ECEN 5023-001, -001B, -740

Mobile Computing & IoT Security

Lecture #9

14 February 2017

Agenda

- Class Announcements
- Reading Assignment
- Quiz #5 Assigned
- Quiz 4 review
- ESD diodes
- Load Power Management
- Bluetooth

Class Announcements

- Quiz #5 is due at 11:59pm on February 19th, 2017 at 11:59pm
- Reducing ADC Energy with DMA is due on Wednesday, February 15th, 2017 at 11:59pm

Reading List

Below is a list of required reading for this course. Questions from these readings plus the lectures from January 17th, 2017 onward will be on the weekly quiz.

1. Texas Instruments application note SWRY007 – Three flavors of Bluetooth: Which one to choose?
   http://www.ti.com/lit/wp/swry007/swry007.pdf
2. Adafruit Learning System: Introdution to Bluetooth Low Energy
   https://learn.adafruit.com/downloads/pdf/introduction-to-bluetooth-low-energy.pdf
3. Bluetooth in Wireless Communications
   http://www.cs.nccu.edu.tw/~ttsai/mobilecomm_ttsai/papers/0090sair.pdf
4. TI application note SWRA349 - Coin cells and peak current draw
   http://www.ti.com/lit/wp/swra349/swra349.pdf
5. Silicon Labs' Leopard Gecko Reference Manual – I2C section
   http://www.silabs.com/Support%20Documents/TechnicalDocs/EFM32LG-RM.pdf

Recommended reading:

Silicon Labs' I2C application note - AN0011
http://www.silabs.com/Support%20Documents/TechnicalDocs/AN0011.pdf

Quiz #5 assigned

- Quiz #5 is due at 11:59pm on Sunday, February 19th, 2017
- Questions from the required readings plus the lectures from January 17th, 2017 onward will be on the weekly quiz.

Quiz Review

A magnetometer alone cannot provide an accurate compass heading for which reason(s)? (select all that apply)

- [ ] Magnetometer requires calibration to determine its own offset
- [ ] Magnetic field measurements varies significantly with its angle or tilt to the earth.
- [ ] Magnetometers are affected by the acceleration of the device
- [ ] Magnetometer requires calibration from hard-iron effects.

Quiz Review

If the magnetometer is inverted, what orientation will the y-axis be at its maximum?

- South
- West
- East
- North

Quiz 4 review

All accelerometers are not affected by rotations about the horizontal axis.

- ○ True
- ○ False

Quiz 4 review

How strong will a magnetic field be at 30mm away from a current carrying conductor if the magnetic field is 3 uT at 10mm away?

- 1.5 uT
- 1 uT
- 0.75 uT
- 0.33 uT

Quiz 4 review

What are the required PCB placement and layout considerations while designing with a magnetometer? (select all that apply)

- [ ] Magnetometer aligned with their X, Y, and Z sensing directions.
- [ ] Far enough away from current carrying wires so that their induced magnetic fields are below the design target error budget.
- [ ] Mounted away from ferromagnetic materials that will produce a constant additive magnetic field known as the "hard iron field."
- [ ] Examples of ferromagnetic materials to not be placed near are copper, aluminum, and brass.

Quiz 4 review

If the relative humidity was measured at 70% at 25C, what would be the approximate relative humidity at 24C?

- ○ 75%
- ○ 73.5%
- ○ 70%
- ○ 65%
- ○ 66.5%

Quiz 4 review

For Silicon Labs' temperature and humidity sensors, prolonged exposure to high humidity can cause a gradual drift to the humidity sensor readings. How can this shift due to prolong exposure to humidity be reversed?

- ◯ Turn off the humidity sensor for 48 hours to enable the part to reset
- ◯ Turn on the integrated heater to increase the die temperature by 5C to evaporate excess moisture.
- ◯ Us the integrated heater to heat the die to over 100C for 24 hours

Quiz 4 review

Best practices in ESD protection of the Silicon Labs' humidity and temperature sensors. (select all that apply)

- [ ] Environmental access port ground shield
- [ ] Unused leads should be connected to GND
- [ ] Unused leads should be connected to VDD
- [ ] Placement of the sensor so that high-level ESD events go to an exposed ground trace

Quiz 4 review

Silicon Labs humidity and temperature sensors have unique applications and use requirements that are not common to other conventional (non-sensor) IC solutions. Select all that apply.

- [ ] Prevent contamination of the sensor through-out its product life cycle
- [ ] Humidity sensor "memory"
- [ ] Access to the ambient air
- [ ] The need to protect the sensor during board assembly

Quiz 4 review

Position-based gesture sensing is based on timing of the changes in signals to determine the direction of an object's motion.

- ◯ True
- ◯ False

Quiz 4 review

In an infrared based gesturing system using multiple LEDs, the general guideline is to insure there is no "dead spot." Where is this "dead spot" most likely to occur?

- ◯ Over the LEDs
- ◯ In the middle between the detector and the LED
- ◯ Over the middle of the detectable area

Quiz 4 review

In an Infrared Phase-based gesturing system, if diode 1 is to the left of the sensor, diode 2 is to the right of the sensor, and diode 3 is below the system, what direction is the hand gesturing if the rising in feedback comes in the following order; D1 and D2, then D3?

- Right to Left
- Top to Bottom
- Bottom to Top
- Left to Right

Quiz 4 review

After enabling the ADC in the Leopard Gecko, what energy mode enumeration (EM0, EM1, EM2, EM3, or EM4) would be used to set the BlockSleepMode() routine?

Quiz 4 review

After enabling the ACMP in the Leopard Gecko, what energy mode enumeration (EM0, EM1, EM2, EM3, or EM4) would be used to set the BlockSleepMode() routine?

Quiz 4 review

Using the Leopard Gecko data sheet and reference manual, what would be the lowest sleep mode that the Leopard Gecko could enter after enabling the DMA and a successful BlockSleepMode() call from the DMA setup routine?

(Use the enumerations EM0, EM1, EM2, EM3, or EM4)

Quiz 4 review

Using the Leopard Gecko data sheet and reference manual, what would be the lowest sleep mode that the Leopard Gecko could enter after enabling the ADC and a successful BlockSleepMode() call from the ADC setup routine?

(Use the enumerations EM0, EM1, EM2, EM3, or EM4)

Quiz 4 review

Using the Simplicity Energy Profiler, it was measured that the ADC and DMA operation took 44mS. If the ADC is set up to perform 12,500 conversion per second, how many conversions did the ADC perform during the measured 44mS?

Quiz 4 review

Using the Simplicity Energy Profiler, it was measured that the ADC and DMA operation took 18mS. If the ADC is set up to perform 18,000 conversion per second, how many conversions did the ADC perform during the measured 18mS?

Quiz 4 review

Using the Simplicity Energy Profiler, it was measured that the ADC and DMA operation took 22mS. If the ADC is set up to performed 308 conversions during these 22mS, at what conversion rate is the ADC operating? (Just include the number below)

Quiz 4 review

Using the Simplicity Energy Profiler, it was measured that the ADC and DMA operation took 36mS. If the ADC is set up to performed 540 conversions during these 36mS, at what conversion rate is the ADC operating? (Just include the number below)

Quiz 4 review

You need to set up the Leopard Gecko's Acquisition time and prescaler of its ADC that requires a minimum of 4uS of acquisition time for the following ADC measurement requirements:

Samples per second: 20,000

Resolution: 12-bits

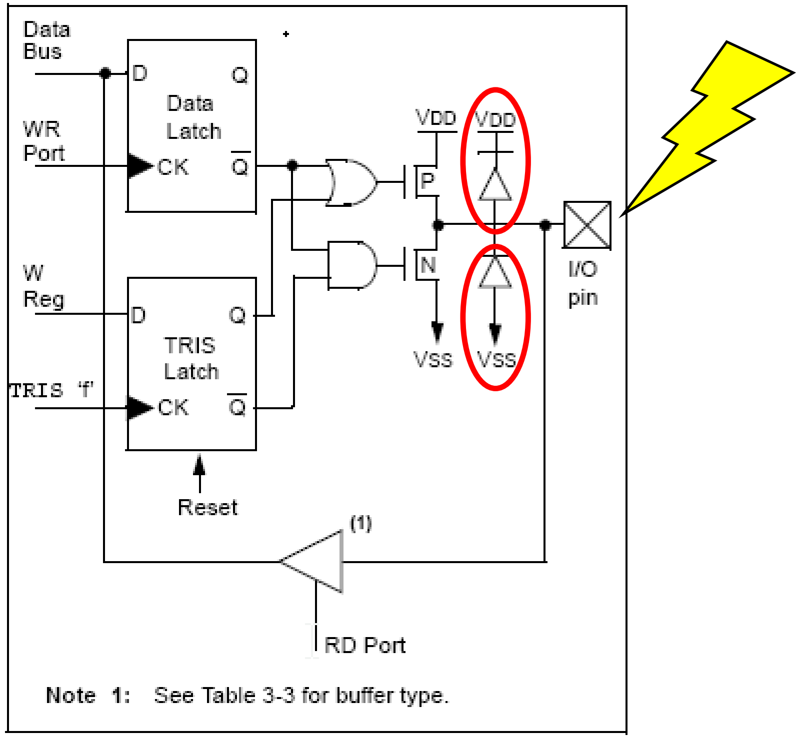
HFCLK: 14 MHz

What should the ADC prescaler be set to to enable the above sampling requirements? (Answer needs to be a number)

How many ADC clock cycles should the ADC Acquisition time be set to?

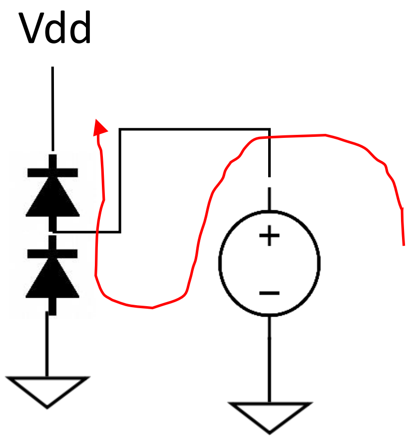
Why an ESD diode to protect the I/O pin?

FIGURE 5-1: PIC12F508/509/16F505 EQUIVALENT CIRCUIT FOR A SINGLE I/O PIN



Normal Operation

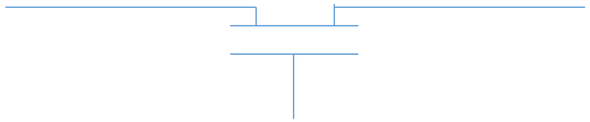
- Vdd = 3.3v and Vss = 0.0v
- An Electro Static Discharge event occurs



- The ESD event is much greater voltage than Vdd
- Current will flow from the ESD event through the top ESD diode
- This diode clamps the voltage to the IC at Vcc + Vdiode
- Protecting the IC

Sensor – How to get around the standby current of active sensors?

- Use the microcontroller to turn on and off the power to the active sensor
  - Put the active sensor on its own power plane
    - Use a FET controlled by the microcontroller to provide power to the active sensor power plane
    - Device power source



Sensor Vcc power plane or pin

Ucntlr GPIO pin

Sensor – How to get around the standby current of active sensors?

- Use the microcontroller to turn on and off the power to the active sensor
  - Use a GPIO pin to drive the active sensor VCC power plane or pin
  - Selectable output drives
  - Will need to determine the following?
    - Capacitance to maintain the proper voltage on the active sensor on the Vcc power plane/pin
    - How long it takes for the active sensor Vcc pin to stabilize?
    - Active sensor power up reset time
    - Proper set up of the I/O pins on the microcontroller and active sensor while the active sensor is not powered

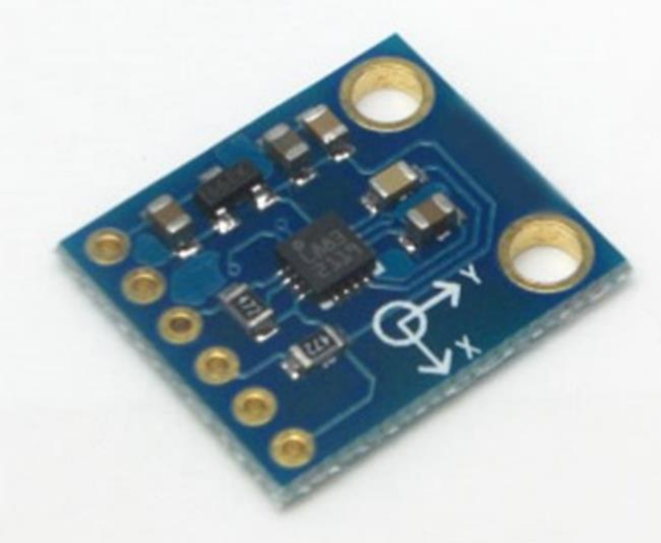
enum GPIO_DriveMode_TypeDef

GPIO drive mode.

Enumerator	
gpioDriveModeStandard	Default 6mA
gpioDriveModeLowest	0.5 mA
gpioDriveModeHigh	20 mA
gpioDriveModeLow	2 mA

Sensor examples

- 3-axis Magnetometer
  - GY-271 HMC5883L Triple Axis Compass Magnetometer Sensor Module



FEATURES	BENEFITS
3-Axis Magnetoresistive Sensors and ASIC in a 3.0x3.0x0.9mm LCC Surface Mount Package	Small Size for Highly Integrated Products. Just Add a Micro-Controller Interface, Plus Two External SMT Capacitors Designed for High Volume, Cost Sensitive OEM Designs Easy to Assemble & Compatible with High Speed SMT Assembly
12-Bit ADC Coupled with Low Noise AMR Sensors Achieves 2 milli-gauss Field Resolution in ±8 Gauss Fields	Enables 1° to 2° Degree Compass Heading Accuracy
Built-In Self Test	Enables Low-Cost Functionality Test after Assembly in Production
Low Voltage Operations (2.16 to 3.6V) and Low Power Consumption (100 μA)	Compatible for Battery Powered Applications
Built-In Strap Drive Circuits	Set/Reset and Offset Strap Drivers for Degaussing, Self Test, and Offset Compensation
I²C Digital Interface	Popular Two-Wire Serial Data Interface for Consumer Electronics
Lead Free Package Construction	RoHS Compliance
Wide Magnetic Field Range (+/-8 Oe)	Sensors Can Be Used in Strong Magnetic Field Environments with a 1° to 2° Degree Compass Heading Accuracy
Software and Algorithm Support Available	Compassing Heading, Hard Iron, Soft Iron, and Auto Calibration Libraries Available
Fast 160 Hz Maximum Output Rate	Enables Pedestrian Navigation and LBS Applications

Picture from Amazon.com and data from Honeywell's HMC5883L data sheet

Sensor examples

- Barometric Pressure Temperature Sensor
  - BME280 Pressure Temperature Sensor Module with I2C

DIGITAL PRESSURE SENSOR

Key parameters

- Pressure range — 300 ... 1100 hPa (equiv. to +9000...-500 m above/below sea level)
- Package — 8-pin LGA metal-lid; Footprint : 2.0 × 2.5 mm², height: 0.95 mm
- Relative accuracy (950 ... 1050hPa @25°C) — ±0.12 hPa, equiv. to ±1 m
- Absolute accuracy (950 ...1050 hPa, 0 ...+40 °C) — typ. ±1 hPa
- Temperature coefficient offset (25 ... 40°C @900hPa) — 1.5 Pa/K, equiv. to 12.6 cm/K
- Digital interfaces — I²C (up to 3.4 MHz); SPI (3 and 4 wire, up to 10 MHz)
- Current consumption — 2.7µA @ 1 Hz sampling rate
- Temperature range — -40 ... +85 °C
- RoHS compliant, halogen-free
- MSL 1

Sensor supply voltage	V_{DD}	ripple max. 50mVpp	1.71	1.8	3.6	V
Interface supply voltage	V_{DDIO}		1.2	1.8	3.6	V

Picture from Amazon and Key parameters from Bosch BME280 data sheet

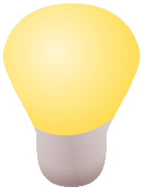
Sensor examples

- 3-axis accelerometer
  - SparkFun Triple Axis Accelerometer Breakout - MMA8452Q

MMA8452Q

Features

- 1.95V to 3.6V supply voltage
- 1.6V to 3.6V interface voltage
- ±2g/±4g/±8g dynamically selectable full-scale
- Output Data Rates (ODR) from 1.56 Hz to 800 Hz
- 99 µg/√Hz noise
- 12-bit and 8-bit digital output
- I²C digital output interface
- Two programmable interrupt pins for six interrupt sources
- Three embedded channels of motion detection
  - — Freefall or Motion Detection: 1 channel
  - — Pulse Detection: 1 channel
  - — Transient Detection: 1 channel
    - Orientation (Portrait/Landscape) detection with set hysteresis
    - Automatic ODR change for Auto-WAKE and return to SLEEP
    - High-Pass Filter Data available real-time
    - Self-Test
    - RoHS compliant
    - Current Consumption: 6 µA to 165 µA



- Separate power for I2C and digital logic
- Enabling ease or Load Power Management via GPIO pin

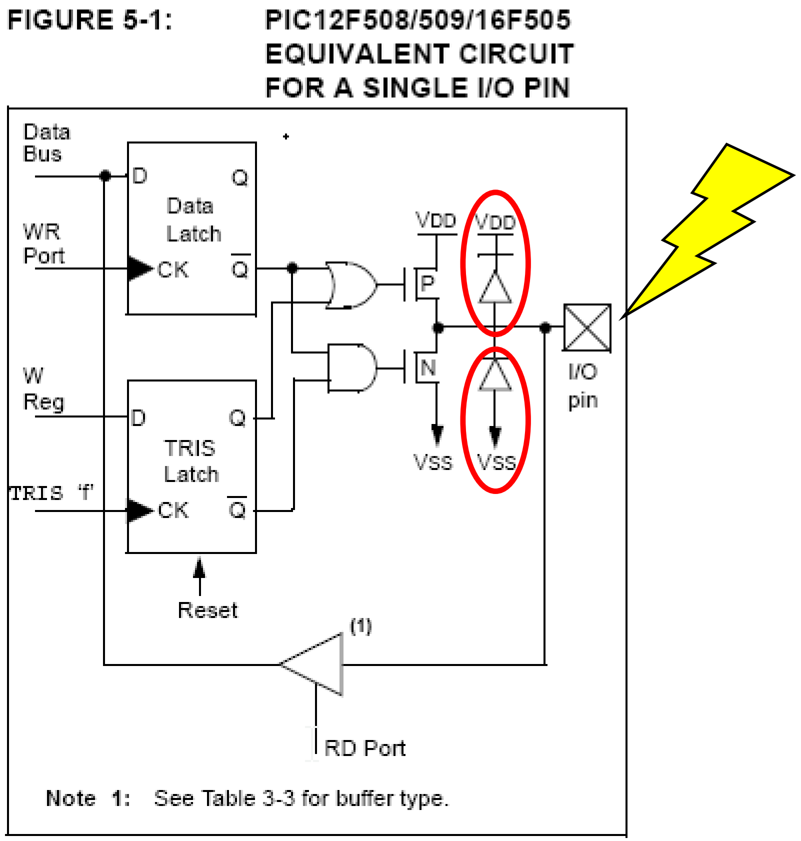
Photo from the Sparkfun.com and the MMA8452Q features from its NXP datasheet

Sensor examples

- Gesture sensor
  - Sparkfun proximity and Gesture Sensor

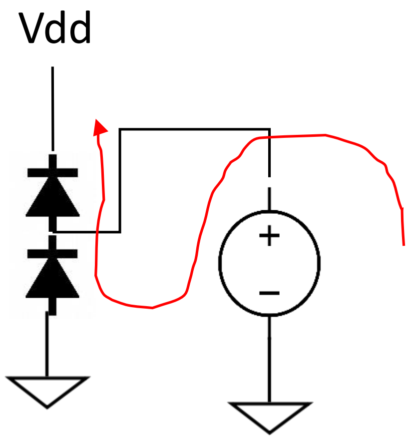
- Features
  - Operating Voltage: 2.4 – 3.6v
  - 10 – 790uA
  - Ambient Light and RGB Color Sensing
  - Proximity Sensing
  - • Complex Gesture Sensing
    - Four separate diodes sensitive to different directions
  - Interrupt driven I2C communications

Why an ESD diode to protect the I/O pin?



Normal Operation

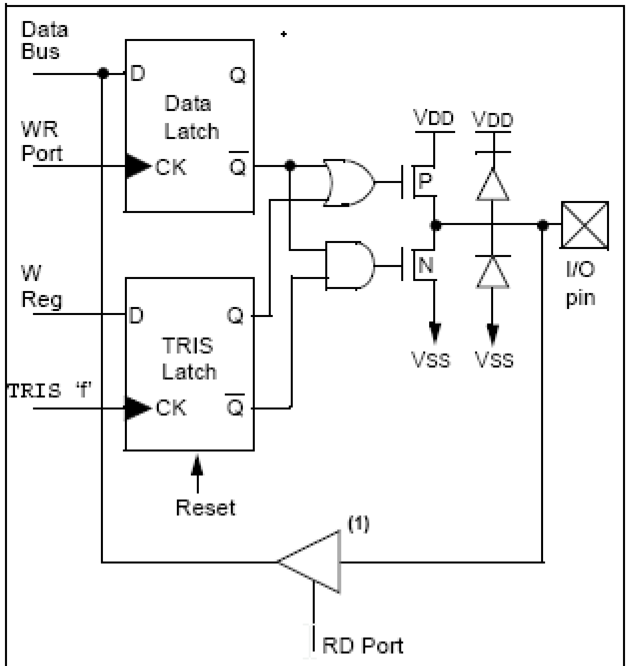
- Vdd = 3.3v and Vss = 0.0v
- An Electro Static Discharge event occurs



- The ESD event is much greater voltage than Vdd
- Current will flow from the ESD event through the top ESD diode
- This diode clamps the voltage to the IC at Vcc + Vdiode
- Protecting the IC

Modeling an IC that is connected to an I2C device

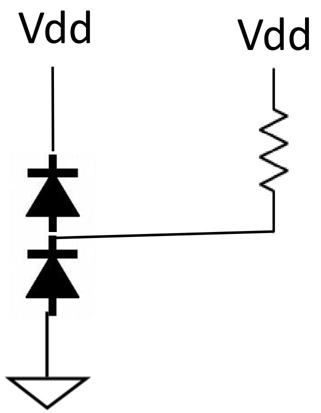
FIGURE 5-1: PIC12F508/509/16F505 EQUIVALENT CIRCUIT FOR A SINGLE I/O PIN



Note 1: See Table 3-3 for buffer type.

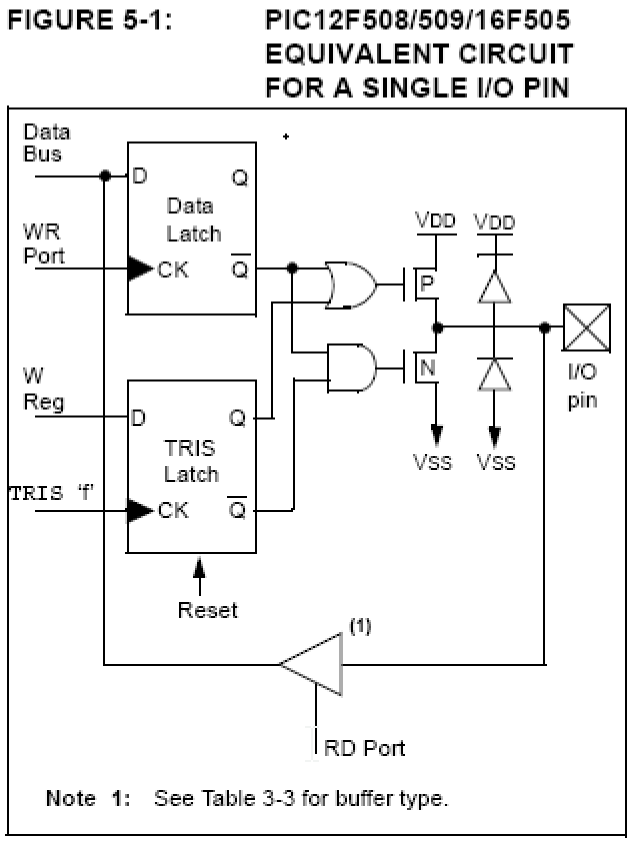
IC Vdd is turned on

- Vdd = 3.3v and Vss = 0.0v



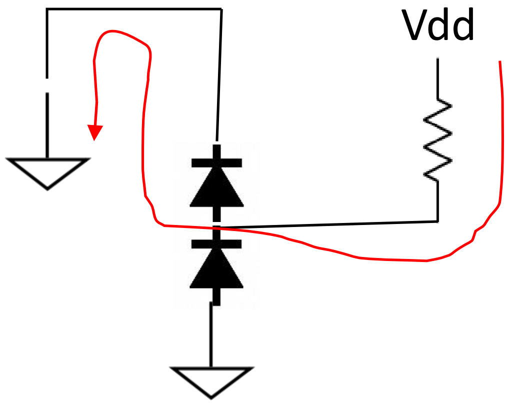
- If the I/O pin is not pulling the I/O low, the pull-up resistor will pull the I2C line high, to Vdd = 3.3v

What happens when just the IC's Vdd is turned off?



IC Vdd is turned off

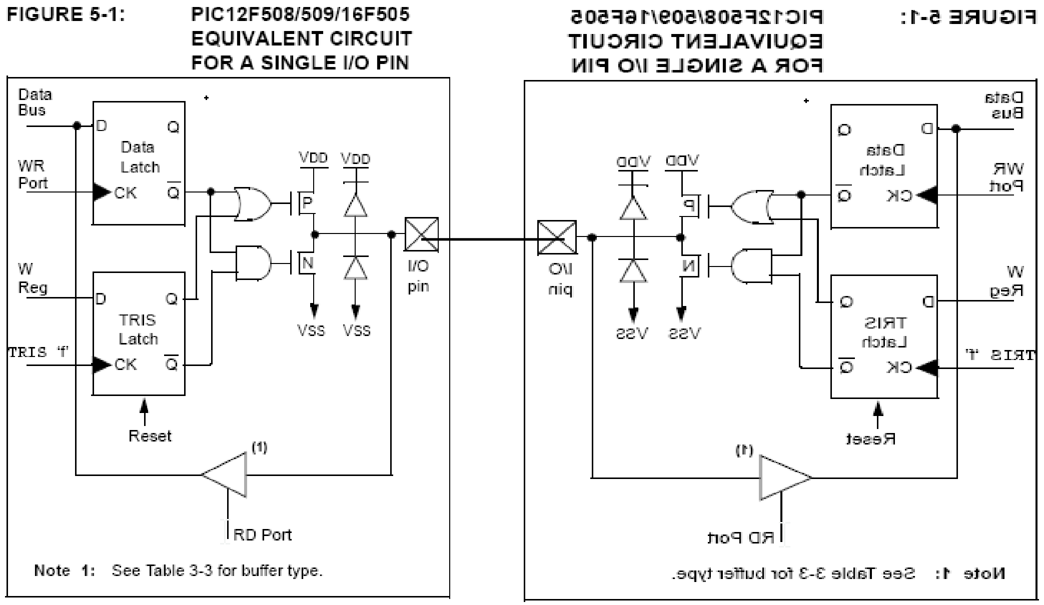
- Vdd = 0.0v and Vss = 0.0v

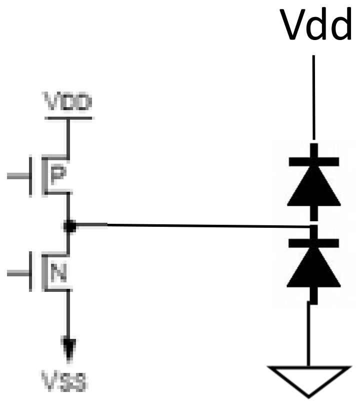


- When Vdd is 0.0v, the I2C signal is continuous pulled to ground through the upper ESD diode
- I2C voltage is now continuously equal to 0 + Vdiode
- I2C bus is now not operational
- And, each I2C line is pulling current equal to (Vdd – Vdiode) / Rpull-up
- This continuous current can damage the I/O pin

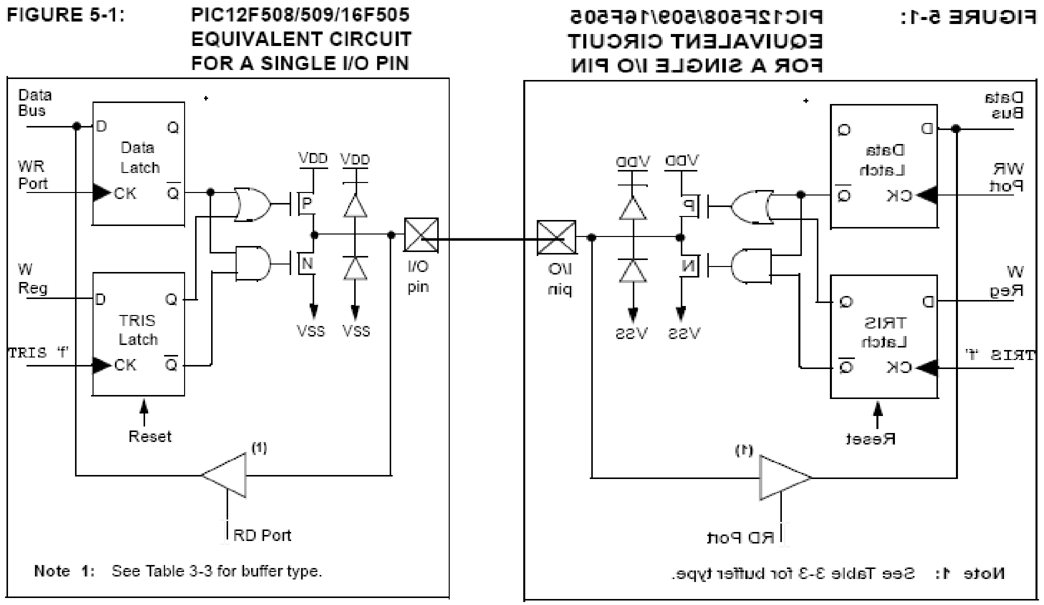
Modeling an IC with two standard I/Os

- Normal Operation
  - Left IC output: Vdd = 3.3v and Vss = 0.0v
  - Right IC input: Vdd = 3.3v and Vss = 0.0v
  - Output can drive 6mA



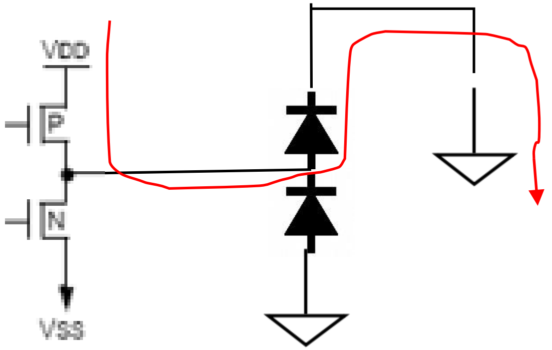


Modeling an IC when 1 IC is turned off



1 IC is turned off

- Left IC output: Vdd = 3.3v and Vss = 0.0v
- Right IC input: Vdd = 0.0v and Vss = 0.0v
- Output can drive 6mA



- When left IC wants to drive the output high, the left IC Vdd drives current through its P-channel FET and the right input pin Vdd ESD diode
- Instead of a high output, the output goes to 0v + Vdiode
- The current through the diode could equal the drive strength of the output, 6mA
- Possibly damaging the IC

Load Power Management

- What is it?
  - Turning off a peripheral when not needed to save energy
  - Common technique used in notebooks, computers, embedded systems, and battery powered products
  - You are already doing it!!!!
    - By not turn on peripherals that are not in use
    - And, by disabling the ACMP0 when not required
    - And, by disabling the ADC0 when not in use

Load Power Management

- Now, lets take a look at load power management of a non-MCU peripheral
- Basic steps include the following:
  - Enable power to the device
    - Via GPIO control instead of CMU_ClockEnable()
    - It will take some time for the GPIO power pin to stabilize
  - Wait for external device to complete its Power On Reset (POR)
  - Initialize the device
  - Enable Interrupts if will be used

Sensor examples

- 3-axis accelerometer
  - SparkFun Triple Axis Accelerometer Breakout - MMA8452Q

MMA8452Q

Features

- 1.95V to 3.6V supply voltage
- 1.6V to 3.6V interface voltage
- ±2g/±4g/±8g dynamically selectable full-scale
- Output Data Rates (ODR) from 1.56 Hz to 800 Hz
- 99 µg/√Hz noise
- 12-bit and 8-bit digital output
- I^2C digital output interface
- Two programmable interrupt pins for six interrupt sources
- Three embedded channels of motion detection
  - Freefall or Motion Detection: 1 channel
  - Pulse Detection: 1 channel
  - Transient Detection: 1 channel
    - Orientation (Portrait/Landscape) detection with set hysteresis
    - Automatic ODR change for Auto-WAKE and return to SLEEP
    - High-Pass Filter Data available real-time
    - Self-Test
    - RoHS compliant
    - Current Consumption: 6 µA to 165 µA

- Separate power for I2C and digital logic
- Enabling ease or Load Power Management via GPIO pin

Load Power Management via GPIO pin

- For the MMA8452Q, any of the gpio Drive Mode settings should be sufficient
  - To insure that the Vdd to the external IC can support the transients required by the IC, the GPIO Power pin should be decoupled at the IC
  - The power setting of the gpio power pin should be set high enough to drive the capacitive load in a reasonable time to power up the IC in the time required for the application

enum GPIO_DriveMode_TypeDef

GPIO drive mode.

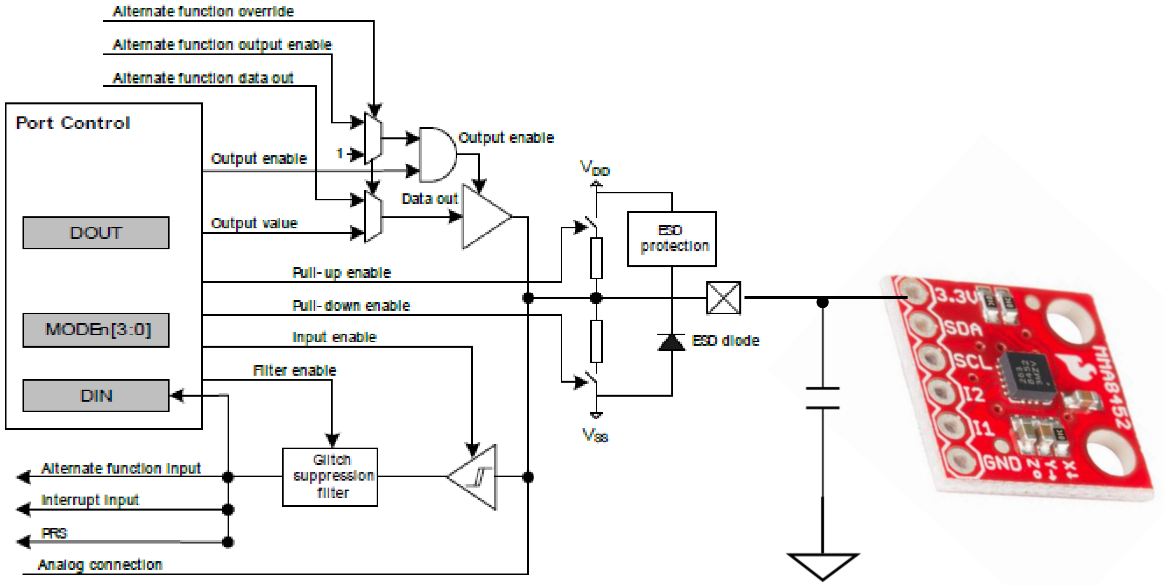
Enumerator	
gpioDriveModeStandard	Default 6mA
gpioDriveModeLowest	0.5 mA
gpioDriveModeHigh	20 mA
gpioDriveModeLow	2 mA

Definition at line **281** of file **em_gpio.h**.

Load Power Management via GPIO pin

- Setting up LPM via GPIO pin
  1. Connect GPIO pin from output pin to Vdd of external peripheral
  2. Add appropriate decoupling capacitors
     a. Refer to the external peripheral IC recommended decoupling capacitors
  3. Configure the GPIO output to be a Push-Pull output
     a. Set the default output setting to 0, turned off

Figure 32.1. Pin Configuration



Load Power Management via GPIO pin

- The MMA8452Q has two power connections
  - One to the VDD, digital logic
  - The second, to VDDIO
  - This enables the digital logic to be powered off with out causing issues with the ESD diodes on the I2C bus
  - Total capacitance on the VDD line is 4.7uF

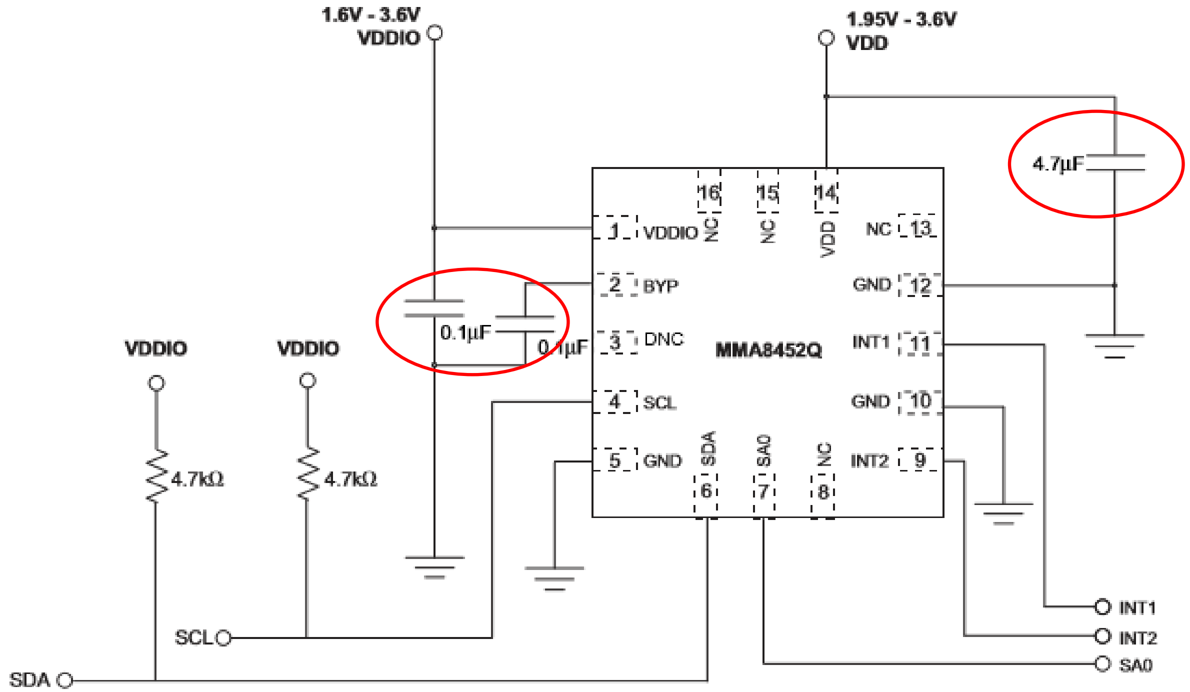
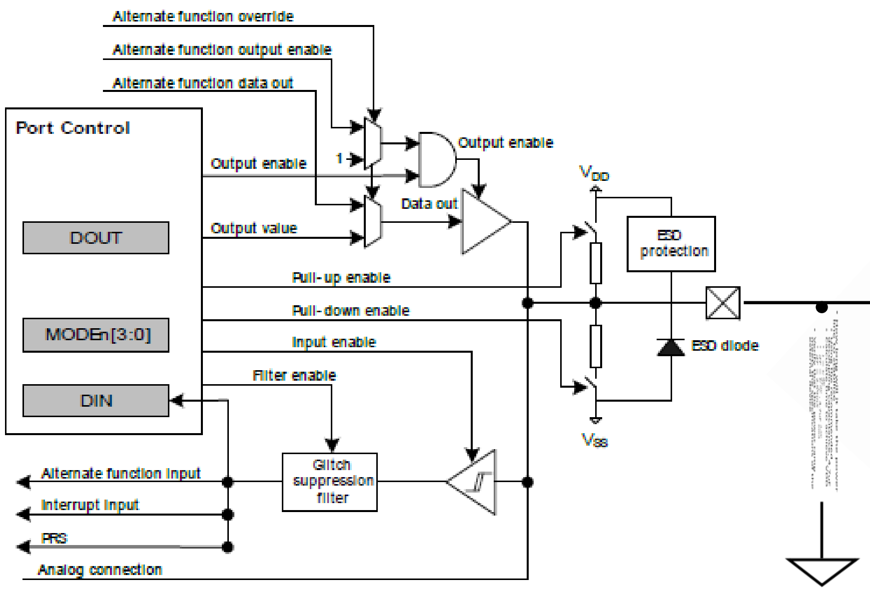


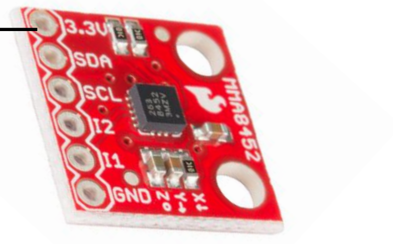
Figure 4. Application diagram

Load Power Management via GPIO pin

- How long will it take the power line to stabilize
  - Using the recommended decoupling capacitance, 4.7uF
  - Calculate time to achieve VDD
    - $i = C\frac{dV}{dT}$
    - $dT = C\frac{dV}{i}$, 4.7uF $\frac{3.3V}{6mA}$
    - $dT = 2.59mS$
  - Verify that the power ramp meets the specifications of the external device

Figure 32.1. Pin Configuration





Power on ramp time	—		0.001		1000	ms

Verified

Load Power Management via GPIO pin

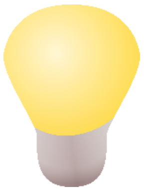
- Enabling the external device pseudo code
  - Turn power onto the external device
    - Set GPIO pin to 1
  - Wait for power to stabilize + external boot time
    - For the MMA8452Q
      - 2.59mS + 500uS
      - 3.09mS

Boot time	Time from VDDIO on and VDD > VDD min until I^2C is ready for operation, Cbyp = 100 nF	Tbt	—	350	500	µs

  - Enable GPIO pins on MCU after peripheral to protect ESD diodes
  - Initialize the device for operation
  - Enable Interrupts if required
  - Device is ready to be used!

Load Power Management via GPIO pin

- Disabling the external device pseudo code
  - Disable Interrupts if used
  - Disable GPIO I/O pins to protect ESD diodes
  - Turn off power to the GPIO pin by clearing the pin
    - Do not disable, but clear the pin to 0
  - Device is now deactivated and you are saving energy!



Bluetooth Classic

- Perceived User Scenarios
  - Connection to peripheral devices
    - Wireless means no cables, and most likely battery operated
    - Low power wireless a must
  - Ad-hoc Networking
  - Bridging of Networks
    - Bluetooth has targeted lower cost, lower bandwidth applications
    - WiFi/WLAN designed for higher bandwidth, longer range, and larger devices

Bluetooth Classic – Technology Summary

- Globally free spectrum
  - 2.45 GHz, ISM band
  - GFSK modulation
  - Frequency Hopping (1600 hops/sec)
- Range
  - 10m piconet (0dBm)
  - 100m optional (+20dBm)
- Data and voice capable (1Mbps)
  - Full duplex: 478kbps, Asymmetric 721kbps
- Secure
  - Authentication
  - 128 Encryption
  - Limited Signal range 0 – dBm
  - Pseudo Random hop sequence

IBM Bluetooth Wireless Technology presentation @ 2003
http://www.ncsysadmin.org/meetings/0506/slides.pdf

Bluetooth Classic - What does Bluetooth provide?

- Provides point-to-point connections.
- Provides ad-hoc networking capabilities.
- Bluetooth specification details how the technology works.
- Bluetooth Profiles detail how specific applications work to ensure interoperability.

IBM Bluetooth Wireless Technology presentation @ 2003
http://www.ncsysadmin.org/meetings/0506/slides.pdf

Bluetooth Classic - Master /Slave Bluetooth Network Topology

- 1 master and up to 7 slaves
- Basic network structure – Star Network

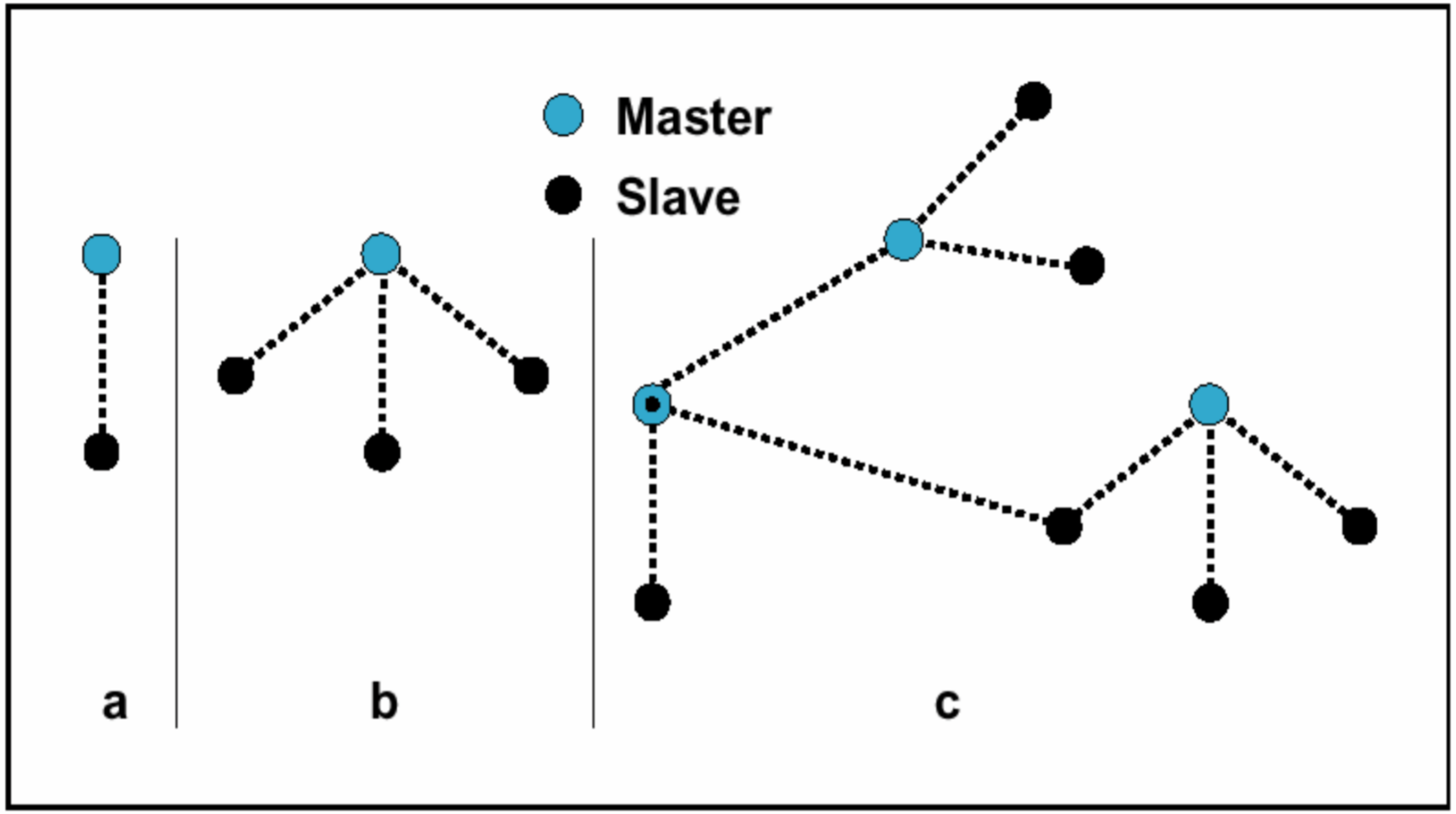
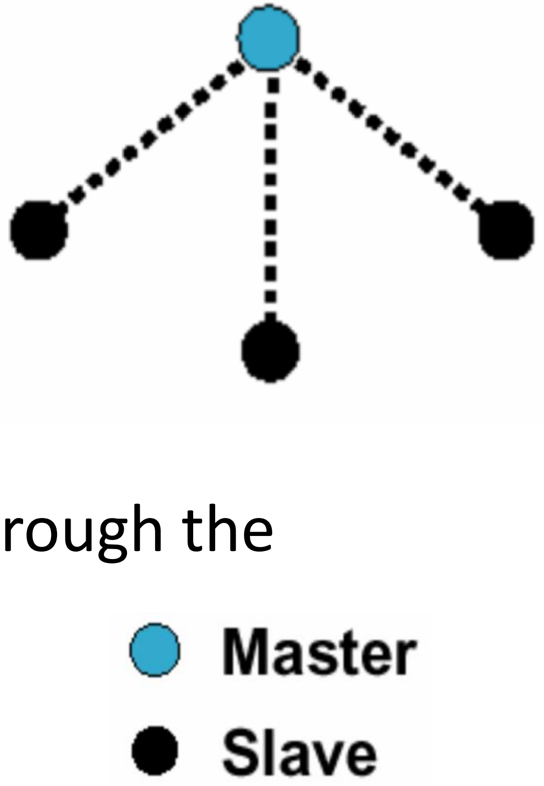


Figure 1.2: Piconets with a single slave operation (a), a multi-slave operation (b) and a scatternet operation (c).

Bluetooth Classic – Point-to-Point (Piconet)

- Two devices locate each other
- Form a connection and transfer data
- “Wireless cable replacement” scenario
- The device that initiates the connection is called the Master
- Any other devices the Master is connected to are referred to as Slaves.

Bluetooth Classic – Point-to-Multi-Point (The Piconet)



- Two devices create a point-to-point connection
- A third device comes into range
- The new device is discovered
- It is added to the piconet and data can be transferred
- Up to seven slaves can be connected to one master
- Slaves cannot pass data to other slaves without sending through the master
- The master defines the timing for the piconet
  - Each Piconet has a unique hopping pattern
- Piconets can collide if their unique hopping sequences overlap in a frequency band
  - Due to Ad-Hoc networking and not an infrastructure network!

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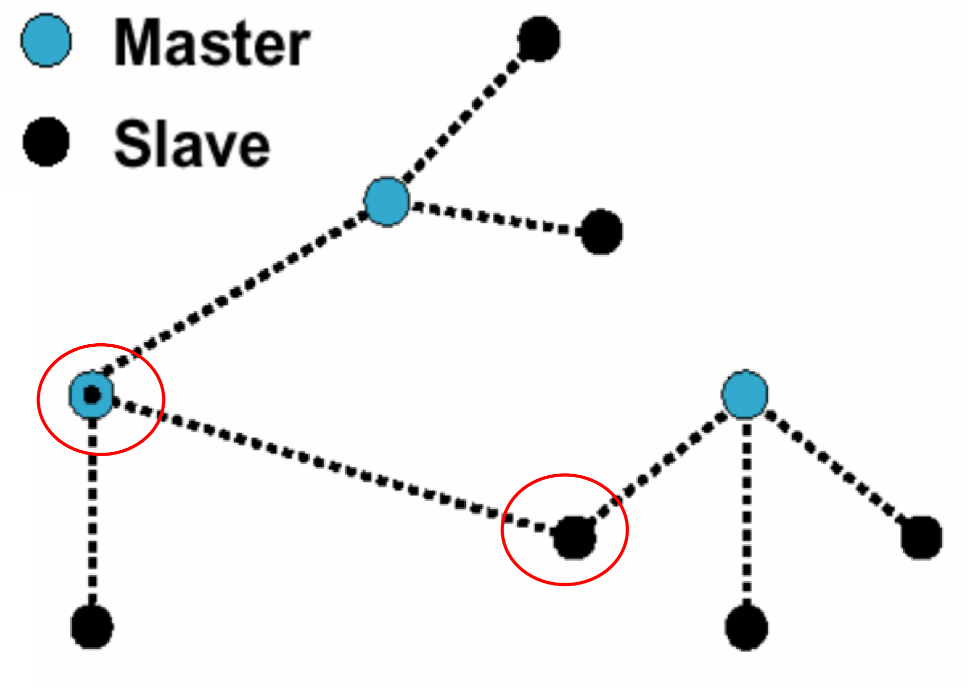
Bluetooth Classic - Piconet-to-Piconet: The Scatternet

- Scatternets allow devices to be active in numerous piconets
- The device can be a slave in one piconet and a master in another. It cannot be a master in two piconets which would result in two Piconets with the same frequency hopping sequence.
- The device can act as a gateway from one piconet to another.
- Before a slave leaves to participate in another Piconet, the slave must inform the current master that it will be unavailable for a period of time.
- As soon as a master leaves a Piconet to participate in another Piconet, all traffic within the original Piconet is suspended until the master returns.



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