Day 1: INTRODUCTION

SUMMER CHALLENGE COURSE

SMART LIGHTING

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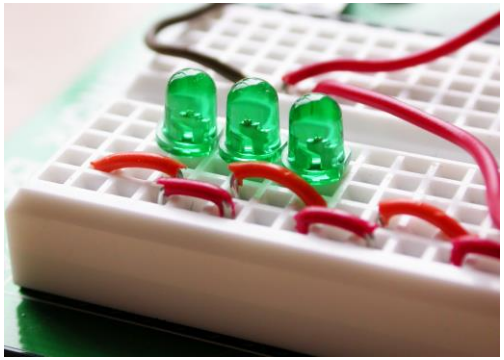
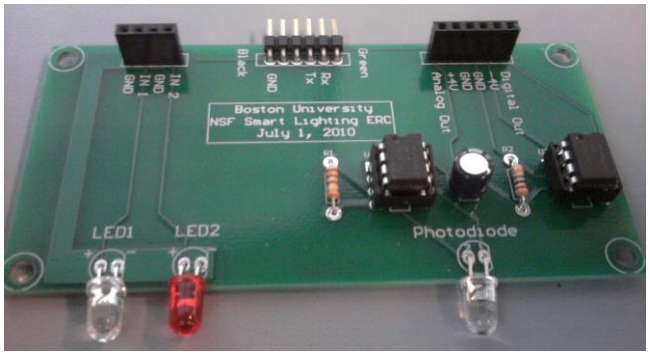
Course prepared by Prof. Tom Little

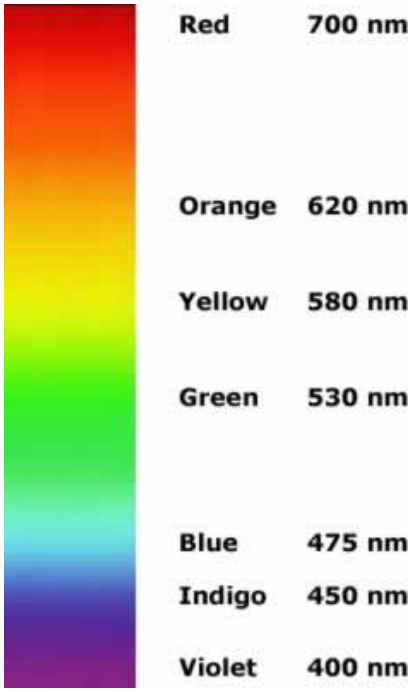
BOSTON UNIVERSITY

- Objectives
- Course Structure
- Module Structure
- Visual Light Communications (VLC)
- The Smart Lighting Kit
- Lab 1: Rhett Board

- To become familiar:
  - The basic electrical components, circuits, signals and tools
  - The light emitting diode (LED) technology
  - The visible light communication (VLC) technology







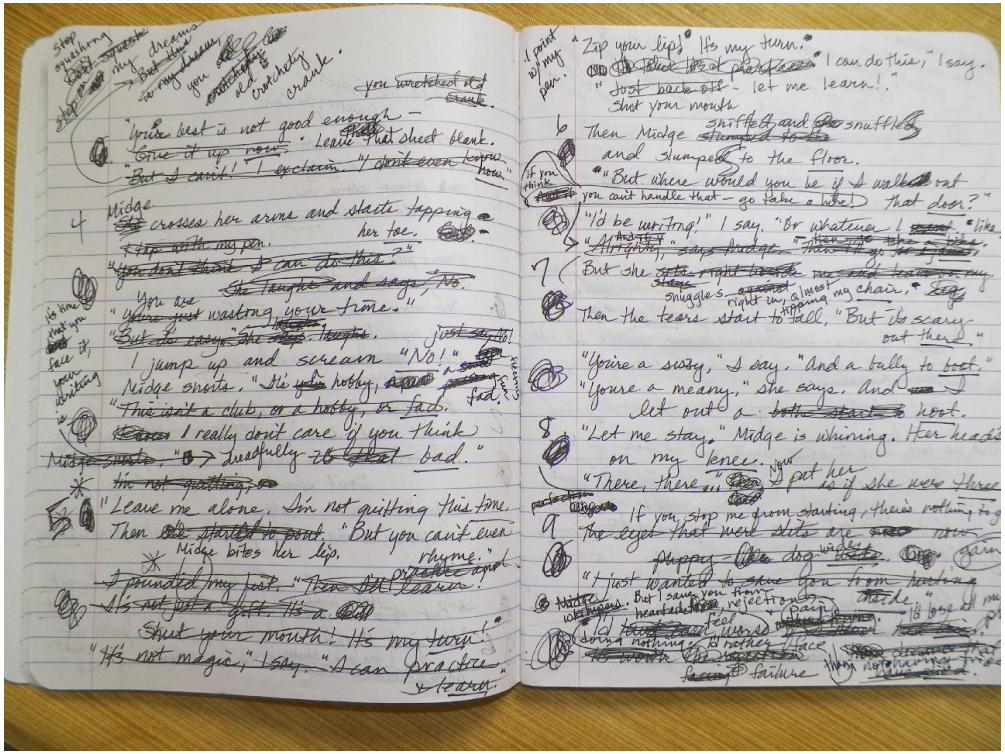
- To be inform about contemporary LED and lighting events
- To develop engineering communication skills

Module	Topic	Activities
0	Introduction	Lecture: Course Overview and Smart Lighting Kit
1	The Rhett Board	Operating the Rhett Board
2	Basic Circuits	Investigate the Operation of Basic Circuits
3	LEDs	LED Operation and Electrical Characterization
4	PDs and VLC Channel	PD Operation and VLC Channel Characterization
5	The VLC Link	Establishing a VLC link between the LED and PD
6	The Smart Lighting Board	Assemble and test a PCB-based VLC Transceiver
7	Analog Transmission	Investigate VLC Transmission using Analog Signals
8	Digital Transmission	Investigate VLC Transmission using Pulsed Signals
9	Heart Monitor	Acoustic Signal Detection
10	Presentations	Student Presentation and Open Discussion

Time	Activity
09:30am-09:50am	Short Presentation
09:50am-10:50am	Experiment
10:50am-11:00am	Short Break
11:00am-11:20am	Experiment
11:20am-11:30am	Finalize your Laboratory Notebook

Key entries:

- Name
- Group name
- Date of entry
- Introduce each experiment
- Sketches of laboratory setup
- Measurements
- Calculations
- Results
- Observations
- Summarize each experiment



- Ozan Tuncer (PhD student, Boston University)

  otuncer@bu.edu

- Jonathan Bell (Undergraduate student, Boston University

  jbell@bu.edu

Forming Laboratory Groups:

- 2 students per group
- Group Members
- Group Name
- Introduce yourself and your group

5 minutes!

http://smartlighting.rpi.edu

- 10 years > $18M from National Science Foundation

Core Academic Members

Rensselaer

BOSTON UNIVERSITY

UNM

http://www.bu.edu/smartlighting

- Boston University role: Communications and networking

Outreach Universities

MORGAN STATE UNIVERSITY

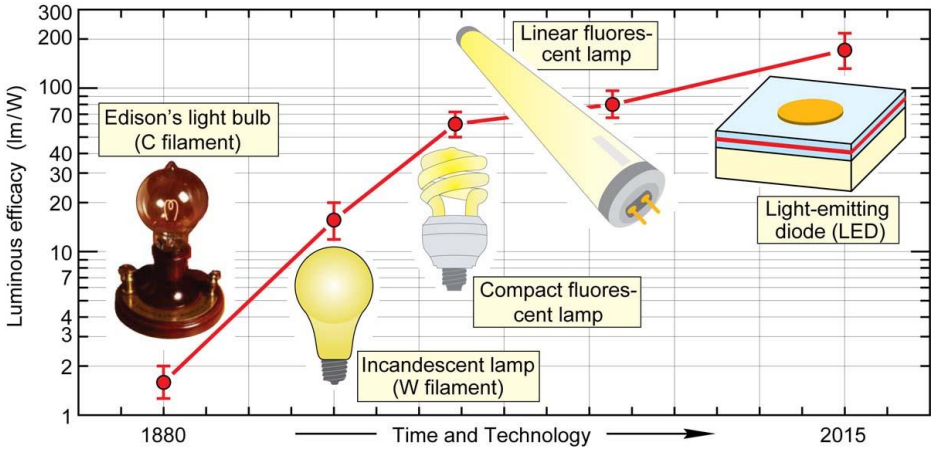
ROSE-HULMAN INSTITUTE OF TECHNOLOGY

1867 HOWARD UNIVERSITY

BU Department of Electrical & Computer Engineering

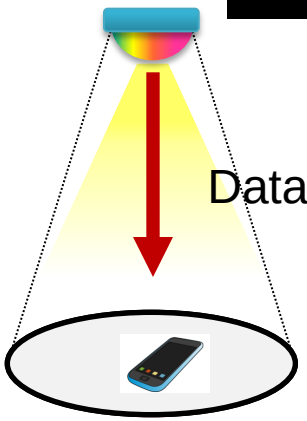
Engineered light for:

Energy Efficiency



Health

Data Access



First Wave

Common 60W Incandescent Bulb

uses 60W per bulb for 800 lumens

1 bulb lasts 1,200 hrs

20 years = 21 bulbs

Common 14W CFL Bulb

uses 14W per bulb for 800 lumens

1 bulb lasts 10,000 hrs

20 years = 3 CFL bulbs

Philips 12.5W AmbientLED Bulb

uses 12.5W per bulb for 800 lumens

1 bulb lasts 25,000 hrs

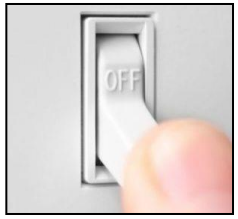
20 years = 1 LED bulb

Everyone is a Lighting User

Electrical Lighting

Electronic Lighting

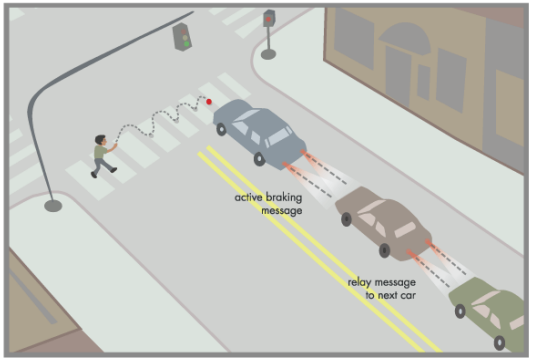
- Human Control:
  - On/Off
  - Dimming
- Sensor Control: Limited or not used
  - Daylight sensor
  - Motion sensor




Courtesy: Fraunhofer HHI

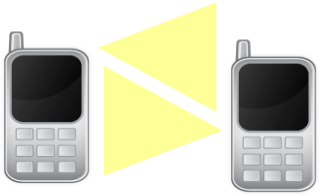
Smart Lighting
- Location based services
- Control

Vehicle & transportation
- Vehicle-to-Vehicle
- Vehicle-to-Infrastructure



Courtesy: ledgb.com

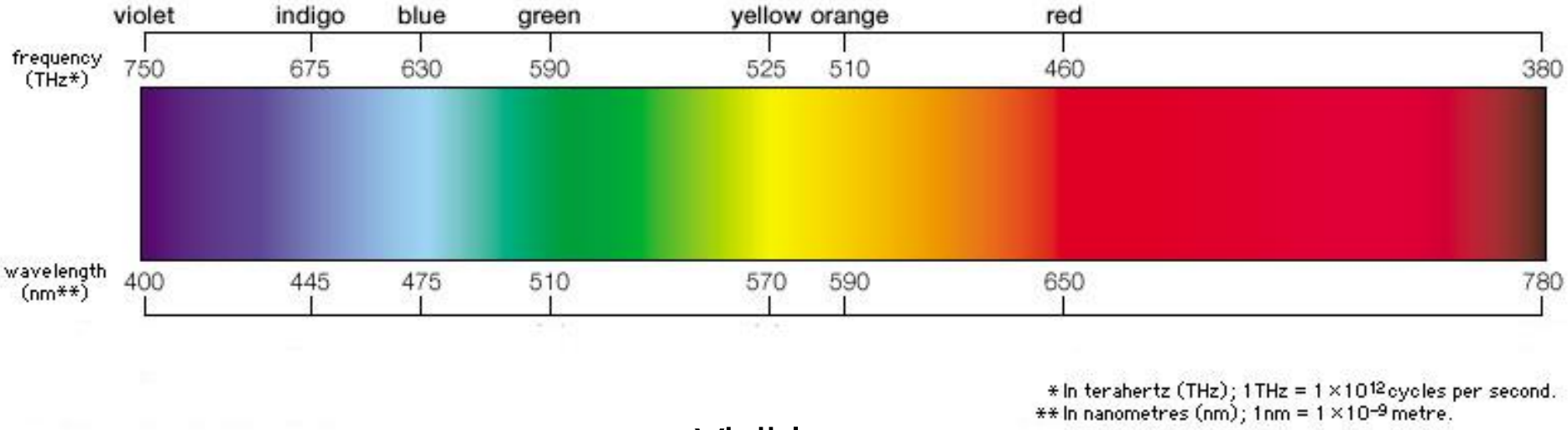
Device-to-Device Communication



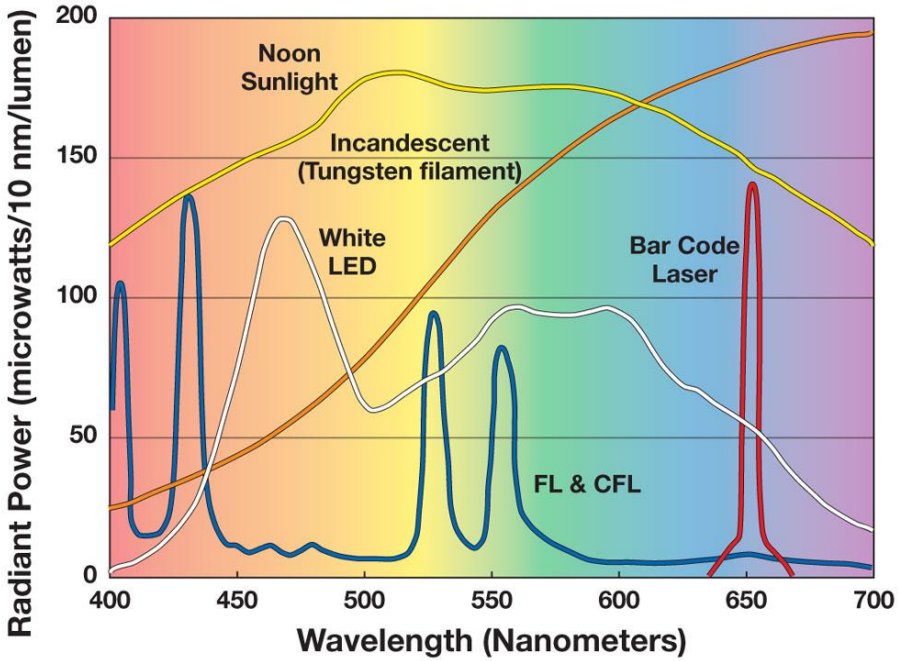
Places where RF is undesirable?
- Hospitals
- Airplanes

Courtesy: 123F

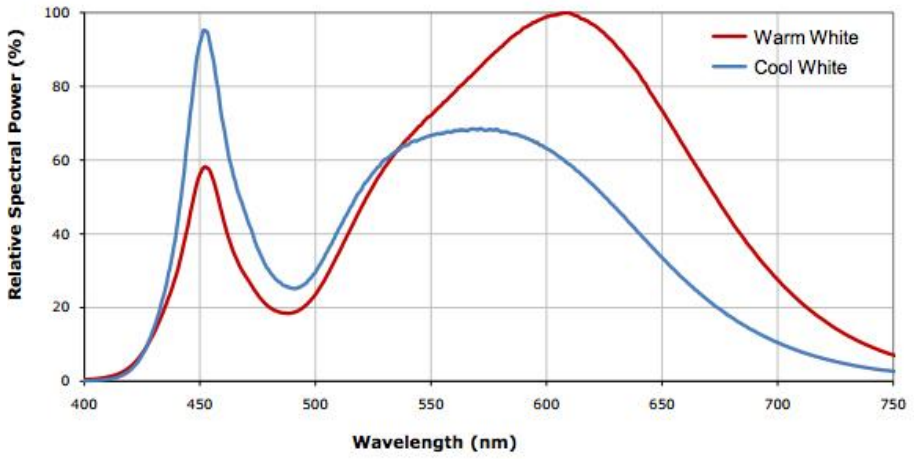
Electromagnetic



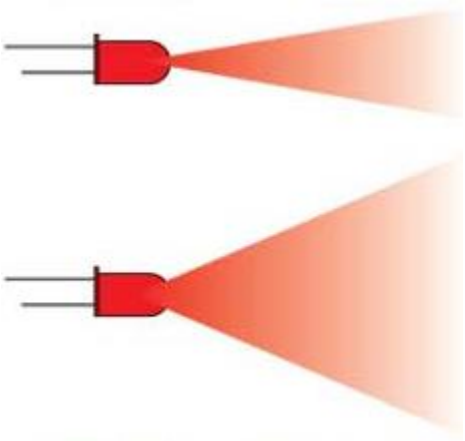
Visible



Light Sources



Color-Temperature



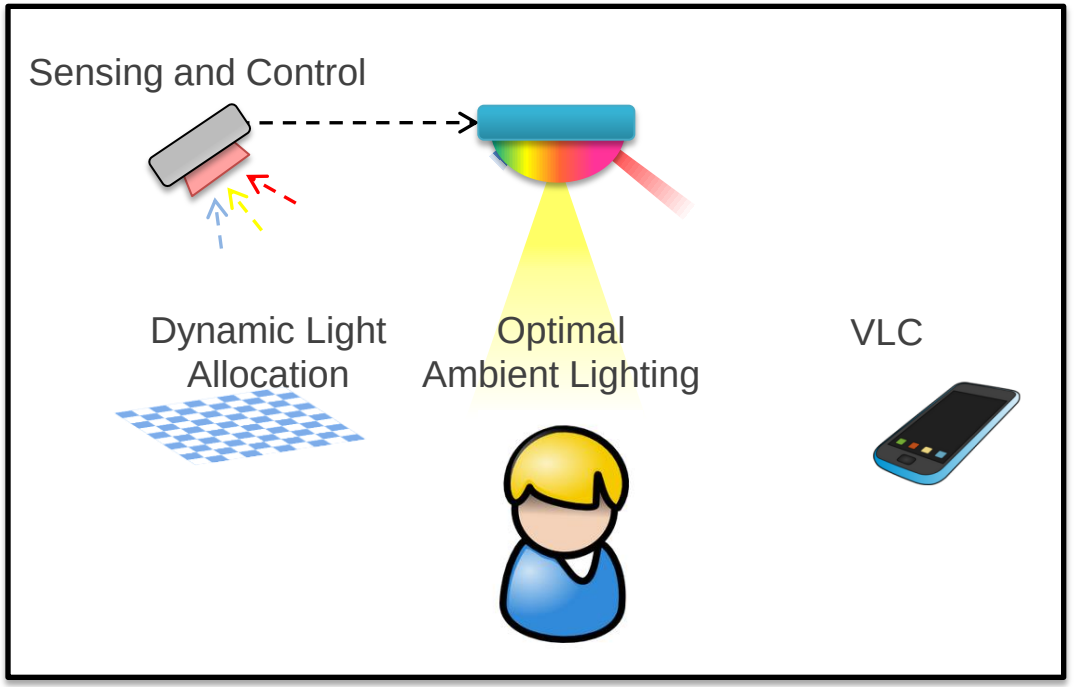
Beam Angle

Intensity Modulation

Second Wave

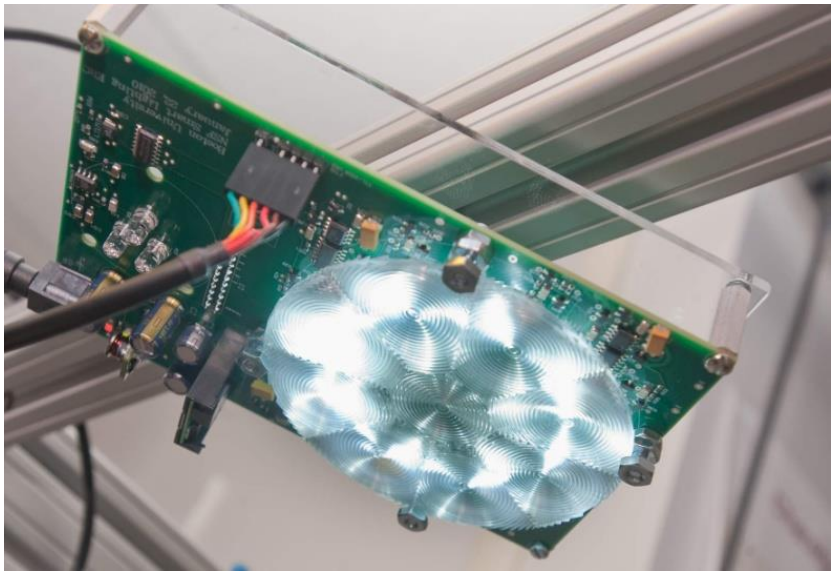
Integrate Controls and

VLC Research



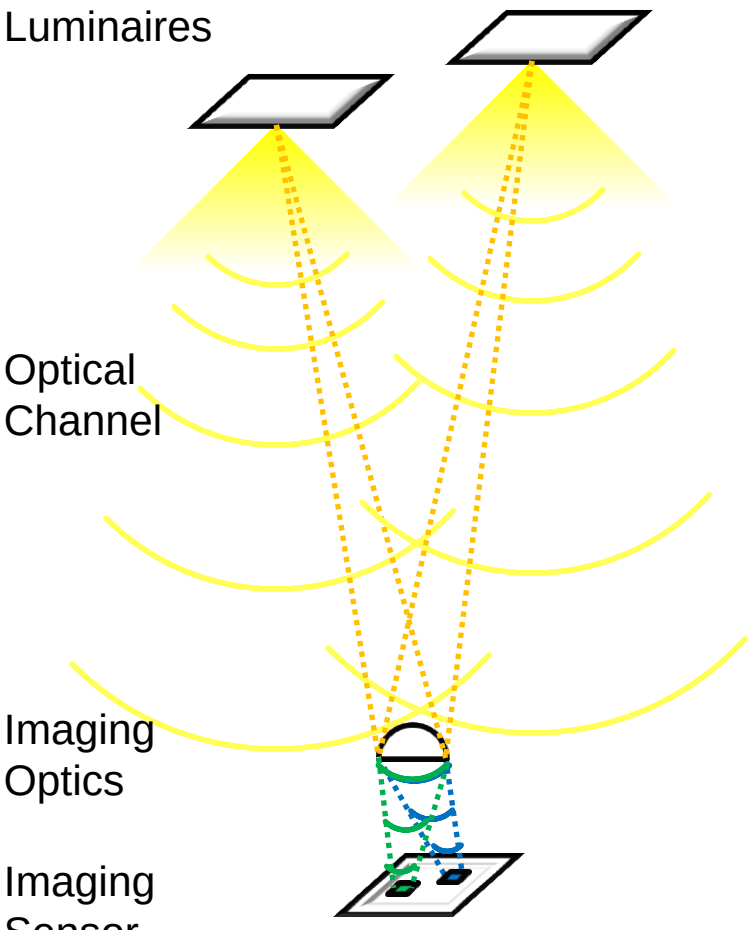
- Spectral Control
- Color-Temperature Control
- Spatial Control
- Temporal Control; VLC

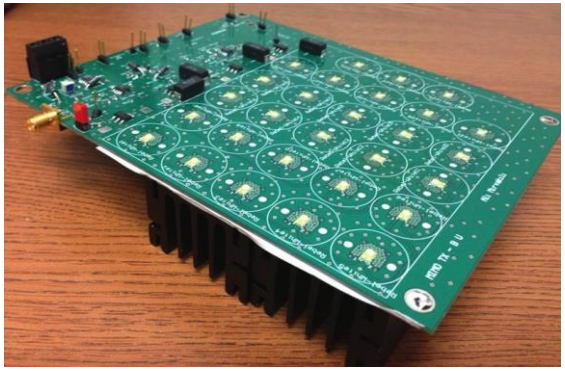
Lighting and Display Fusion



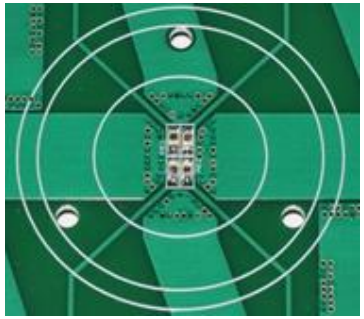
TiLED Project

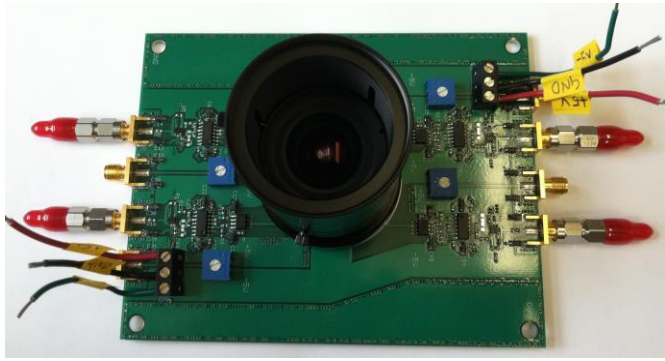
multiple-input and multiple-output (MIMO)





MIMO Transmitter

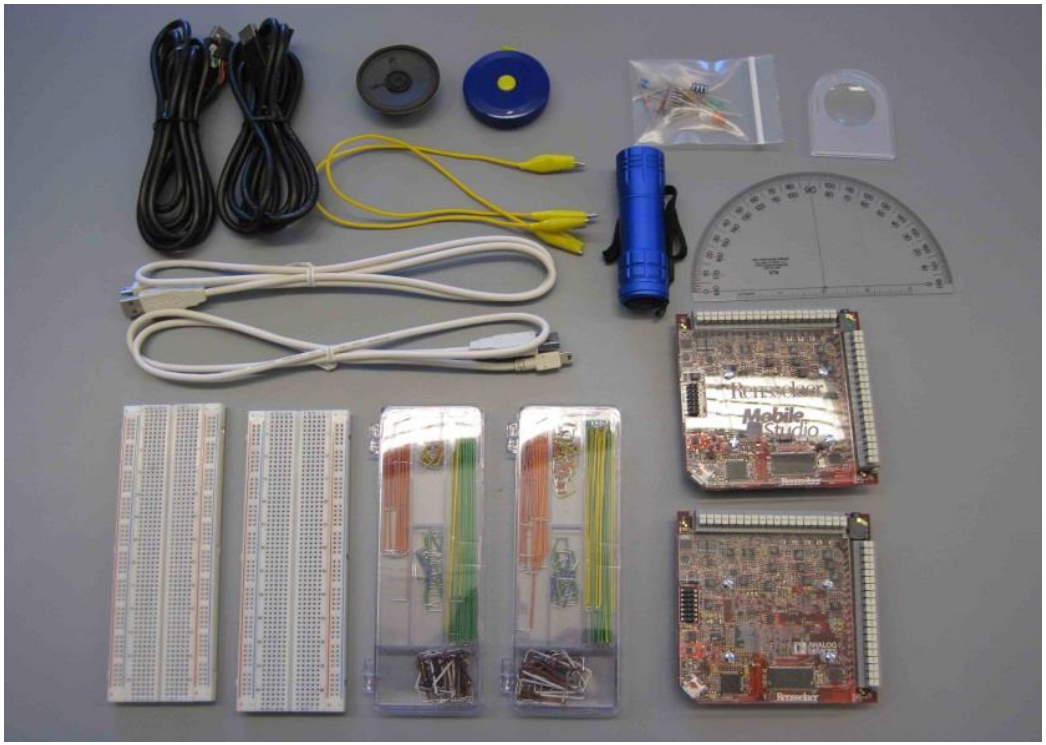




2x2 MIMO Receiver

Concept:
Install an access point in every light bulb

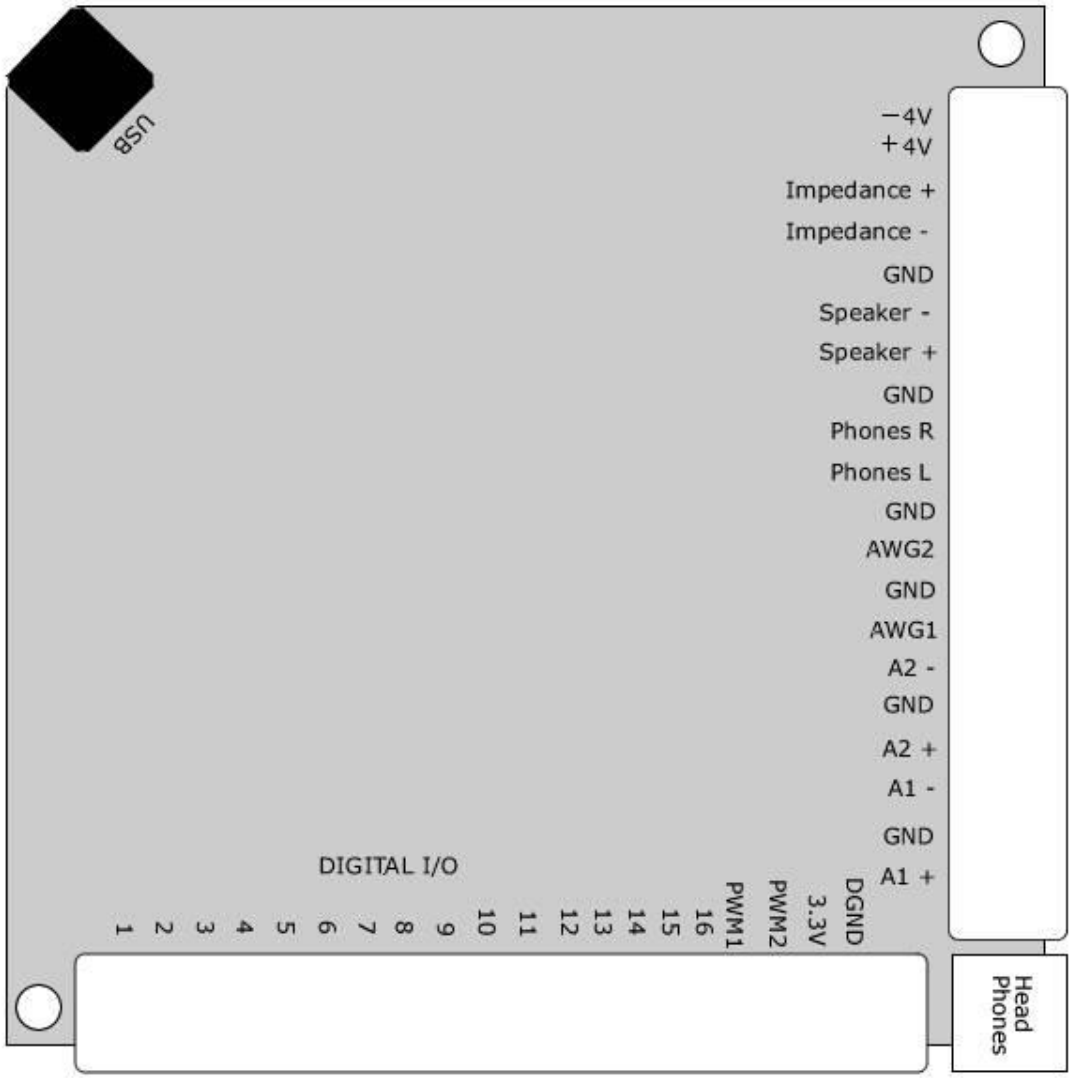
PoE: power over Ethernet



Smart Lighting Lab kit contents:

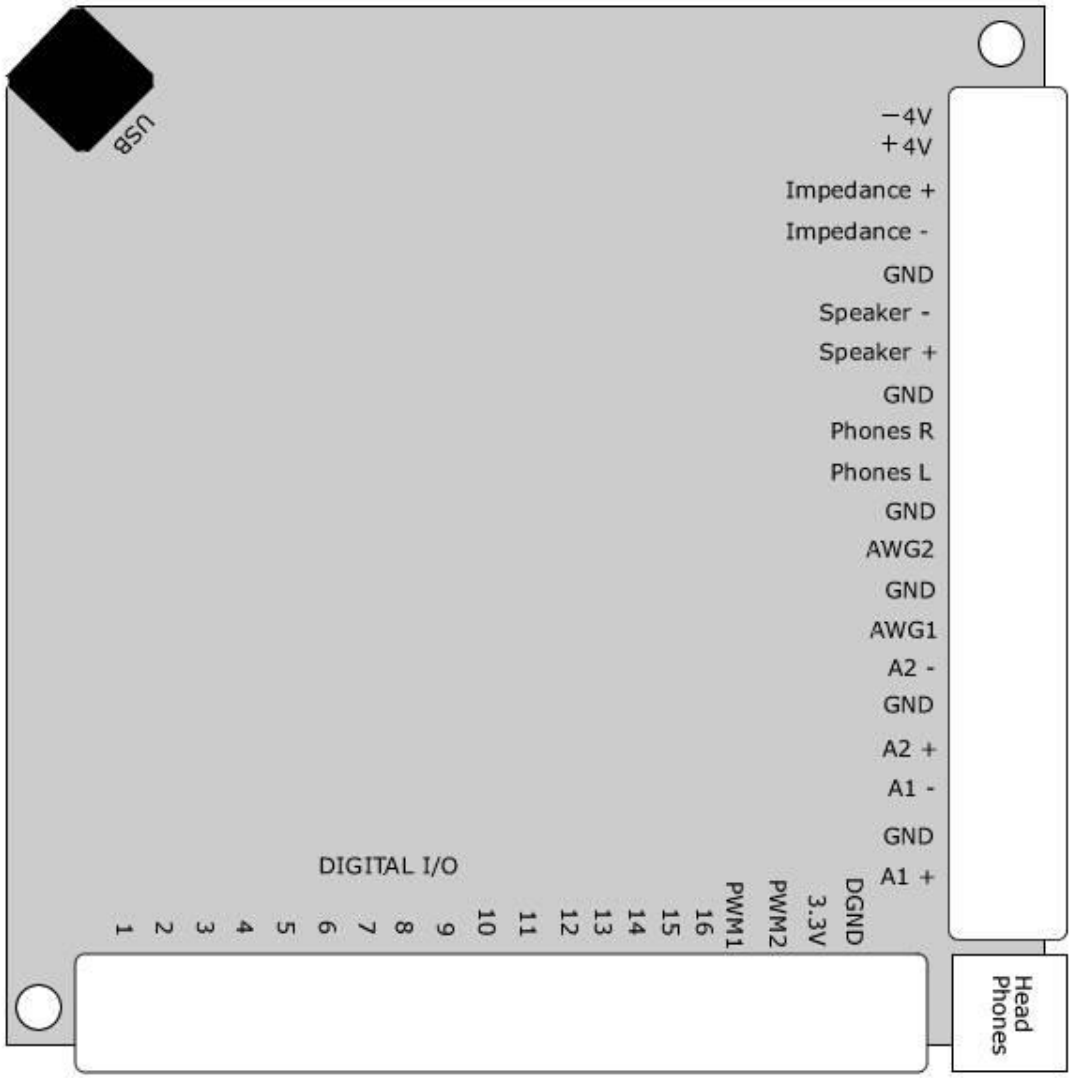
- 2 Rhett Boards
- 2 USB to micro-USB cables
- 2 Breadboards
- 2 Wiring kits
- Resistors and capacitors
- Red, green and white LEDs
- Photodiode(PD)
- Operational amplifier (Op-Amp)
- Exclusive-OR (XOR) gate
- Lens
- Flashlight
- Tape measure
- Protractor
- Speaker
- Transceiver printed circuit board (PCB)
  - Board Components
  - 2 USB to serial cables (FTDI)

Course website: http://www.bu.edu/dbin/ece/people/acoskun/BUSC13/
Mobile Studio Project: http://www.mobilestudioproject.com/



-V: -4V DC (capable of providing ~ 50mA)
+V: +4V DC (capable of providing ~ 50mA)
Impedance Analyzer *(not released)*
Impedance Analyzer *(not released)*
GND : Analog ground
Speaker - : Audio Out
Speaker + : Audio Out
GND : Analog ground
Phones R : Audio, Out Right Channel
Phones L : Audio, Out Left Channel
GND : Analog ground
AWG2 : Arbitrary Waveform Generator, Channel 2
GND : Analog ground
AWG1 : Arbitrary Waveform Generator, Channel 1
A2- : Analog, Channel 2 Input
GND : analog ground
A2+ : Analog, Channel 2 Input
A1- : Analog, Channel 1 Input
GND : Analog ground
A1+ : Analog, Channel 1 Input

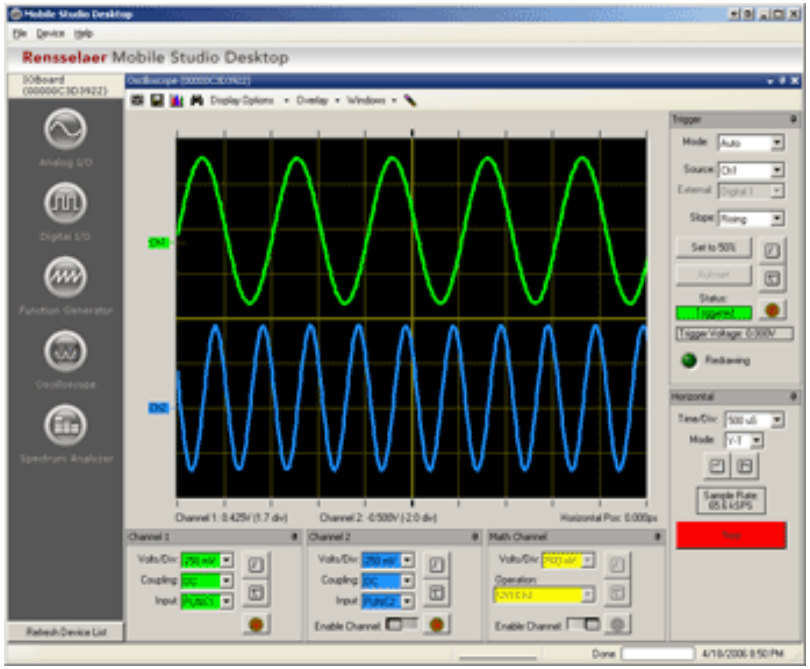
Vertical Connector
(top to bottom)



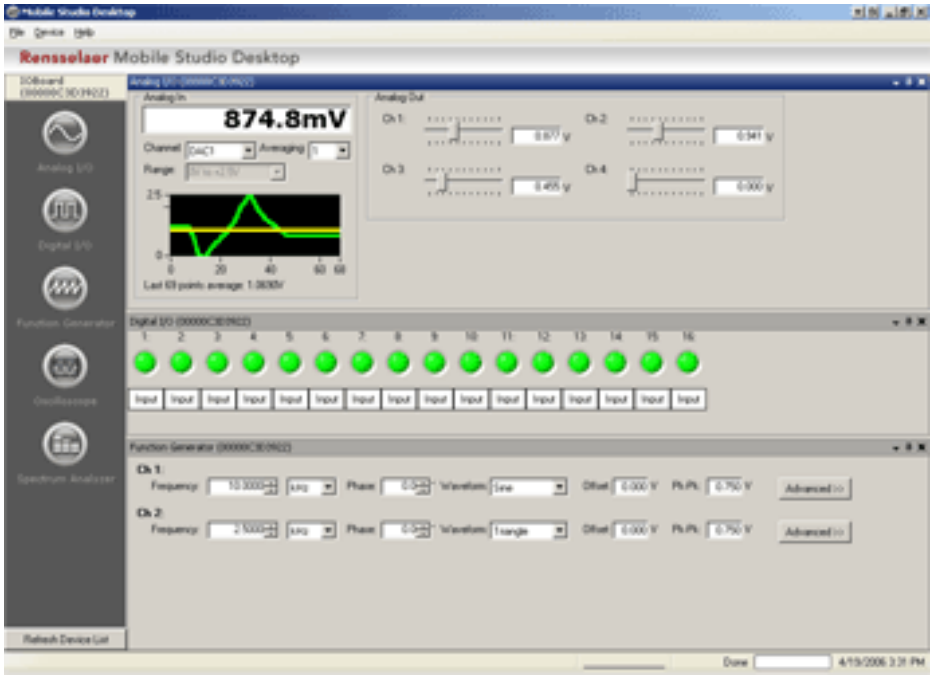
Digital I/O 1 - 16 : Digital Input/Output Pins
PWM1 : Pulse Width Modulation, Channel 1
PWM2 : Pulse Width Modulation, Channel 2
3.3V : +3.3V DC
DGND : Digital ground

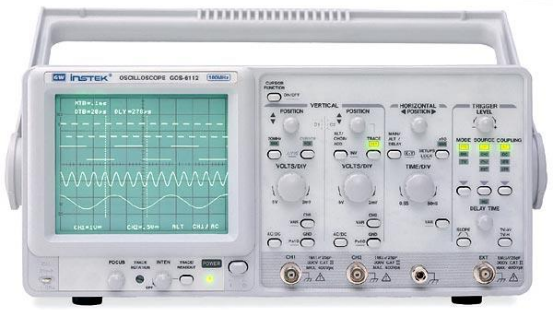
Horizontal Connector
(left to right)

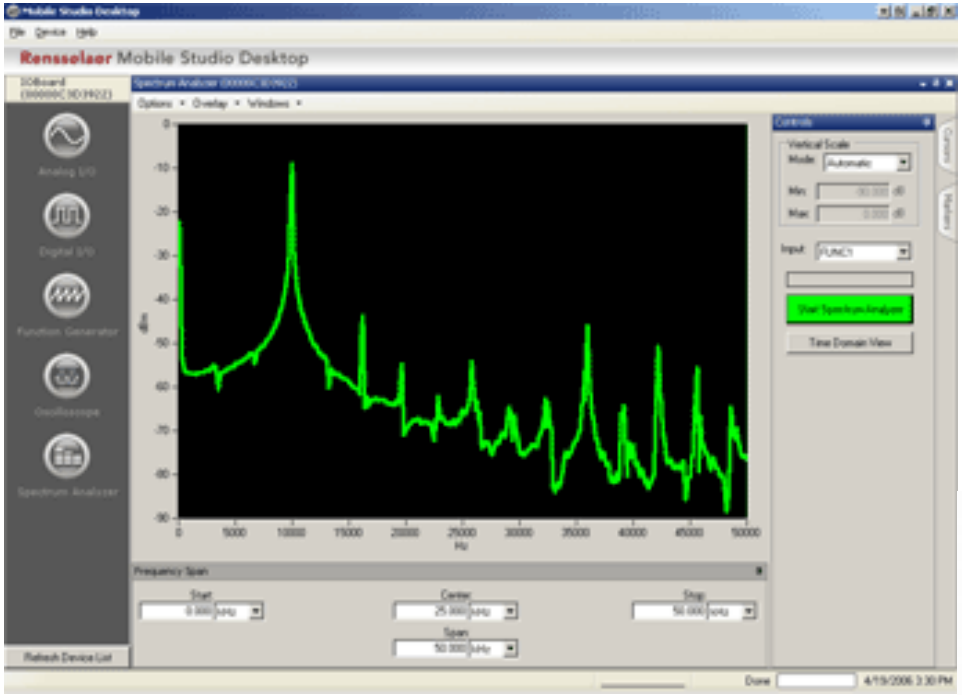
The Oscilloscope Display



The Function Generator Display

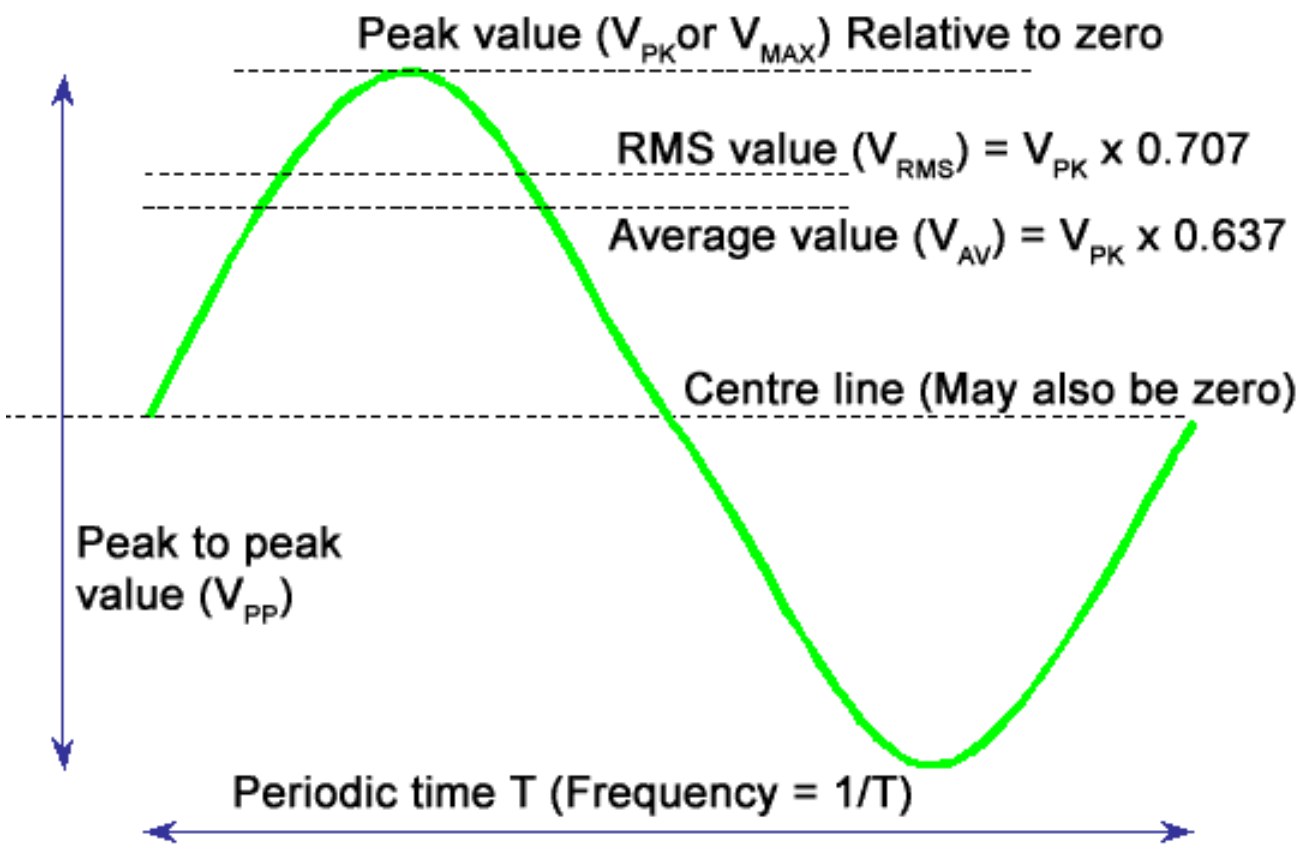






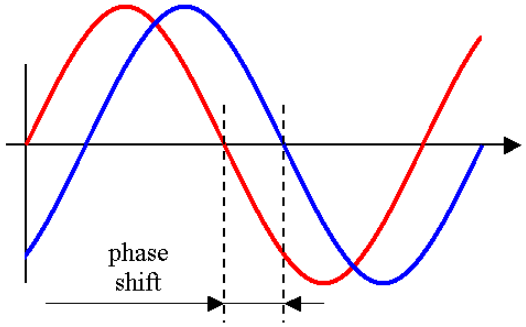
Time/Frequency Domain

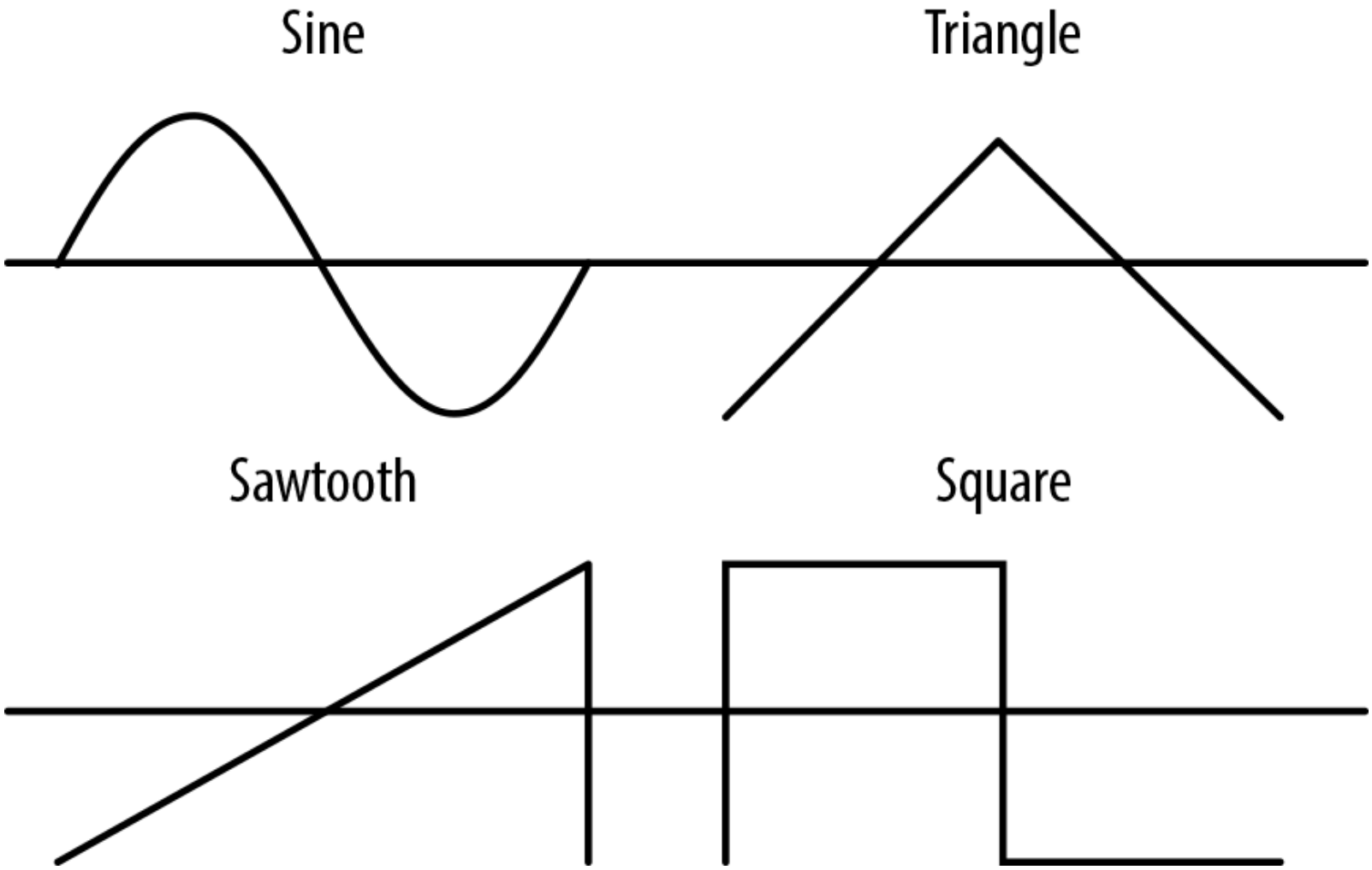
The Spectrum Analyzer Display

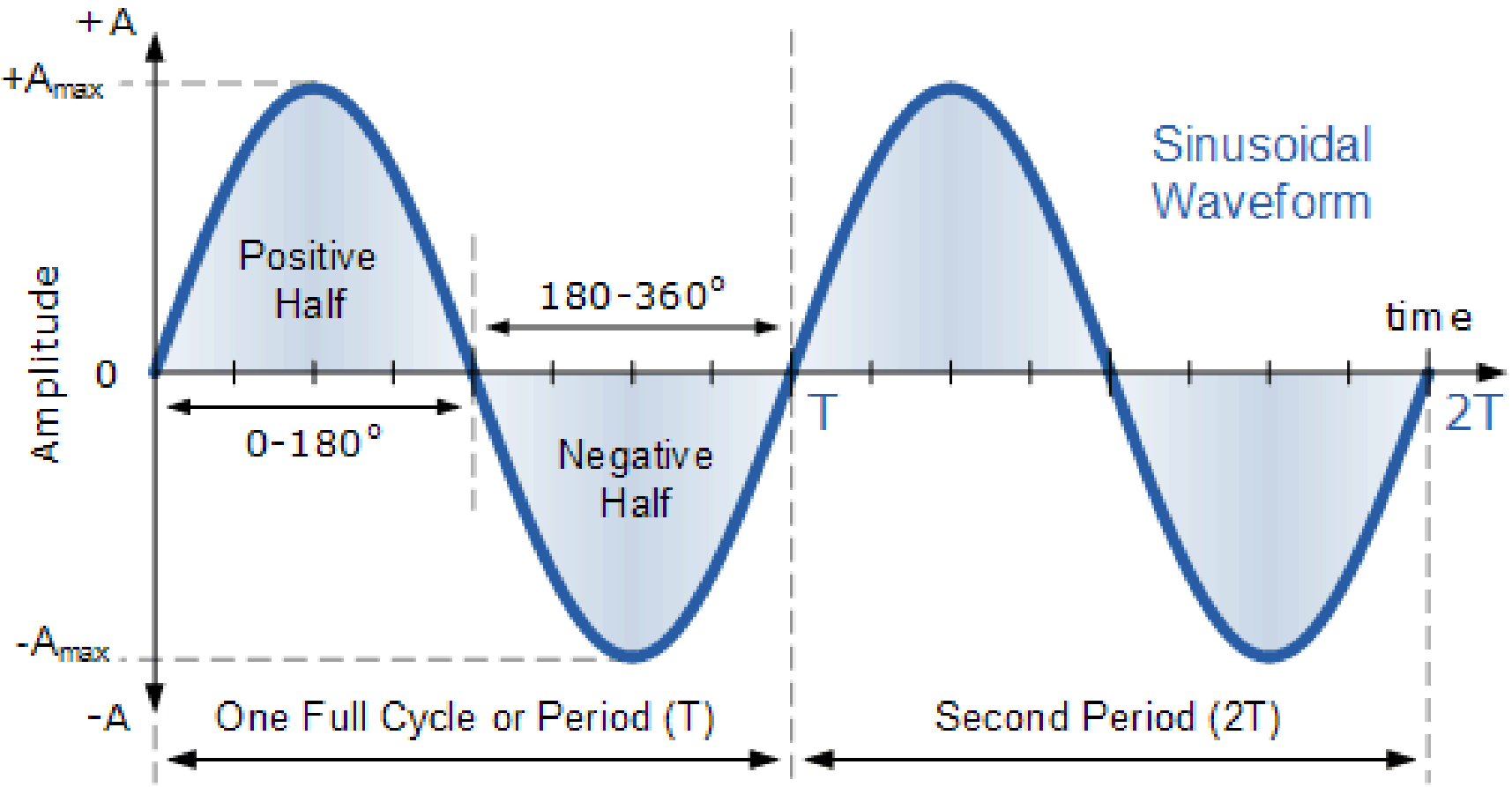


AC/DC coupling

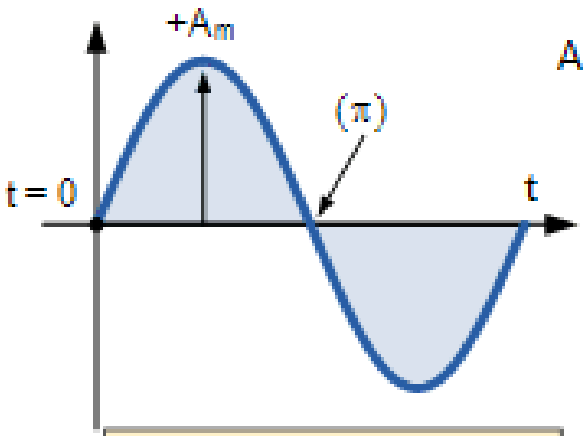
Phase Shift




Sine
Triangle
Sawtooth
Square

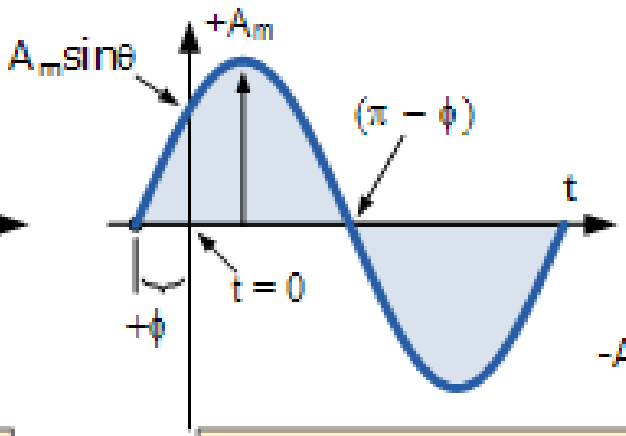

+A
+Amax
Amplitude
0
-Amax
-A
Positive Half
Negative Half
0-180°
180-360°
T
2T
time
Sinusoidal Waveform
One Full Cycle or Period (T)
Second Period (2T)

In-phase ($\phi = 0°$)



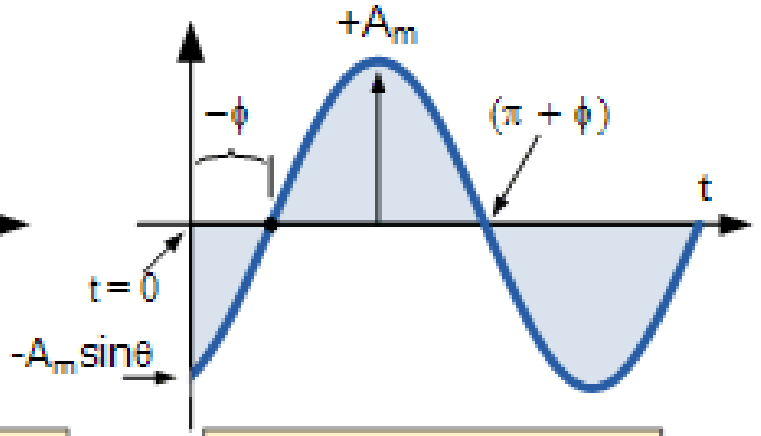
$A_{(t)} = A_m \sin(\omega t)$

Positive Phase ($+\phi$)

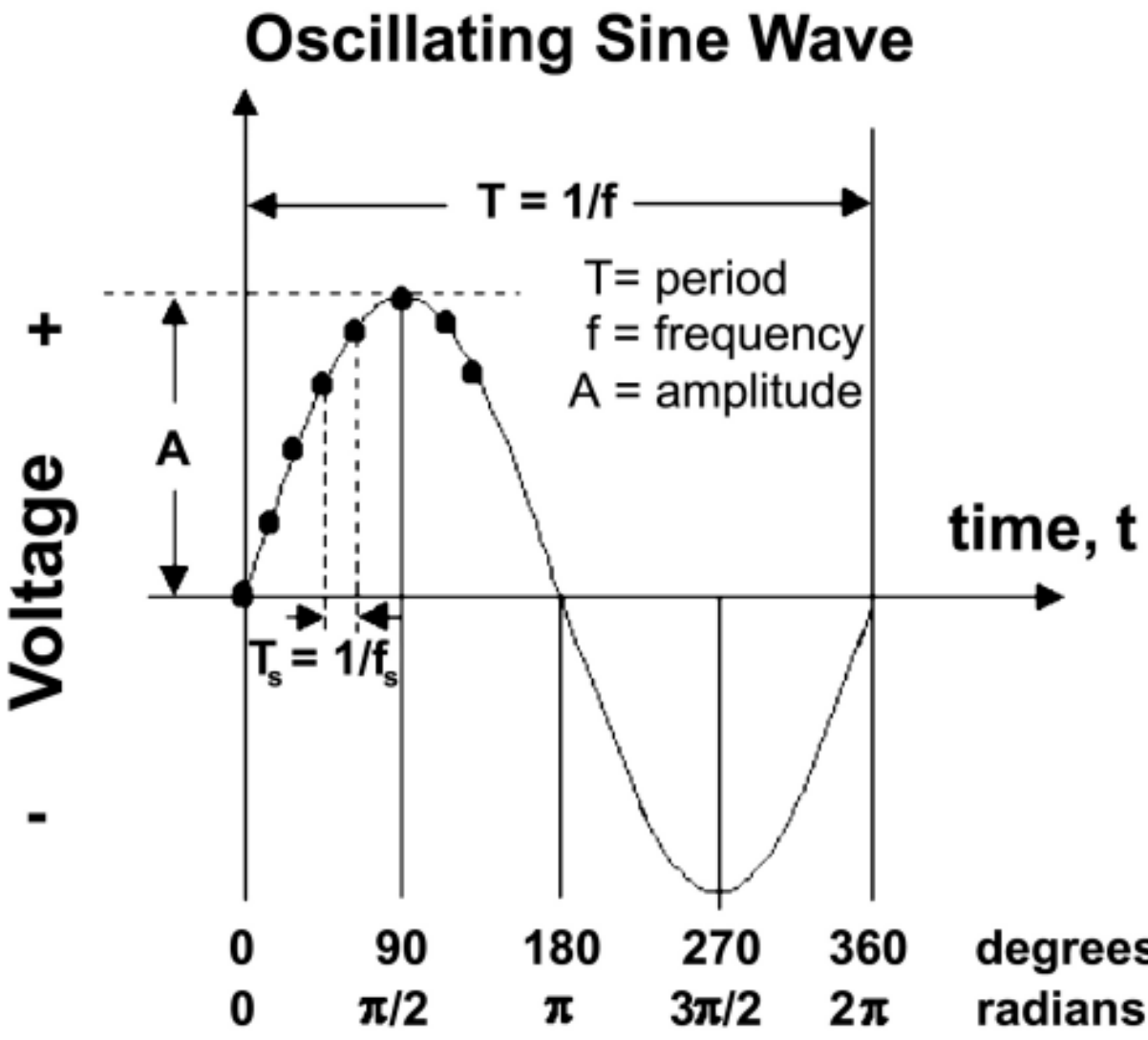


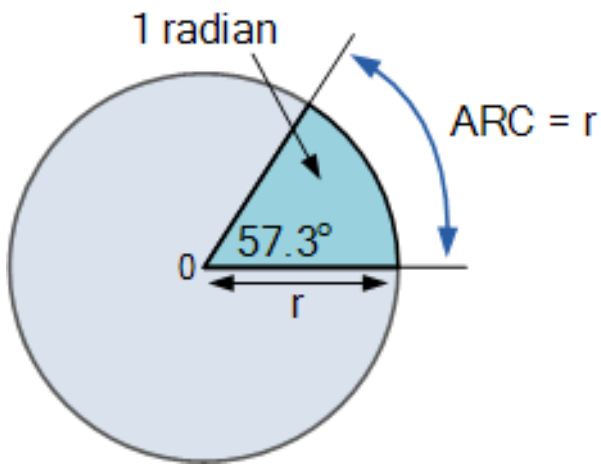
$A_{(t)} = A_m \sin(\omega t+\phi)$

Negative Phase ($-\phi$)



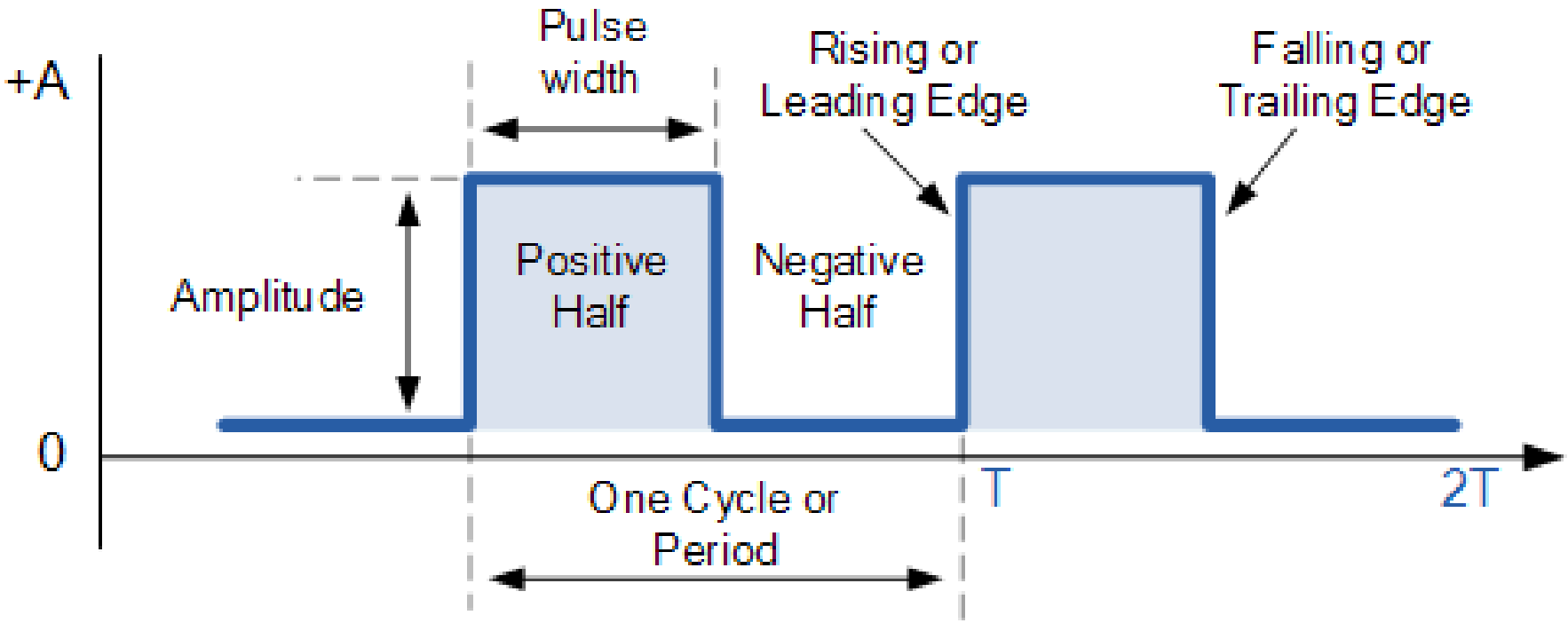
$A_{(t)} = A_m \sin(\omega t-\phi)$





$2\pi \text{ rads} = 360^{\circ}$

$\therefore 1\text{rad} = 57.3^{\circ}$


+A
0
Pulse width
Rising or Leading Edge
Falling or Trailing Edge
Amplitude
Positive Half
Negative Half
T
2T
One Cycle or Period

Approximate a square-wave pattern with a suitable sum that involves a fundamental sine-wave plus a combination of harmonics of this fundamental frequency. Such sums are called **Fourier series**.