PRIMER: Functional Specification

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Statement of Work

Is this a feature?

- Computer
- Reset
- Assembly
- Data Transmission
- Power Supply

Generally features are unique capabilities that can be validated

Intro to Functional Spec

- The functional specification mostly states **what** the proposed system is to do, and not so much **how** it's to be done or designed.
  - However in writing it, some consideration of design issues must take place, to ensure a realistic system is specified.
  - Successful engineering teams overlap the phases in the development process without getting too far ahead.   This is an incredibly important skill.

Do not underestimate the importance of research and early experimentation!

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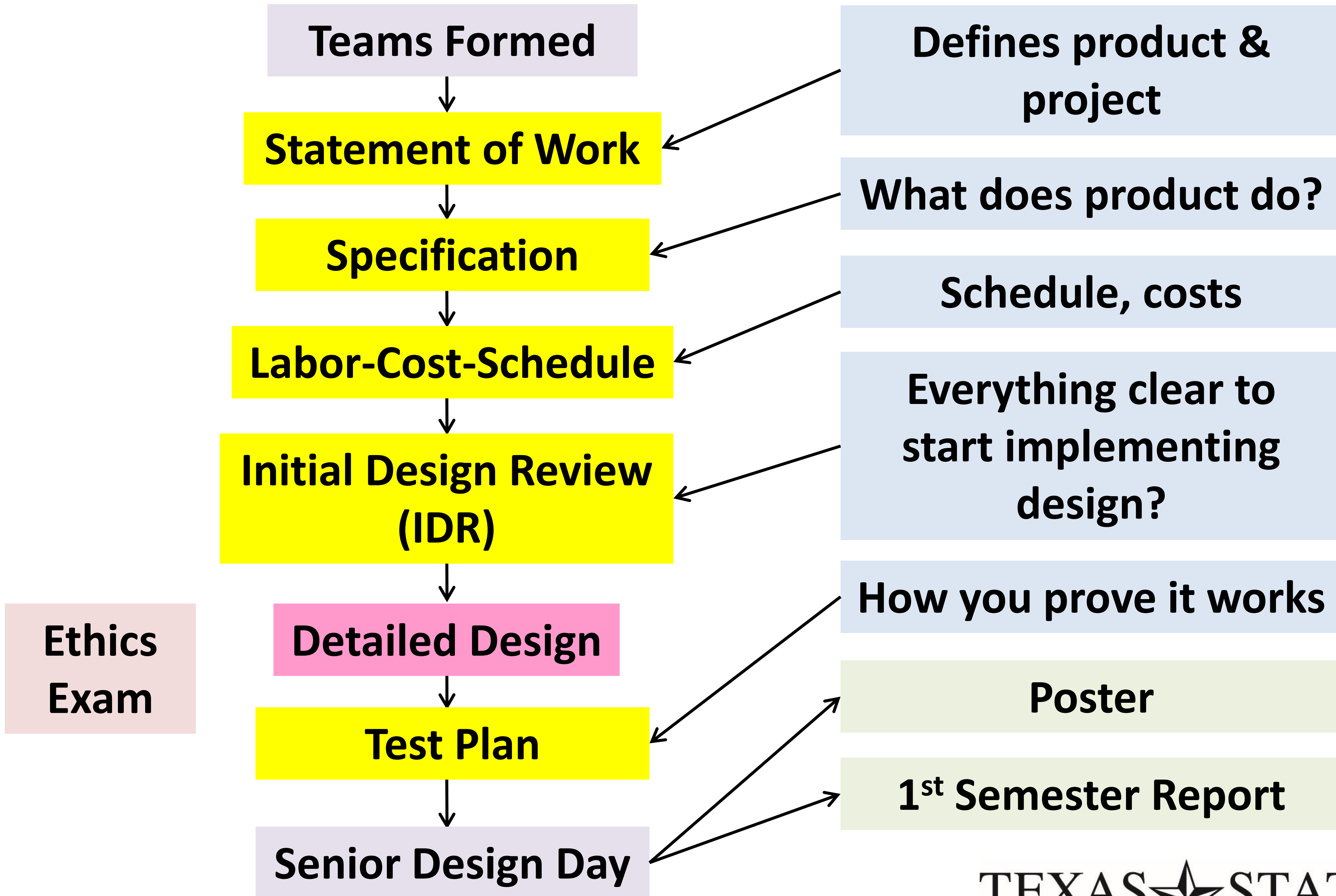
1st Semester Summary



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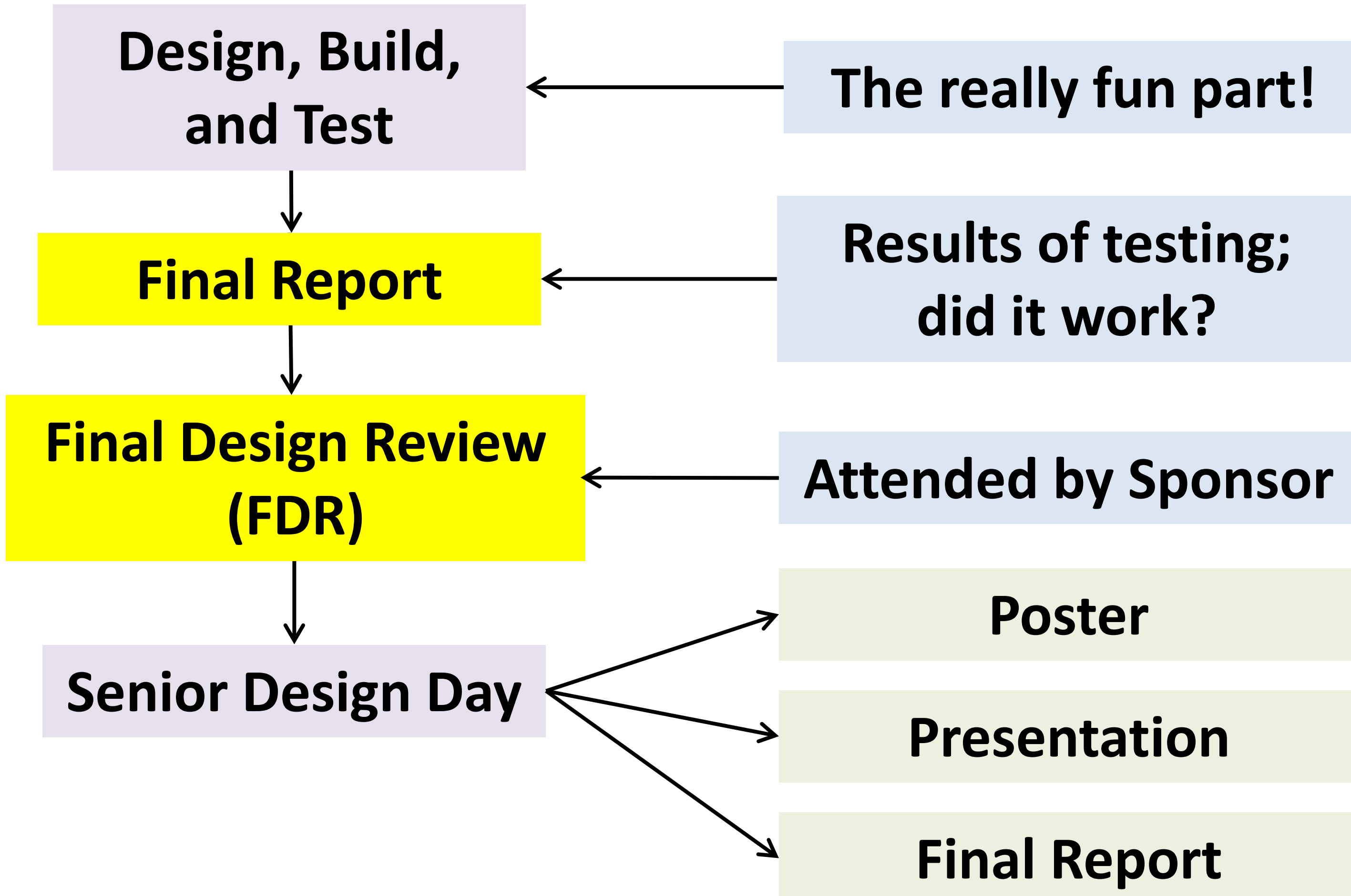
2nd Semester Summary



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Intro to Functional Spec

- **The functional specification should be clear, consistent, precise and unambiguous.**
  - It is important that there is a draft functional specification ***before*** the design stage on any project is started and that the functional specification is ***agreed upon***.
  - The functional specification must be kept up-to-date, as this is the communication with the world outside the development staff.

Research (or lack thereof) will make or break you!

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Document Revisions

Your documents must have an up-to-date revision block. For many Senior Design documents just 1.0 will be fine.

- 0.1 – Most sections identified, authors named
- 0.5 – Preliminary content for most sections
- 0.9 – Complete, number of changes diminishing
- 1.0 – Approval candidate, hopefully signed off
- 1.1 – Minor changes after sign off
- 2.0 – Major update, perhaps next gen product

Revision blocks are for you, the reviewers, and your customers. Documented changes allow everyone to understand latest information without rereading entire document.

Procedure

- Treat your project as a "black box"
- List all the features and functions
- List the min/max of every input and output to the extent possible
- Understanding the system and the interfaces is key:
  - If supply voltage is USB 5.0V, then either state 5V nominal or list USB voltage specification range.
  - Battery life minimum may be appropriate, maximum rarely is.
  - If you are generating an electrical output going to another component then min/max voltage and min/max current should be specified.
- Reference specs from other documents or provide internet links (e.g., LM75 temp sensor, 2600mAh 18650 Li-Ion Cell, Arduino Rev B) Pull out relevant data from off-the-shelf products – do not simply copy and paste tables and lists from 3rd party datasheets! Include in Appendix if critical.

GET STARTED ASAP!!!

Work closely with Sponsor / Faculty Sponsor / D2

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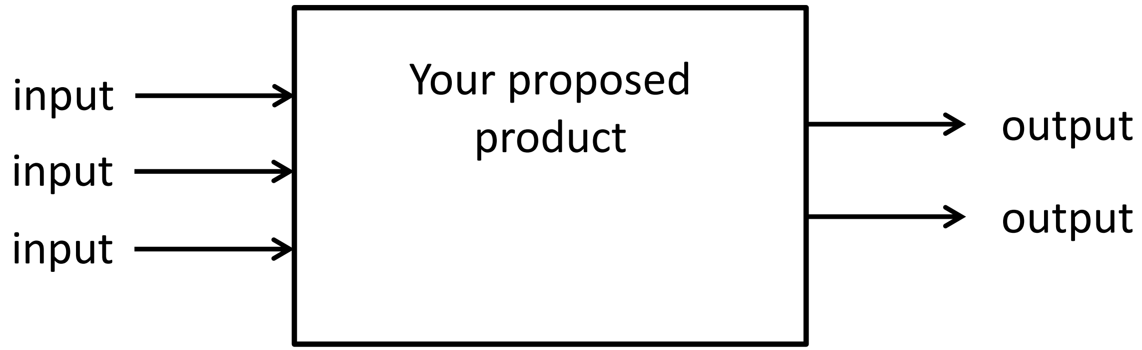
Explain using Diagrams and Examples

- **Make diagrams! Do not simply copy component diagrams – modify to best explain <u>your</u> product**
- **Share a top level diagram if on joint project**
- **Specs without diagrams will be rejected. <seriously>**
- **Use examples!** A brief, concrete example often illustrates a point much more succinctly than an explanation.
  - "A day in the life of" – If near freezing temperatures are detected alarm will sound until silenced by pressing acknowledge button
  - Bonus: interesting examples engage the reader and increases the value of your project

Block Diagrams

Every product can be represented by this abstract diagram



The functions happen inside this block – but you have to know what goes in and what is supposed to come out

Example: IoT Temperature Alarm

The "Elevator Pitch"

"My product is a temperature sensor and alarm for use in garages or unheated buildings.   When it detects near freezing temperatures it sounds an audible alert and sends a text message to the owner's phone.   The system runs on 110V AC but will operate up to 24 hours on battery backup in the case of power failure."

What are the inputs and outputs?

Inputs	Outputs
Temperature	Audible Alarm
Power & Status	Text Message
Wireless Credentials	Local Display?

- Power on?
- Temperature?
- Wireless connected?

Is ‘Temperature’ enough?

Your functional spec should provide enough detail to write a test procedure.

“Senses temperature” – not enough

“Senses temperature from -25°C to 50°C with an accuracy of +/- 3°C” – good, consider summarizing in a table

Features, Functions, and Performance Targets

A <u>function</u> answers the question “What does it do?”

Senses the temperature

Displays the temperature in Celsius or Fahrenheit

Sounds alarm and sends text when near freezing

Indicates low battery

<u>Performance targets</u> define the correct operation

A <u>feature</u> is sometimes used when the answer to the question “What does it do?” is unclear or difficult to describe. Best used in context of feature + benefit list.

Features an “Intel Core i7 processor” – why?
Now with “Super Oxy Power” – do I care?

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Now we start to consider the design

Test the goals, are we trying to build:

A. Cheap and disposable (e.g. Amazon Dash)

B. More functionality but higher cost

How to find this?

RESEARCH!

Cheap	More Functionality
Analog thermistor with a simple comparator circuit might be good enough	LM75 is an off-the-shelf solution that is pre-calibrated and provides a digital output
Lots of calibration and testing required to insure freeze detection	Can focus on other functions, lowering risk, etc.

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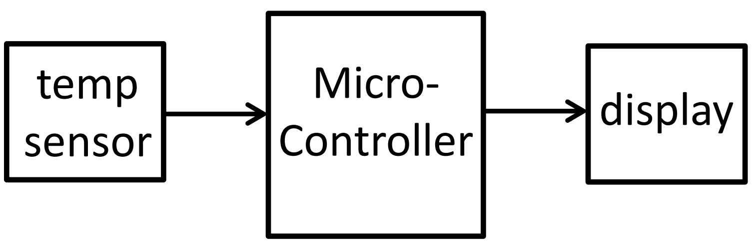
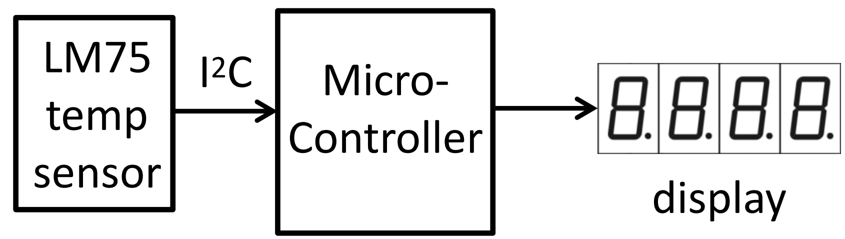
Block Diagrams: General Guidelines

You decide the appropriate level of abstraction (detail & # of blocks)
Do not put a ton of detail for off-the-shelf blocks
Most projects will have 2 or 3 block diagrams
- Entire system
- Your component
- Details of interesting subsystems

Try to keep inputs on left, outputs on right
Use graphics only when it adds clarity



Accurate diagram, but limited info



Better version

image: http://www.learningaboutelectronics.com/Articles/4-digit-7-segment-LED-circuit-with-an-arduino.php

LM75 Datasheet

19-4385; Rev 0; 3/09

MAXIM

Digital Temperature Sensor and Thermal Watchdog with 2-Wire Interface

LM75

General Description

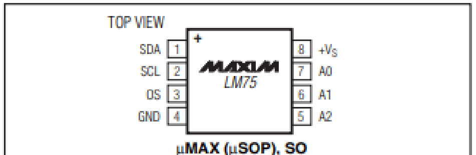
The LM75 temperature sensor includes a delta-sigma analog-to-digital converter, and a digital overtemperature detector. The host can query the LM75 through its I²C interface to read temperature at any time. The open-drain overtemperature output (OS) sinks current when the programmable temperature limit is exceeded. The OS output operates in either of two modes, comparator or interrupt. The host controls the temperature at which the alarm is asserted (T_{OS}) and the hysteresis temperature below which the alarm condition is not valid (T_{HYST}). Also, the LM75's T_{OS} and T_{HYST} registers can be read by the host. The address of the LM75 is set with three pins to allow multiple devices to work on the same bus. Power-up is in comparator mode, with defaults of T_{OS} = +80°C and T_{HYST} = +75°C. The 3.0V to 5.5V supply voltage range, low supply current, and I²C interface make the LM75 ideal for many applications in thermal management and protection.

Applications

Thermal System Management
Thermal Protection
Test Equipment
Computers and Office Electronics

µMAX is a registered trademark of Maxim Integrated Products, Inc.

Pin Configuration

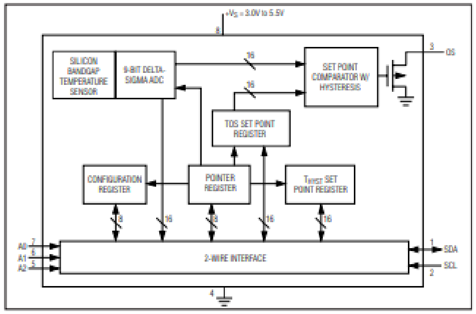


µMAX (µSOP), SO

Features

- SO (SOP) and µMAX® (µSOP) Packages
- I²C Bus Interface
- Separate Open-Drain OS Output Operates as Interrupt or Comparator/Thermostat Input
- Register Readback Capability
- Power-Up Defaults Permit Stand-Alone Operation as a Thermostat
- 3.0V to 5.5V Supply Voltage
- Low Operating Supply Current 250µA (typ), 1mA (max)
- 4µA (typ) Shutdown Mode Minimizes Power Consumption
- Up to Eight LM75s Can Be Connected to a Single Bus
- Pin- and/or Register-Compatible with Improved-Performance Maxim Sensors Including MAX7500, MAX6625, MAX6626, DS75LV, and DS7505

Functional Diagram



Ordering Information/Selector Guide

PART	PIN-PACKAGE	PKG	SUPPLY VOLTAGE (V)	TOP MARK
LM75BIM-3+	8 SO (SOP)	Bulk	3.3	LM75BIM-3

For off the shelf parts do not cut and paste this level of detail into your block diagram unless it is absolutely necessary to understand the operation of your system

Source: https://datasheets.maximintegrated.com/en/ds/LM75.pdf accessed 2/11/2018

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LM75 Datasheet

ELECTRICAL CHARACTERISTICS

($+V_S$ = +3.0V to +5.5V, unless otherwise noted. Temperature accuracy specifications apply for $+V_S$ = 3.3V for versions with "-3" in the suffix and for $+V_S$ = 5V for versions with "-5" in the suffix. T_A = -55°C to +125°C, unless otherwise noted. Typical values are at $+V_S$ = +5V, T_A = +25°C.) (Notes 4, 5)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Accuracy (Six-Sigma)		$-25°C \le T_A \le +100°C$	-2.0		+2.0	°C
		$-55°C \le T_A \le +125°C$	-3.0		+3.0	
Accuracy (Three-Sigma) (Note 6)		$-25°C \le T_A \le +100°C$	-1.5		+1.5	°C
		$-55°C \le T_A \le +125°C$	-2.0		+2.0	
Resolution				9		Bits
Temperature Conversion Time		(Note 7)		100	300	ms
Quiescent Supply Current		I^2C inactive		0.25	0.5	mA
		Shutdown mode, $+V_S$ = 3V		4		µA
		Shutdown mode, $+V_S$ = 5V		6		
$+V_S$ Supply Voltage Range			3.0		5.5	V
OS Output Saturation Voltage		I_{OUT} = 4.0mA (Note 8)			0.8	V
OS Delay		(Note 9)	1		6	Conver-sions
OS Output Fall Time	t_{OF}	C_L = 400pF, I_O = 3mA (Note 10)			250	ns
T_{OS} Default Temperature		(Note 11)		80		°C
T_{HYST} Default Temperature		(Note 11)		75		°C

Can your product exceed this temperature range and accuracy? No
Should you write a test plan for Quiescent Supply Current? No
Do you use this info to write your functional spec? Absolutely!
What if requirements are not met? e.g. need +/- 1°C then this is wrong part!

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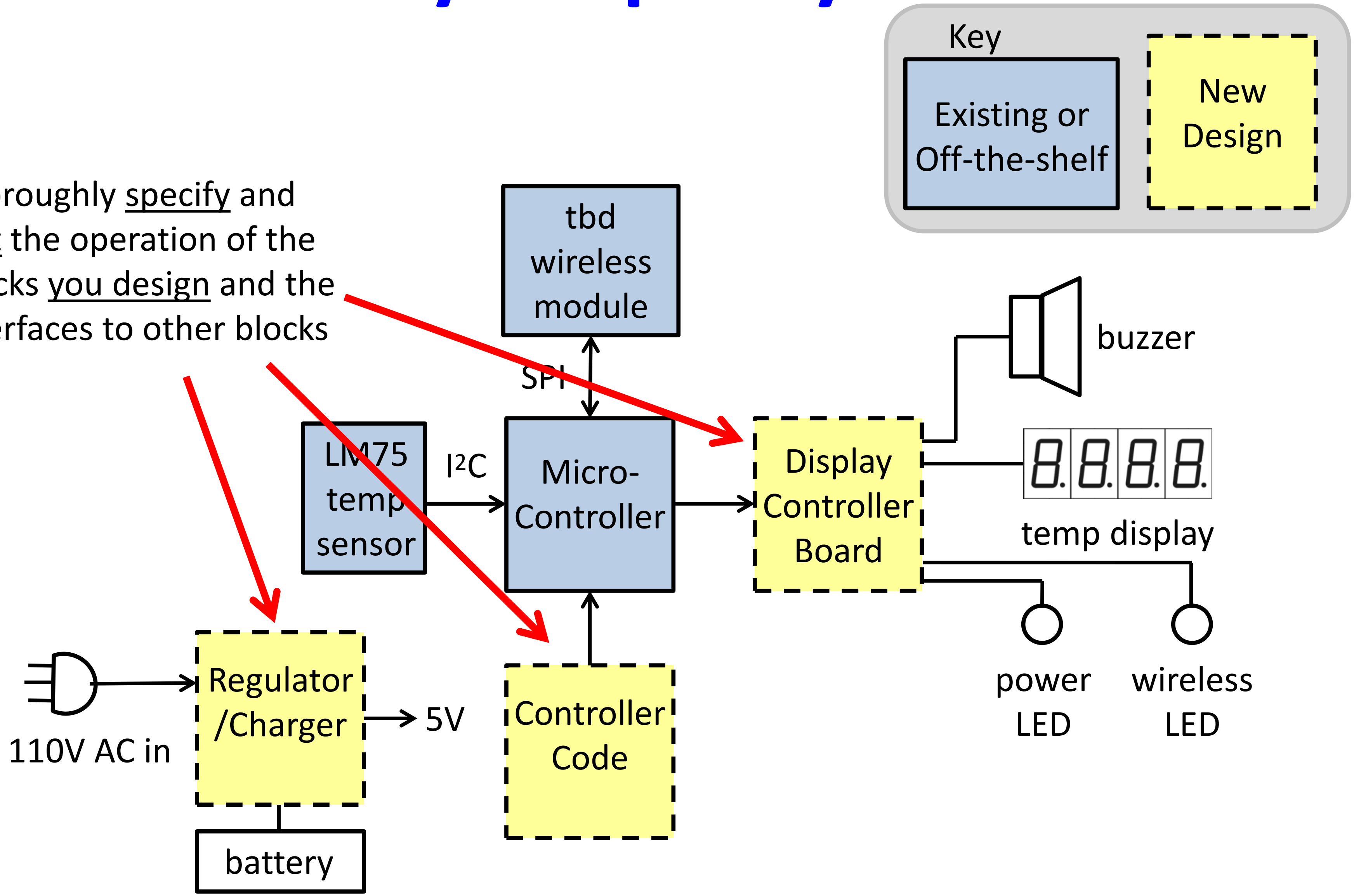
What do you specify and test?

Thoroughly <u>specify</u> and <u>test</u> the operation of the blocks <u>you design</u> and the interfaces to other blocks



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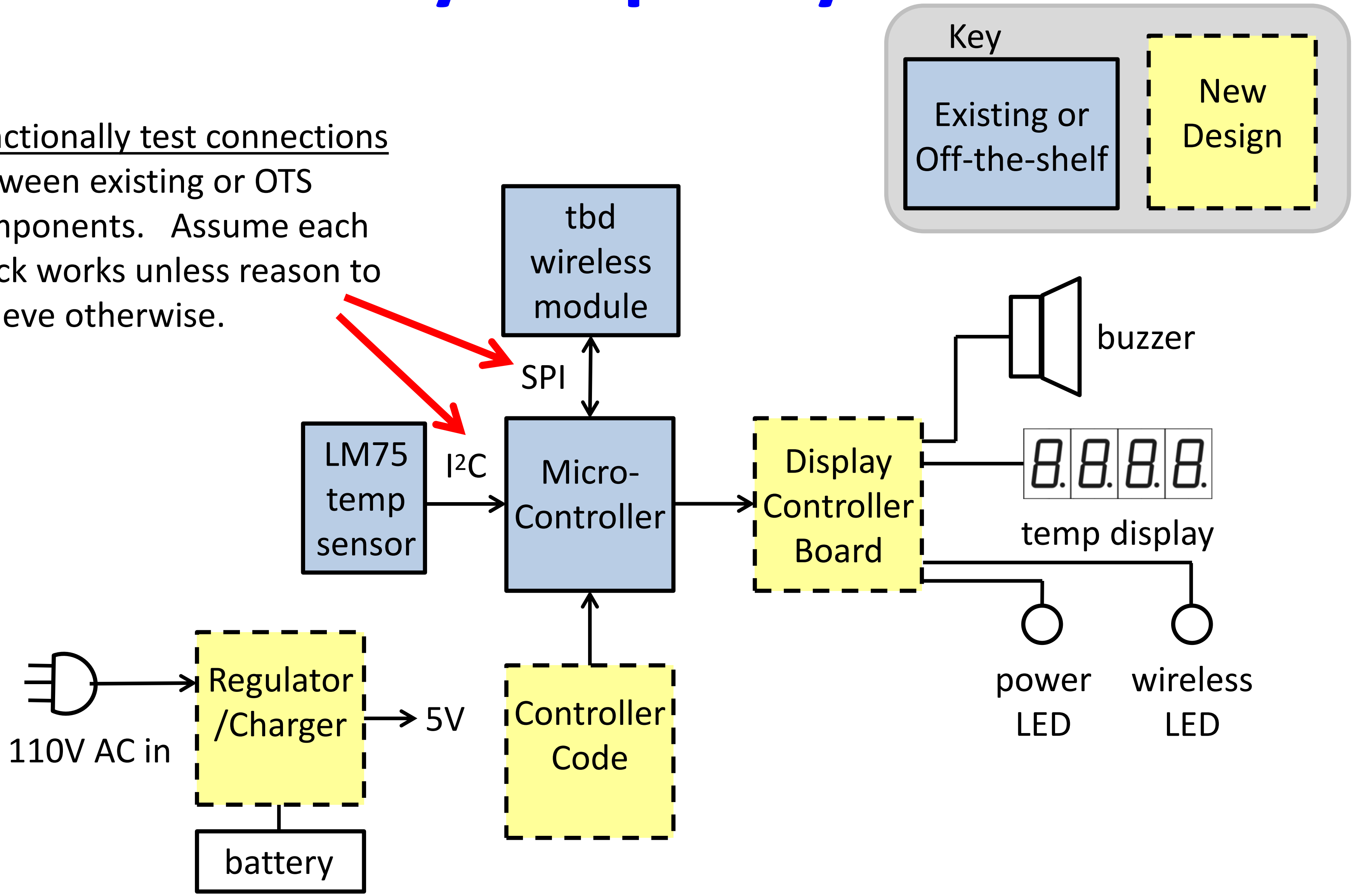
What do you specify and test?

<u>Functionally test connections</u> between existing or OTS components.   Assume each block works unless reason to believe otherwise.



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What do we test???

- You do **NOT** test off-the-shelf components
  - They were tested at the factory*
- **But whenever you connect such components together you must test them as a system**
- **Start small – verify each block or interconnect before trying entire system**
  - **Can micro-controller read from LM75?**
  - **Can I show a static value on display?**
  - **Then put together, show temp on display**

* unless you buy from AliExpress, then test, question life decisions, throw in trash, get new one from Adafruit

Final Words on Testing

- We will cover much more on testing as we discuss the test plan and characterization data.
- You will refer to the functional specification time and time again as you go through the development process. Expect to update it several times.

Template on TRACS

- A template for the Functional Specification is on TRACS
- Word format
- Answer the questions and *then remove the red italics*
- Review it OVER AND OVER with your Sponsor & Faculty Sponsor & D2 Team, i.e., incrementally!!

Warnings & Wrap-up

- This document is a <u>lot</u> of work
- It is <u>crucial</u> to your project
  - If you don't put much time/effort into the spec your project will be poor at best
  - Everyone on the team needs to work at least 9 hours/week on the spec
- Review pieces constantly with your Sponsor!!!
- Do NOT send a 'completed' spec cold to a Sponsor without them having reviewed pieces of it several times!!!!

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Ready – Set – Go!

- Once your SOW is signed by your course instructor you are approved to start on the Functional Spec.
- Check the Master Schedule for its due date.

- It's a lot of work, so
  - You are already behind.