semiconductors
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
PCA9541 - Point-Point Application
Some masters may not be multi-master capable or some masters may not play 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.
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.
PCA9541 – Bus Recovery

- If the I²C bus hangs up, the master will lose control of all slave devices.
- The PCA9541/03 can be used to isolate slave devices without a reset pin, allowing the master to initiate a reset on the upstream devices to regain control of the bus and then command the PCA9541/03 to send 9 clocks pulses and a stop condition to reset the state machine of the downstream slaves so that all devices are waiting for a START condition.
## I²C Multiplexers and Switches

<table>
<thead>
<tr>
<th>Device</th>
<th>Multiplexer (In/Out)</th>
<th>Switch (In/Out)</th>
<th># of Addresses</th>
<th>Interrupt (In/Out)</th>
<th>Hardware RESET</th>
<th>Pin Count</th>
<th>SO (Narrow)</th>
<th>SO (Wide)</th>
<th>TSSOP</th>
<th>HVQFN</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCA9540</td>
<td>1-2</td>
<td>1</td>
<td></td>
<td></td>
<td>8</td>
<td>D</td>
<td>DP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA9541</td>
<td>2-1</td>
<td>16</td>
<td>1-2</td>
<td>✓</td>
<td>16</td>
<td>D</td>
<td>PW</td>
<td>BS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA9542</td>
<td>1-2</td>
<td>8</td>
<td>2-1</td>
<td>✓</td>
<td>14</td>
<td>D</td>
<td>PW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA9543</td>
<td>1-2</td>
<td>4</td>
<td>2-1</td>
<td>✓</td>
<td>14</td>
<td>D</td>
<td>PW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA9544</td>
<td>1-4</td>
<td>8</td>
<td>4-1</td>
<td></td>
<td>20</td>
<td>D</td>
<td>PW</td>
<td>BS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA9545</td>
<td>1-4</td>
<td>4</td>
<td>4-1</td>
<td>✓</td>
<td>20</td>
<td>D</td>
<td>PW</td>
<td>BS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA9546</td>
<td>1-4</td>
<td>8</td>
<td></td>
<td>✓</td>
<td>16</td>
<td>D</td>
<td>PW</td>
<td>BS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA9548</td>
<td>1-8</td>
<td>8</td>
<td></td>
<td>✓</td>
<td>24</td>
<td>D</td>
<td>PW</td>
<td>BS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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
I²C Hot Swap Bus Buffer

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

Application Note
AN10160
Semiconductors
# I²C Hot Swap Bus Buffer

<table>
<thead>
<tr>
<th>Feature</th>
<th>PCA9511</th>
<th>PCA9513</th>
<th>PCA9514</th>
<th>PCA9512</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternate source to Linear Tech LTC4300-1ISM8</td>
<td>Yes</td>
<td>Similar</td>
<td>Similar</td>
<td>-</td>
</tr>
<tr>
<td>Alternate source to Linear Tech LTC4300-2ISM8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Idle Detect</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>High Impedance SDA, SCL pins for Vcc = 0V</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rise Time Accelerator Circuitry on all SDA and SCL lines</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rise Time Accelerator Circuitry Hardware Enable Pin</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Rise Time Accelerator threshold 0.8 V vs 0.6 V improves noise margin</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>Low Icc chip disable &lt; 1 uA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ready Open Drain Output</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Separate Vccs to support 5 V to 3.3 V level translation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>1V Precharge on all SDA and SCL Lines</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>92 uA Current Source on SCLIN and SDAIN for PICMG applications</td>
<td>-</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Improve acknowledge and clock stretching behavior</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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.
The PCA9518 was designed to allow expansion to an unlimited number of segments of 400 pF each.
KEY POINTS

- High drive outputs are used to extend the reach of the I²C bus and exceed the 400 pF/system limit.
- Possible distances range from 50 meters at 85kHz to 1km at 31kHz over twisted-pair phone cable.
- P82B96 has split high drive outputs allowing differential transmission or Opto-isolation of the I²C Bus.
- See Application Note AN255 for more details.
Driving I²C bus signals long distances

- Normal I²C logic levels (3.3 or 5 V)
- Conventional CMOS logic levels (2-15V)
- I²C currents (3mA)
- 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 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
Parallel Bus to $I^2$C Bus Controller

**FEATURES**
- Provides both master and slave functions.
- Controls all the $I^2$C 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 $I^2$C bus.
- Allows the parallel bus system to communicate with the $I^2$C bus.

<table>
<thead>
<tr>
<th></th>
<th>Voltage range</th>
<th>Max $I^2$C freq</th>
<th>Clock source</th>
<th>Parallel interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCF8584</td>
<td>4.5 - 5.5V</td>
<td>90 kHz</td>
<td>External</td>
<td>3 MHz - Slow</td>
</tr>
<tr>
<td>PCA9564</td>
<td>2.3 - 3.6V w/5V tolerance</td>
<td>320 kHz</td>
<td>Internal</td>
<td>50 MHz - Fast</td>
</tr>
</tbody>
</table>

Semiconductors Application Note AN10148
• The PCA9564 converts 8-bit parallel 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 I²C

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 I²C 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 \( \text{I}^2\text{C} \) Bus Ports

- The PCA9564 can be used to convert 8-bit parallel data into additional multiple master capable \( \text{I}^2\text{C} \) port for microcontrollers, microprocessors, custom ASICs, DSPs, etc., that already have an \( \text{I}^2\text{C} \) port but need one or more additional \( \text{I}^2\text{C} \) ports to interface with more \( \text{I}^2\text{C} \) or SMBus components or components that can’t 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 I²C 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 \( I^2C \) serial data stream

- Functioning as a slave transmitter, the PCA9564 can convert 8-bit parallel data into a two wire \( I^2C \) data stream. This prevents having to run 8 traces across the entire width of the PC board.
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)

<table>
<thead>
<tr>
<th></th>
<th>Voltage range</th>
<th>Max $I^2C$ freq</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCF8591</td>
<td>2.5 - 5.5V w/5V tolerance</td>
<td>100 kHz</td>
<td>8-bit</td>
</tr>
</tbody>
</table>
I²C Serial CMOS RAM/EEPROMs

**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

**256 x 8-bit RAM**
Also PCF85102C-2 and PCF85103C-2

**256 x 8-byte (2 kbit)**

**128 x 8-byte (1 kbit)**

**512 x 8-byte (4 kbit)**

**1024 x 8-byte (8 kbit)**

**2048 x 8-byte (16 kbit)**

**1024 x 8-byte (8 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

Semiconductors
FEATURES
• Nonvolatile memory – I²C 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, 5 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.

PCA24S08 – 8 kbit EEPROM with access protection

Semiconductors
Samples Sep 03 – Release Dec 03
I²C Temperature Sensors

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
– SE95A accurate to ± 0.5 °C from 0 to 100 °C
I²C Temperature Sensors with Remote Sensor

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

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

New!

I²C Temperature and Voltage Monitor (Heceta4)
SA56004 Applications

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 I²C 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.
The µcontroller provides the brains behind the I²C bus operation and most feature at least one I²C port.

<table>
<thead>
<tr>
<th>Microcontroller</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>P87C55x</td>
<td>100 kHz I²C</td>
</tr>
<tr>
<td>P87C6xxX2</td>
<td>400 kHz I²C</td>
</tr>
<tr>
<td>P87LPC76x</td>
<td>100 kHz I²C</td>
</tr>
<tr>
<td>P89C66x</td>
<td>100 kHz I²C</td>
</tr>
<tr>
<td>P89LPC932</td>
<td>400 kHz I²C</td>
</tr>
</tbody>
</table>
In December we've released a new P87C654X2 and with this family we also released our first microcontroller (P87C661) with two separate byte oriented I²C interfaces.

The two I²C blocks are useful for applications:

- Which need to support different transmission rates (e.g. 400 kHz and 100 kHz)
- With high amount of I²C devices that physically can't be addressed all on one bus due to address conflicts
- Require gateway/re-route capability
I²C Microcontroller - Bit Wise @ 100 kHz

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P87LPC760</td>
<td>8-bit 80C51 (6 Clk) with 1 KB OTP, 128B RAM, IRC, UART, etc – 14 pin</td>
</tr>
<tr>
<td>P87LPC761</td>
<td>8-bit 80C51 (6 Clk) with 2 KB OTP, 128B RAM, IRC, UART, etc – 16 pin</td>
</tr>
<tr>
<td>P87LPC762</td>
<td>8-bit 80C51 (6 Clk) with 2 KB OTP, 128B RAM, IRC, UART, etc – 20 pin</td>
</tr>
<tr>
<td>P87LPC764</td>
<td>8-bit 80C51 (6 Clk) with 4 KB OTP, 128B RAM, IRC, UART, etc – 20 pin</td>
</tr>
<tr>
<td>P87LPC767</td>
<td>8-bit 80C51 (6 Clk) with 4 KB OTP, 128B RAM, 8-bit ADC, IRC, UART, etc – 20 pin</td>
</tr>
<tr>
<td>P87LPC768</td>
<td>8-bit 80C51 (6 Clk) with 4 KB OTP, 128B RAM, PWM, IRC, UART, etc – 20 pin</td>
</tr>
<tr>
<td>P87LPC769</td>
<td>8-bit 80C51 (6 Clk) with 4 KB OTP, 128B RAM, ADC/DAC, IRC, UART, etc – 20 pin</td>
</tr>
</tbody>
</table>
I²C Microcontroller - Byte Wise @ 100 kHz

P80C552  8-bit 80C51 ROMless with 256B RAM, 10-bit ADC, PWM, UART, etc – 68 pin
P80C554  8-bit 80C51 ROMless with 512B RAM, 10-bit ADC, PWM, UART, etc – 64 pin
P87C552  8-bit 80C51 with 8 KB OTP, 256B RAM, 10-bit ADC, PWM, UART, etc – 68 pin
P87C554  8-bit 80C51 with 16 KB OTP, 512B RAM, 10-bit ADC, PWM, UART, etc – 64/68 pin
P87C654X2 8-bit 80C51 (6 Clk) with 16 KB OTP, 256B RAM, UART, etc – 44 pin
P80C557E4 8-bit 80C51 ROMless with 1KB RAM, 10-bit ADC, UART, low EMI, etc – 80 pin
P87C557E8 8-bit 80C51 with 64 KB OTP, 2 KB RAM, 10-bit ADC, UART, low EMI etc – 80 pin
P87C591  8-bit 80C51 with 16 KB OTP, 512B RAM, 10-bit ADC, CAN2.0B, UART, etc – 44 pin
P89C660  8-bit 80C51 (6 Clk) with 16 KB Flash, 512B RAM, PCA, PWM, UART, etc – 44 pin
P89C662  8-bit 80C51 (6 Clk) with 32 KB Flash, 1 KB RAM, PCA, PWM, UART, etc – 44 pin
P89C664  8-bit 80C51 (6 Clk) with 64 KB Flash, 2 KB RAM, PCA, PWM, UART, etc – 44 pin
P89C668  8-bit 80C51 (6 Clk) with 64 KB Flash, 8 KB RAM, PCA, PWM, UART, etc – 44 pin
P89C669  8-bit 80C51 (6 Clk) with 96 KB Flash, 3 KB RAM, PCA, PWM, 2 UARTs, etc – 44 pin
I²C Microcontroller - Byte Wise @ 400 kHz

LPC2104  16/32-bit ARM7 with 128 KB Flash, 16 KB RAM, 2 UART, RTC, SPI, etc – 48 pin
LPC2105  16/32-bit ARM7 with 128 KB Flash, 32 KB RAM, 2 UART, RTC, SPI, etc – 48 pin
LPC2106  16/32-bit ARM7 with 128 KB Flash, 64 KB RAM, 2 UART, RTC, SPI, etc – 48 pin
LPC2114  16/32-bit ARM7 with 128 KB Flash, 16 KB RAM, 10b ADC, UARTs, SPIs, etc – 64 pin
LPC2124  16/32-bit ARM7 with 256 KB Flash, 16 KB RAM, 10b ADC, UARTs, SPIs, etc – 64 pin
P89LPC920 8-bit 80C51 (2 Clk) with 2 KB Flash, 256 B RAM, IRC, UART, RTC, etc – 20 pin
P89LPC921 8-bit 80C51 (2 Clk) with 4 KB Flash, 256 B RAM, IRC, UART, RTC, etc – 20 pin
P89LPC922 8-bit 80C51 (2 Clk) with 8 KB Flash, 256 B RAM, IRC, UART, RTC, etc – 20 pin
P89LPC930 8-bit 80C51 (2 Clk) with 4 KB Flash, 256 B RAM, IRC, UART, RTC, etc – 28 pin
P89LPC931 8-bit 80C51 (2 Clk) with 8 KB Flash, 256 B RAM, IRC, UART, RTC, etc – 28 pin
P89LPC932 8-bit 80C51 (2 Clk) with 8 KB Flash, 256 B RAM, 512 B EE, IRC, CCU, etc – 28 pin
PXAS30   16-bit ROMless with 1 KB RAM, 2 UARTs, PCA, PWM, 8-bit ADC, etc – 68/80 pin
PXAS37   16-bit with 32K OTP, 1 KB RAM, 2 UARTs, PCA, PWM, 8-bit ADC, etc – 68/80 pin
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
I²C Bus Basics - Typical Bus Arrangement

- Microprocessor
  - Reset
  - Interrupt
- 100 kHz and 400 kHz
- EEPROM
- 3.3 V
- LED Blinker
- GPIO
  - GPIO
  - Keyboard
- C++
I²C Bus Basics - Complex Bus Arrangement

- **Microprocessor**
  - Inputs: Hardware
  - Outputs: Interrupt
  - Reset
  - 100 kHz and 400 kHz

- **EEPROM Multiplexer**

- **Voltage Regulator Module**

- **Bus Controller**

- **Repeater**

- **EEPROM**

- **Switch**
  - 5 V
  - 3.3 V
  - 2.5 V
  - 1.8 V

- **LED Blinker**

- **GPIO**

- **Temp Sensor**

- **Keyboard**

- **C++**

- **5 V**
Slot or Gaming Machine Setup

Processor

or

PCA8584
PCA9564

Distribution Hub

-12 V +

4-wire USB cable
SCL & 12 V on one wire pair and SDA & GND on the other wire pair

P82B96
12 V to 5V Reg
LED Blinker
LEDs

P82B96
I/O Expander
Motor Controller

P82B96
12 V to 5V Reg
LCD Display Driver
LCD Display

Semiconductors
Changing I²C bus signals for multi-point applications!

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

NO LIMIT to the number of connected bus devices!

Connect servers together
Intelligent Platform Management Interface

• IPMI is **new Intel initiative** in conjunction with hp, NEC and Dell
• 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
  – 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
Intelligent Platform Management Bus

- Standardized bus and protocol for extending management control, monitoring, and event delivery **within** the chassis:
  - I²C based
  - Multi-master
  - Simple Request/Response Protocol
  - Uses IPMI Command sets
  - Supports non-IPMI devices
- Physically I²C but write only (master capable devices), hot swap not required.
- Enables the Baseboard Management Controller (BMC) to accept IPMI request messages from other management controllers in the system.
- Allows non-intelligent devices as well as management controllers on the bus.
- BMC serves as a controller to give system software access to IPMB
IPMI Details

• Defines a standardized interface to intelligent platform management hardware
  – Prediction and early monitoring of hardware failures
  – Diagnosis of hardware problems
  – Automatic recovery and restoration measures after failure
  – Permanent availability management
  – Facilitate management and recovery
  – Autonomous Management Functions: Monitoring, Event Logging, Platform Inventory, Remote Recovery
  – Implemented using Autonomous Management Hardware: designed for Microcontrollers based implementations

• Hardware implementation is isolated from software implementation
• New sensors and events can then be added without any software changes
Overall IPMI Architecture

CompactPCI, AdvancedTCA and VME use IPMI

<table>
<thead>
<tr>
<th>Known as</th>
<th>Specification</th>
<th>Based on</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>cPCI</td>
<td>PICMG 2.0</td>
<td>NA</td>
<td>No IPMB</td>
</tr>
<tr>
<td>cPCI</td>
<td>PICMG 2.9</td>
<td>IPMI 1.5</td>
<td>Single hot swap IPMB optional</td>
</tr>
<tr>
<td>AdvancedTCA</td>
<td>PICMG 3.x</td>
<td>IPMI 1.5</td>
<td>Dual redundant hot swap IPMB mandatory</td>
</tr>
</tbody>
</table>

• 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
• Backplanes lead AdvancedTCA push – excellent article > http://newsletter.planetanalog.com/cgi-bin4/flo/y/eLZD0CePey0tJ0BwCW0Ay
• Page 32 of AN10216 I²C Manual for additional information

These systems will use the PCA9511/12/13/14/15/16/18 or P82B715/96 to help buffer capacitance and provide hot swap protection.
Agenda

• What is I²C and why would you be interested in using the I²C bus?

• What new I²C devices are there and what are the typical applications?

• How are we going to help you design-in these devices?
I2C 2002-1A 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

Provide easy to use, PC based system to play with the I²C devices and learn how they operate.
PCA9551 LED Blinkers Win-I2CNT Interface Screen

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

Select blinking options

Register information

Select LEDs mode

Device address CC for PCA9551

Write and Read Registers

Semiconductors
I²C Product Flyers and Selection Guides

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

Provide overview of all the devices to make selection easier.

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

Semiconductors
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 I²C Bus Controller ** (July)
AN10149 PCA9564 Evaluation Board ** (Sep)
AN10160 I²C Hot Swap Bus Buffers (preliminary)
AN10216 I²C Manual

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
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