Progress Energy

# PROJECT HELIOS


Group 29

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UCF

College of Engineering & Computer Science

# Motivation

- To provide free energy to people in need
- To design a solar power system
- To travel outside of the country
- To experience new cultures and explore new horizons
- To promote the use of new, clean, and sustainable energy sources

# Pomolong Township

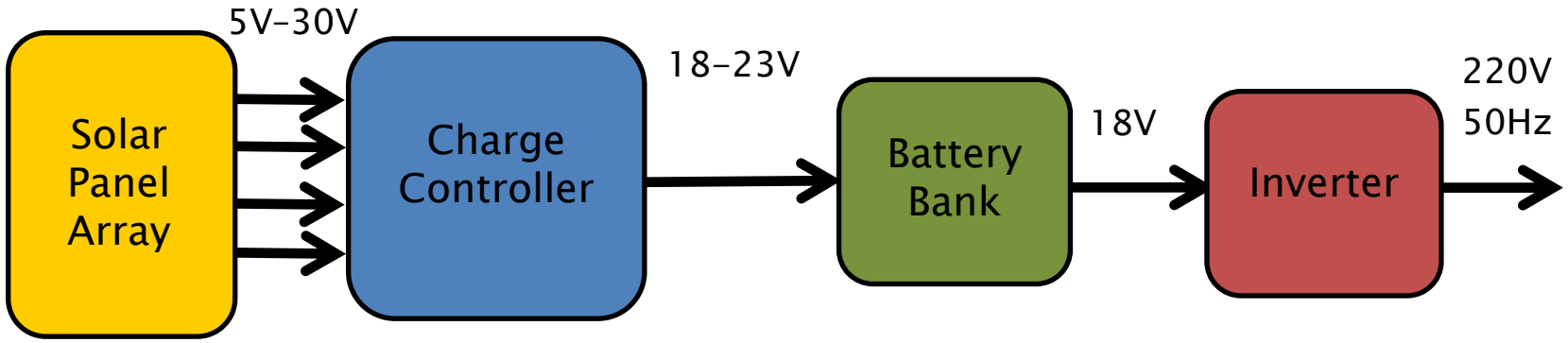
# Goals & Objectives

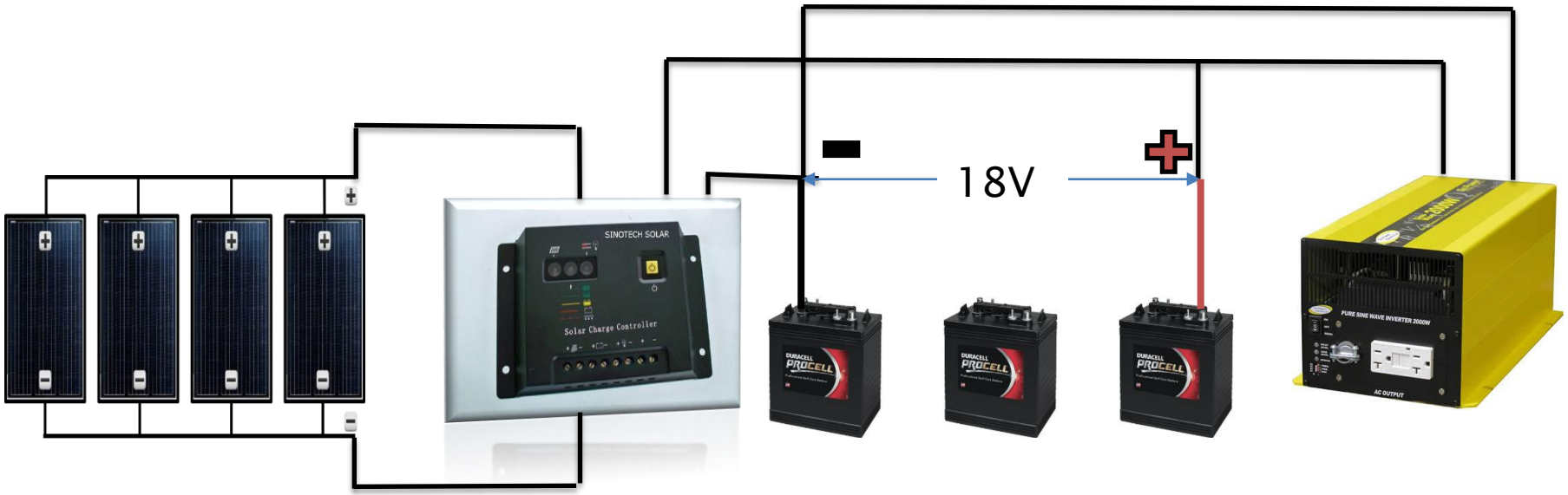
- To generate, store, and distribute power
- Self-sustaining reliable system
- To improve the quality of life of the Pomolong Township
- To deliver AC power

# System Specifications & Requirements

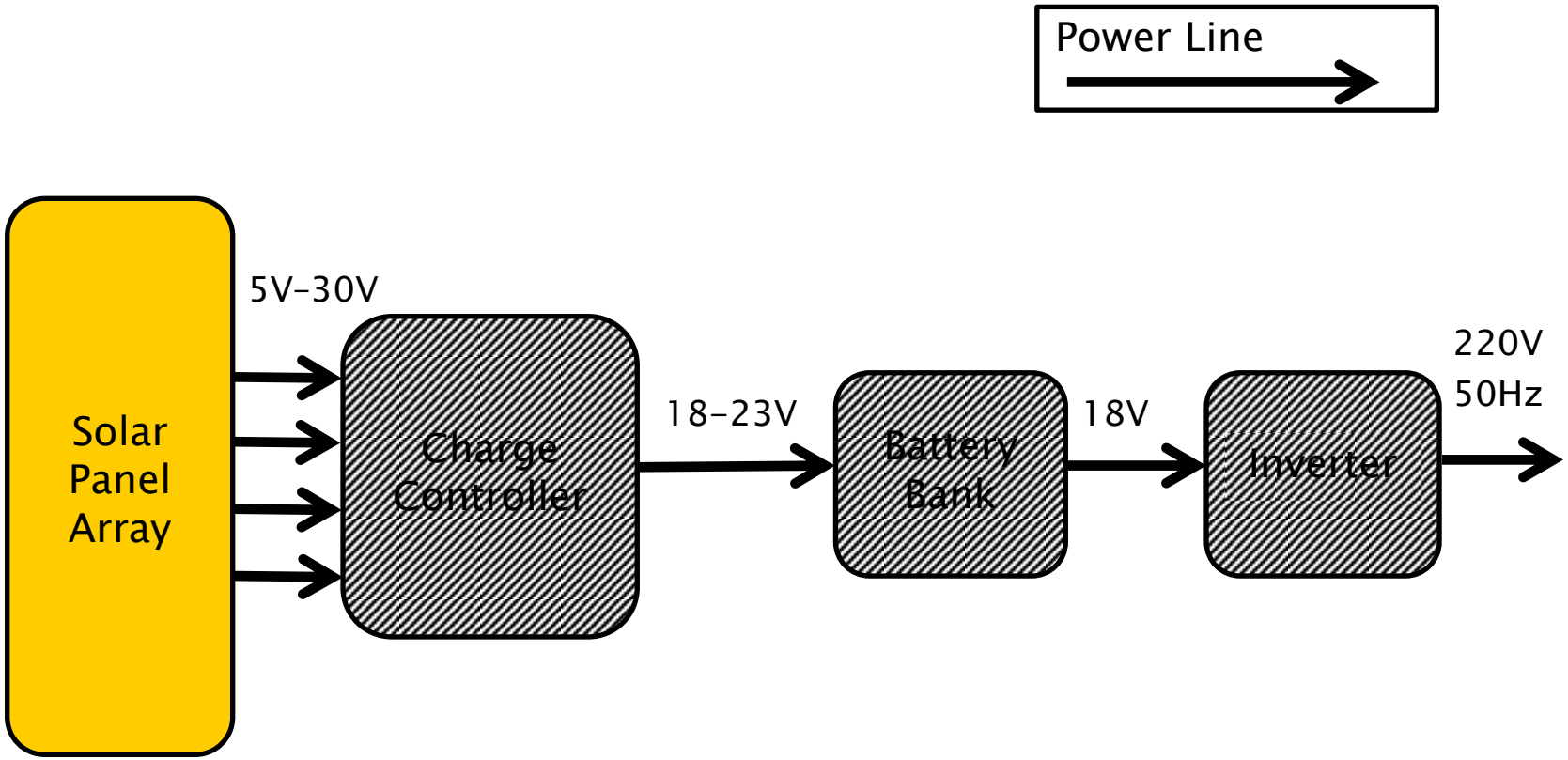
- An off-grid 1000W system
- Output 220V at 50Hz
- Input up to 30V and up to 32A
- Batteries will have a 50% depth of discharge
- 7.5 hours at 10A  without charging
- Work at temperatures from -18 – 52°C

# General Block Diagram



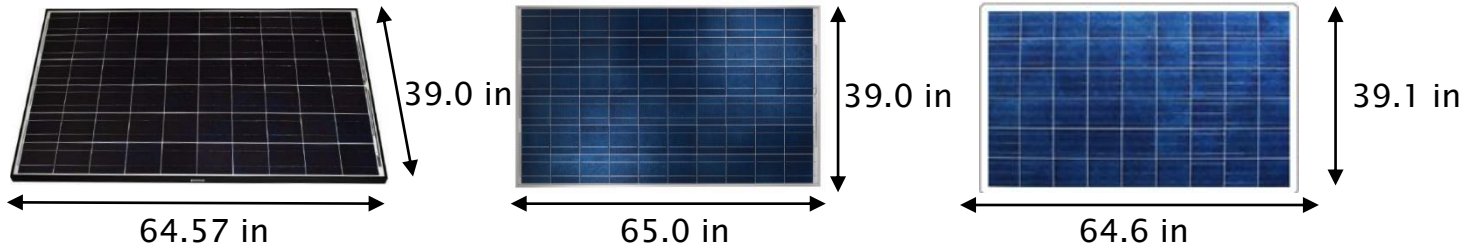



# Solar Panel Array

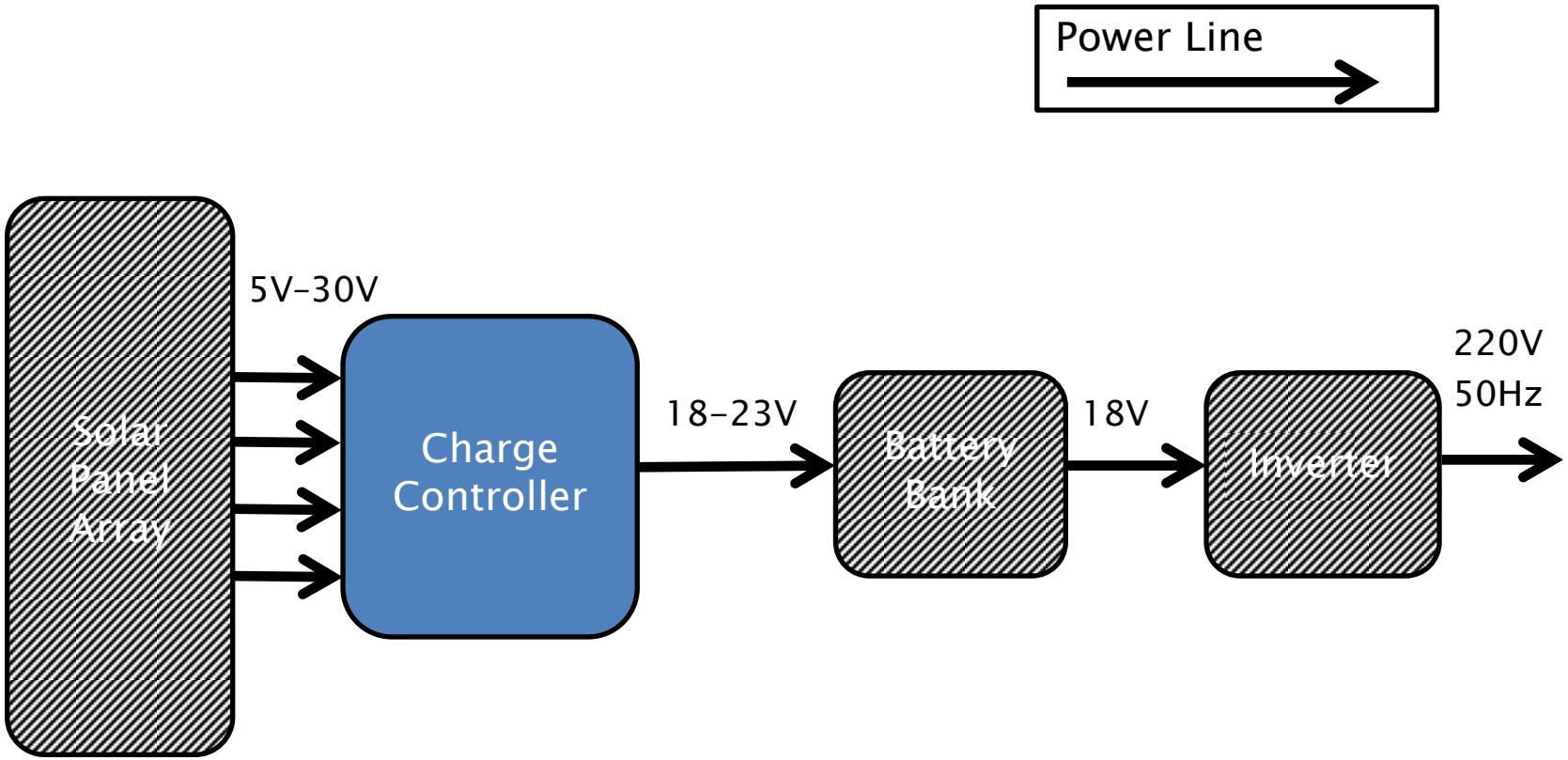


# Solar Panel Comparison

| | ET-P660245B | CHSM6610P | Suntech STP235 |
|---|---|---|---|
| PEAK POWER | 245W | 240W | 235W |
| PEAK VOLTAGE | 30.14V | 29.54V | 30.20V |
| PEAK CURRENT | 8.13A | 8.13A | 7.92A |
| CELL TYPE | POLYCRYSTALLINE | POLYCRYSTALLINE | POLYCRYSTALLINE |
| WEIGHT | 42.6LBS | 44.0LBS | 40.1LBS |
| NUMBER OF CELLS | 60 | 60 | 60 |
| EFFICIENCY | 15.0% | 14.3% | 14.8% |
| COST | $258.00 | $275.00 | $183.00 |

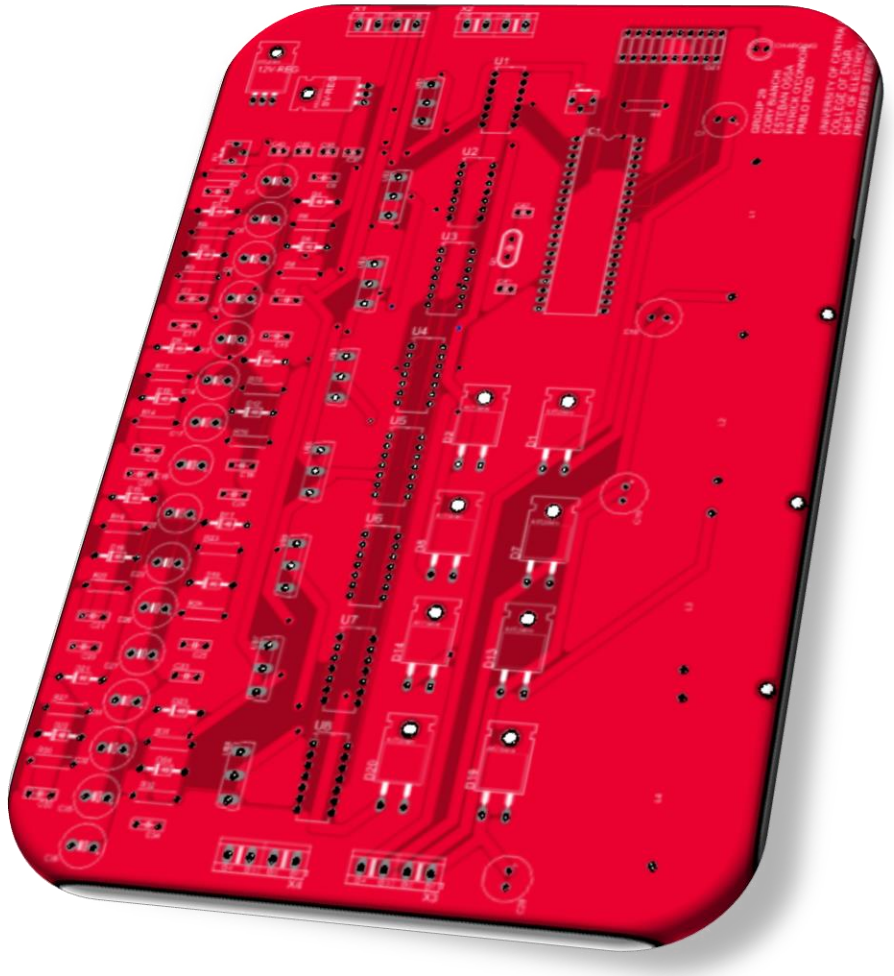


# Charge Controller



# Charge Controller

- Specifications and Requirements
  - 5-30V input
  - Max 32A input
    - Using 4 solar panels that will output 1000W at a maximum of 30V will give us about 32A of maximum input
  - Constant output 20V
    - Need to charge batteries at a higher voltage

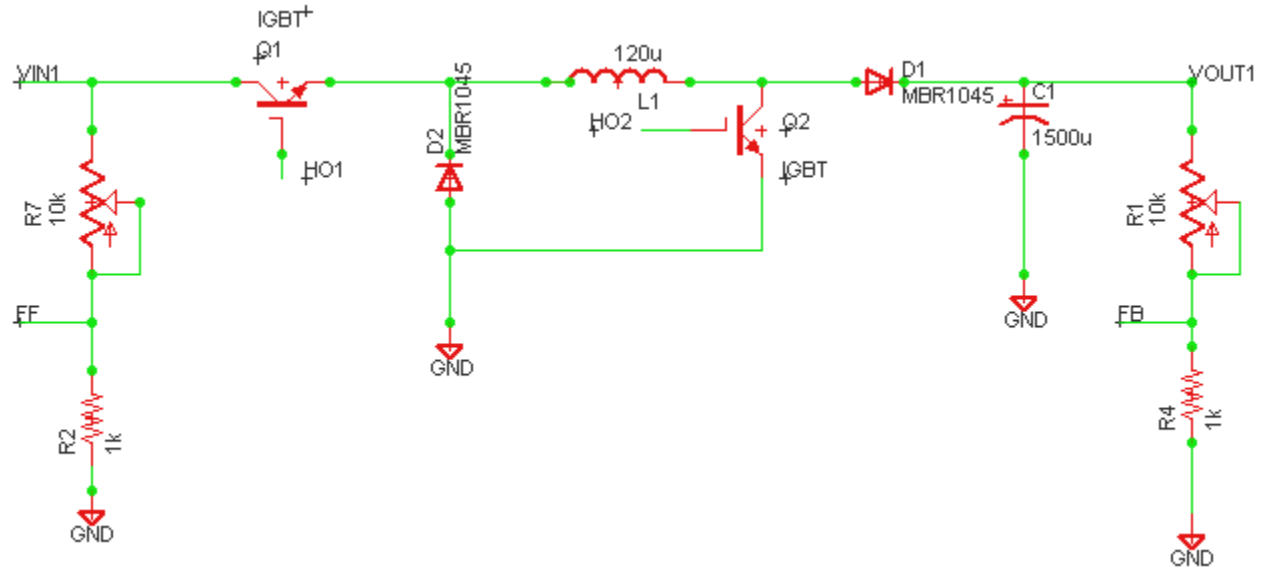


# Charge Controller

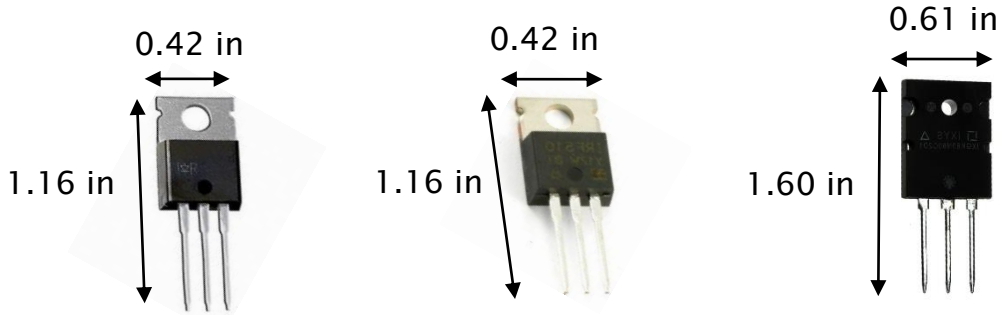
- Analog to Digital Converter
  - 10 bit resolution
  - Step of 4.887mV
  - 5V max input
  - Where Analog to Digital is used
    - 1x Voltage Input
    - 1x Voltage Output
- Battery Charge
  - Check battery voltage using a voltage divider circuit

# Charge Controller

- Buck-Boost Converter
  - Steps voltage up/down
  - Input 5-30V up to 8 A
  - Mode selection based on input voltage
  - Duty cycle is based on output voltage

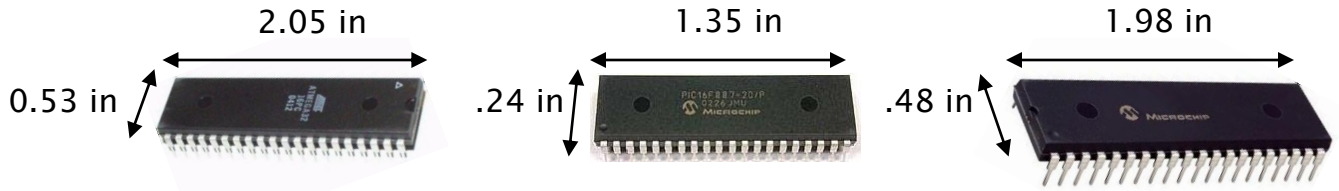


# IGBT/MOSFET Comparison




| | IRL1404 | IRF510 | IXGH6N170 |
|---|---|---|---|
| $V_{max}$ | 40V | 100V | 1700V |
| $I_{max}$ | 160A | 5.6A | 12A |
| $V_{GS}/V_{GE}$ | 3V | 4V | 5V |
| $R_{DS(ON)}$ | 4mΩ | 540mΩ | N/A |
| COST | FREE | FREE | FREE |

# Microcontroller Comparison

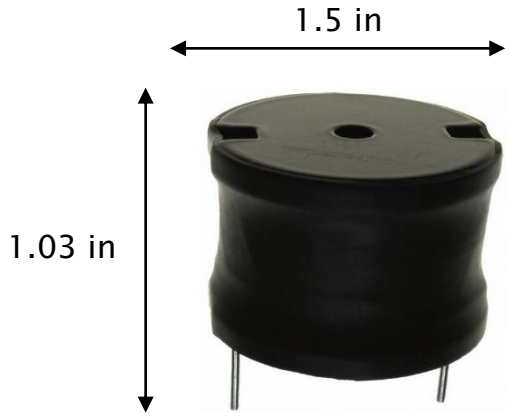



| | ATmega32 | PIC16F887 | PIC18F45K22 |
|---|---|---|---|
| CLOCK | 16MHz | 8MHz | 16MHz |
| ADC CHANNELS | 8 | 14 | 28 |
| PROGRAMMABLE MEMORY | 32Kbytes | 14Kbytes | 32Kbytes |
| INSTRUCTION SET | 131 | 35 | 75 |
| PWM OUTPUT | 4 | 2 | 5 |
| OPERATING VOLTAGE | 2.5 – 5.5V | 2.0 – 5.5V | 2.3 – 5.5V |
| COST | $8.17 | $2.45 | $3.05 |

# Inductor Selection

- $L_{buck} > \frac{Vo*(Vinmax-Vout)}{Kind*Fsw*Vinmax*Iout}$
- $L_{boost} > \frac{Vinmin^2*(Vout-Vinmin)}{Kind*Fsw*Vout^2*Iout}$

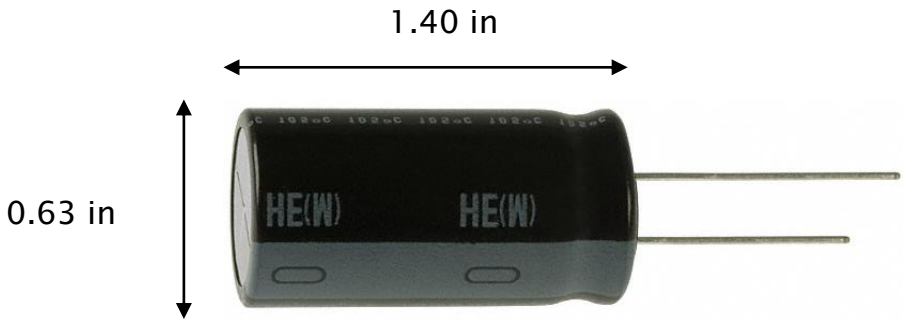
| | 1140-121K-RC |
|---|---|
| INDUCUTANCE | 120uH |
| $I_{max}$ | 14.4A |
| TOLERANCE | ±10% |
| OPERATING TEMPERATURE | -55-105°C |
| COST | $7.17 |



# Capacitor Selection

- Buck
  - $C_{outmin1} > \frac{Kind*Iout}{8*Fsw*\Delta Vout}$
  - $C_{outmin2} > \frac{(Kind*Iout)^2*L}{2*Vout*(ESR*Kind*Iout+\Delta Vout)}$
- Boost
  - $C_{outmin} > \frac{Iout*Dboost}{Fsw*\Delta Vout}$

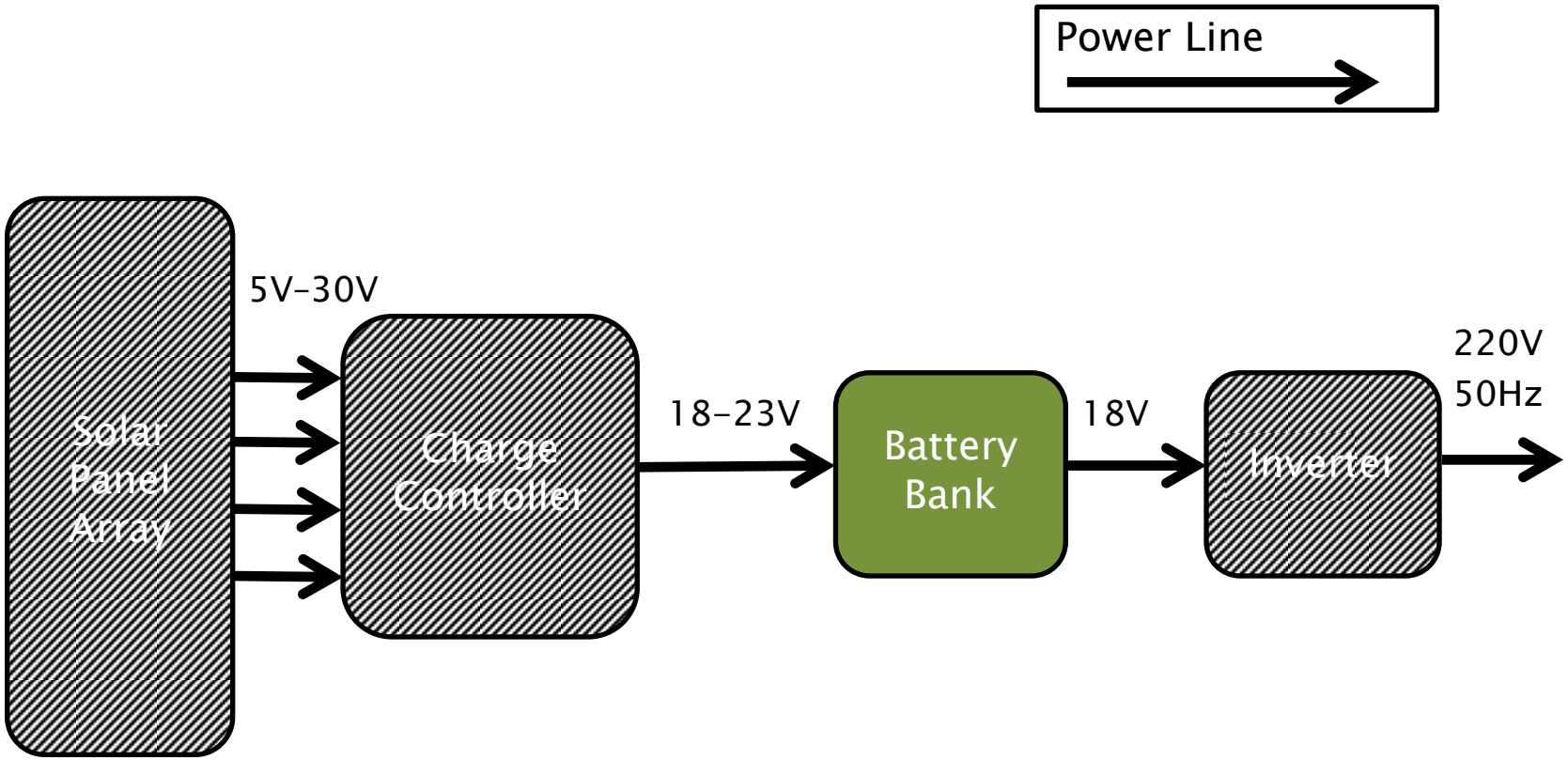
| | UHE1H152MHD |
|---|---|
| CAPACITANCE | 1500uF |
| Vmax | 50V |
| TOLERANCE | ±20% |
| OPERATING TEMPERATURE | -40-105°C |
| COST | $1.29 |



# Diode Selection

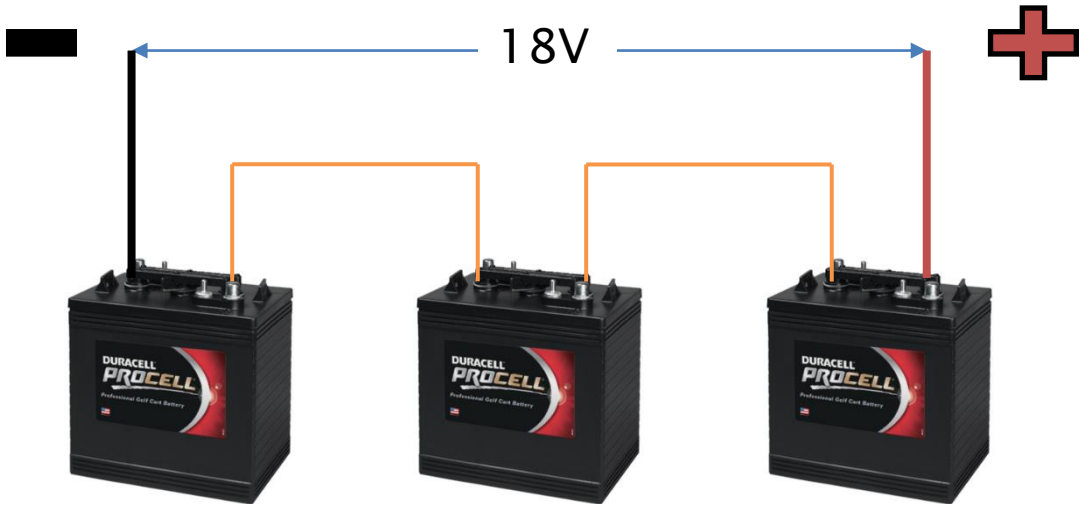
| | MBR1045 |
|---|---|
| $V_{max}$ REVERSE | 45V |
| AVG. FORWARD CURRENT | 10A |
| OPERATING TEMPERATURE | -60-150°C |
| POWER DISSIPATION | 2W |
| COST | $0.64 |

# Battery Bank



# Battery Bank

- Specifications
  - Three 6V batteries
  - Series connection to create a 18V battery bank
  - 215AH Capacity
  - 100AH of usable capacity (50% depth of discharge)
  - Lead acid and deep cycle

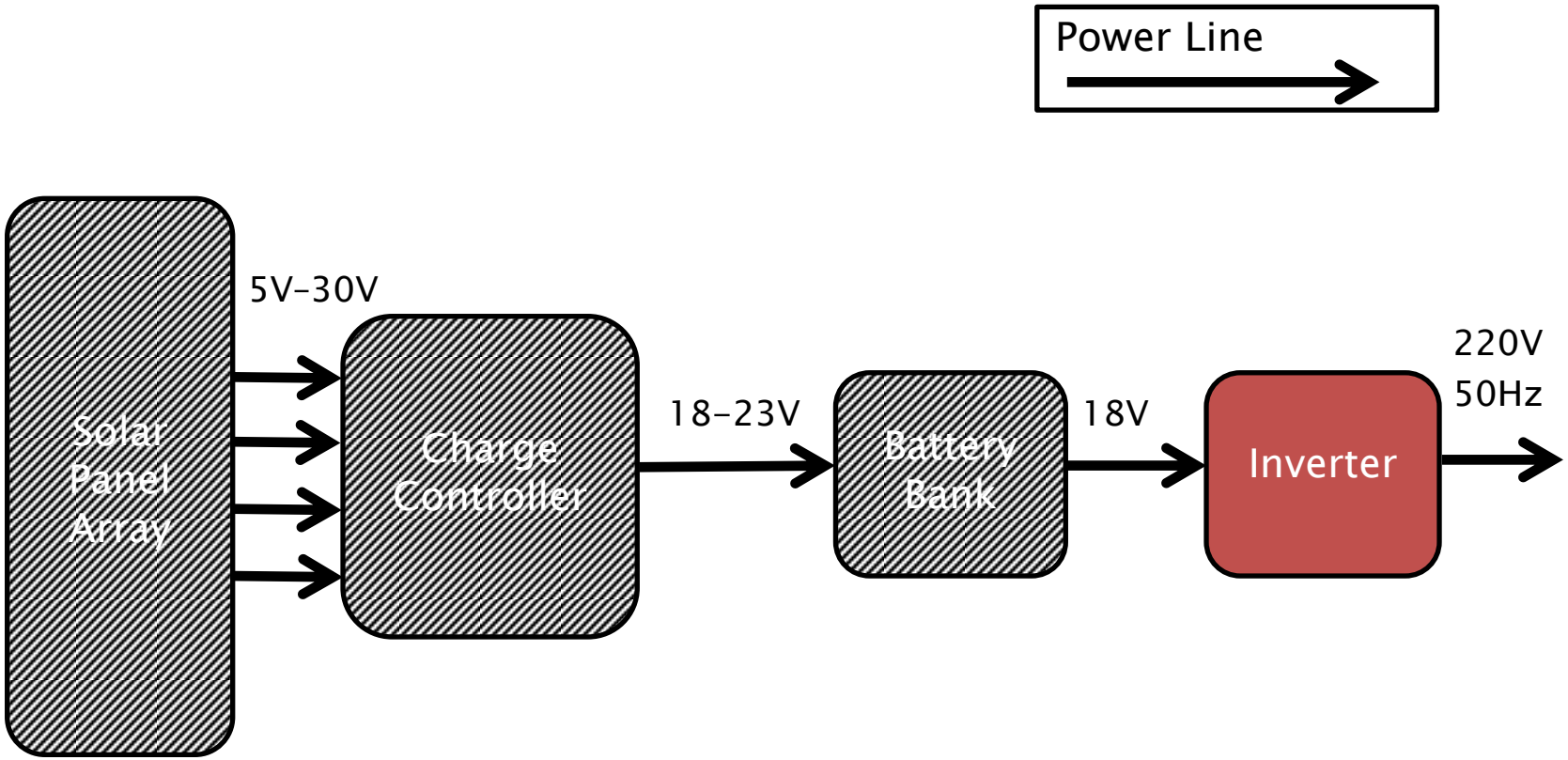


# Battery Comparison

| | DURACELL SLIGC110 | DURACELL EGC2 | TROJAN T-105 |
|---|---|---|---|
| CAPACITY | 215AH | 230AH | 225AH |
| VOLTAGE | 6V | 6V | 6V |
| WEIGHT | 60.5LBS | 64.0LBS | 62.0LBS |
| SIZE | GOLF CART | GOLF CART | GOLF CART |
| COST | $85.00 | $120.00 | $132.00 |

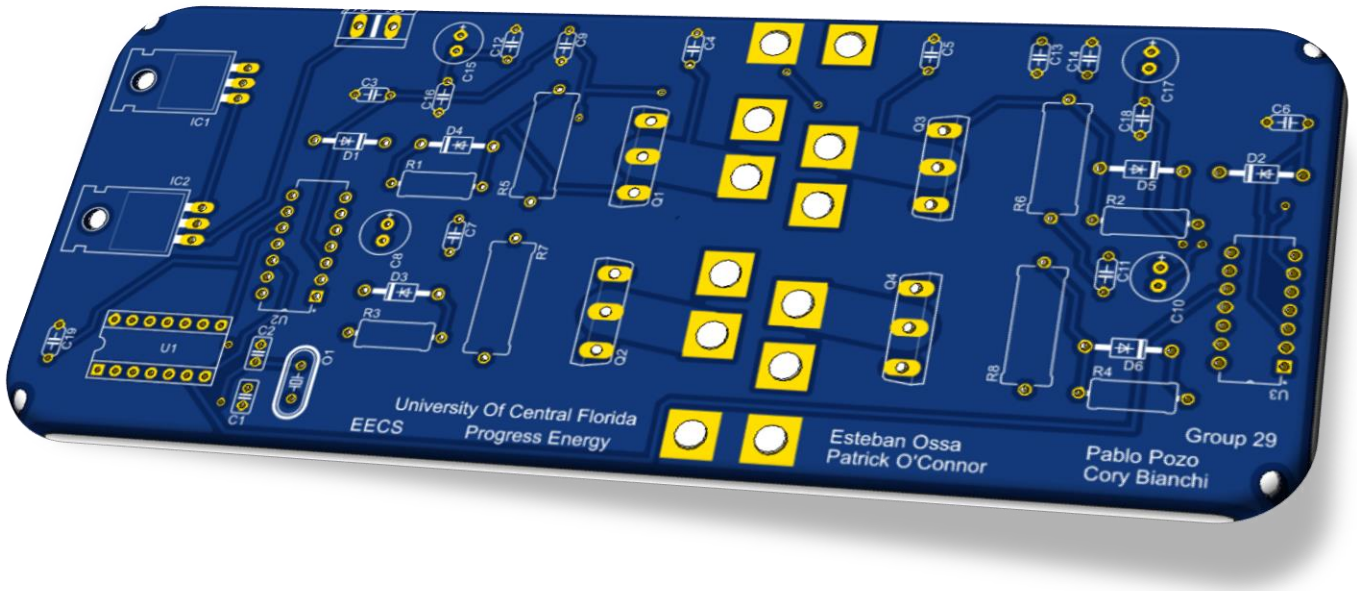


# Inverter

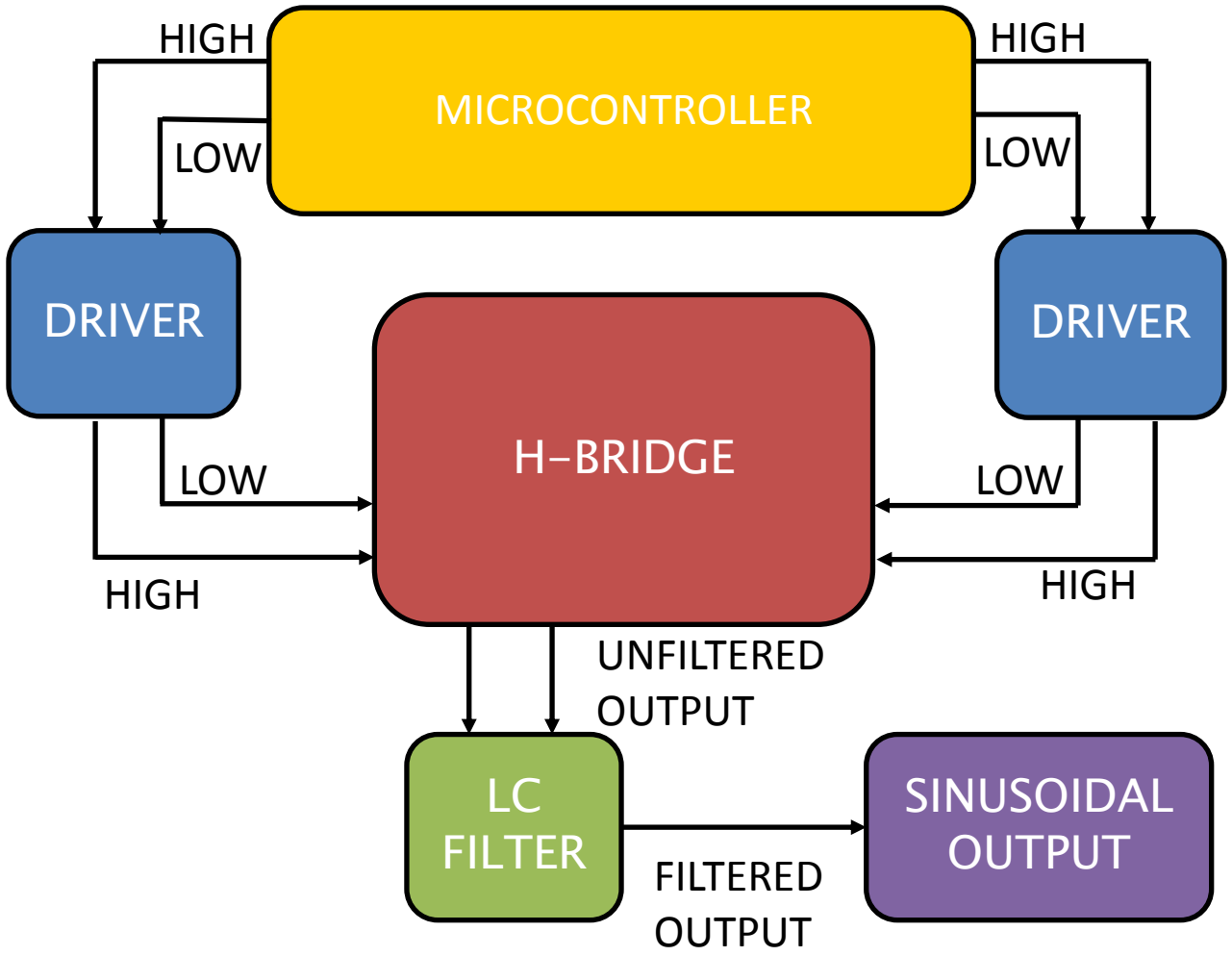

Power Line
Solar Panel Array
5V-30V
Charge Controller
18-23V
Battery Bank
18V
Inverter
220V
50Hz

# Inverter

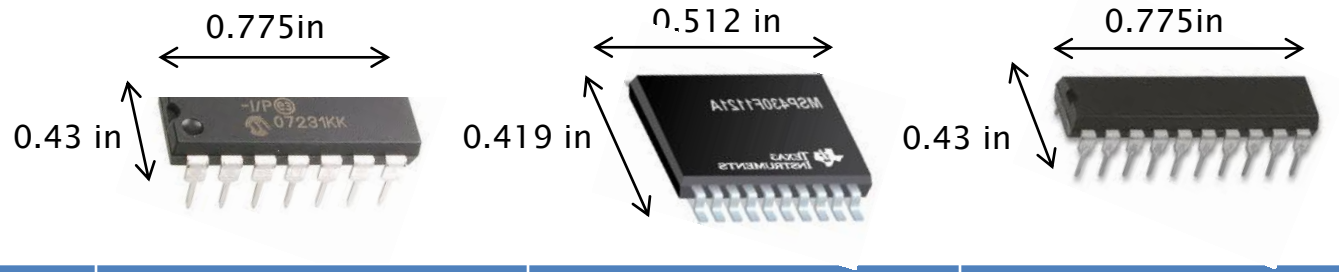
- Specification & Requirements
  - Input voltage 18VDC
  - Pure sine wave output
  - Output 220VAC at 50Hz
  - Deliver 1000W



# Inverter Block Diagram



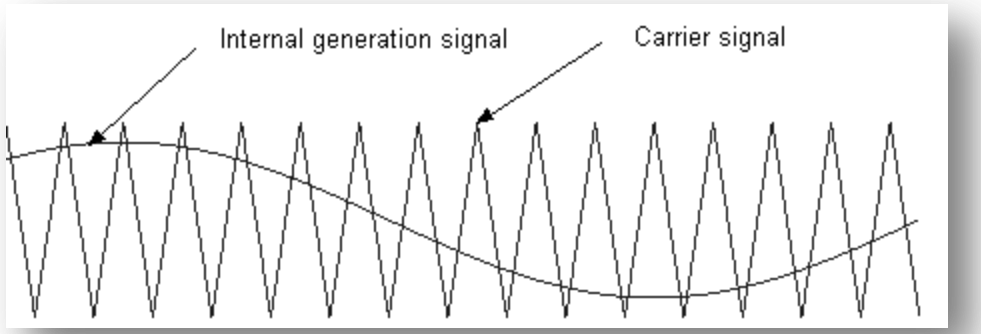
# Microcontroller Comparison

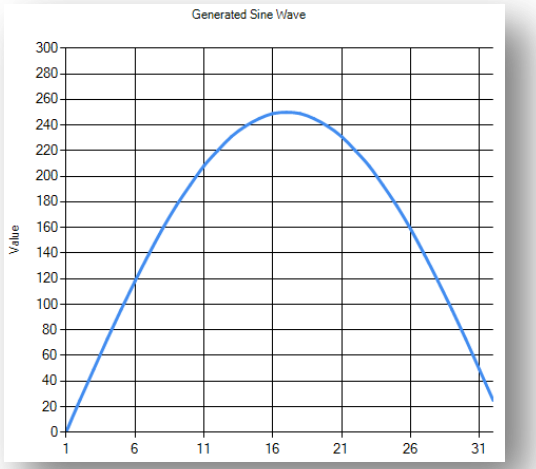



| | PIC16F684-I/P | MSP430F1121A | AT89LP214-20 |
|---|---|---|---|
| CLOCK | 20MHz | 8MHz | 20MHz |
| PROGRAMMABLE MEMORY | 3.5Kbytes | 2Kbytes | 2Kbytes |
| OPERATING VOLTAGE | 2 – 5.5V | 1.8 – 3.6V | 2.4 – 5.5V |
| COMPARATOR | 2 | 1 | 1 |
| PWM | 1 | 1 | 0 |
| COST | $1.96 | $1.75 | $1.96 |

# Programming the PIC16F684

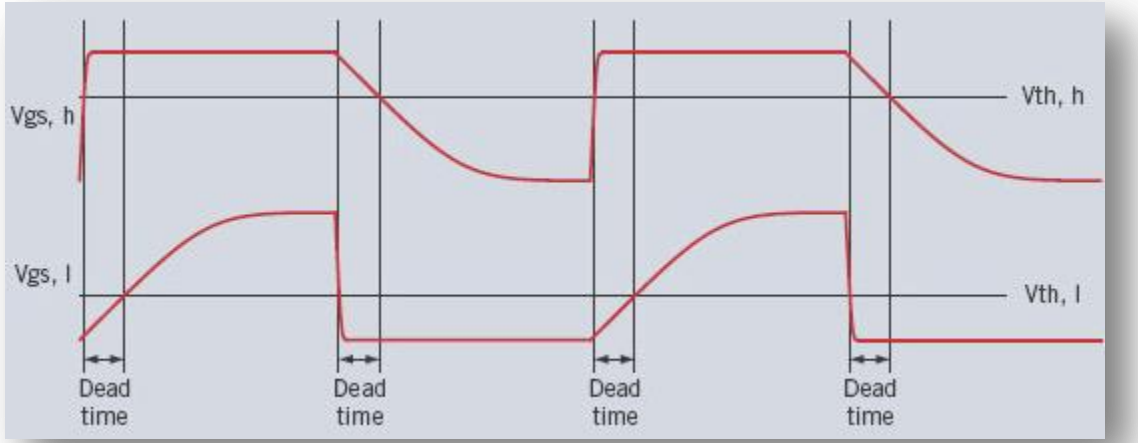
- Digitally produce a sine wave
- Set of values that can approximate a sine wave signal
- Minimum of 32 values to create a proper approximation
- Values will vary from 0° to 360°



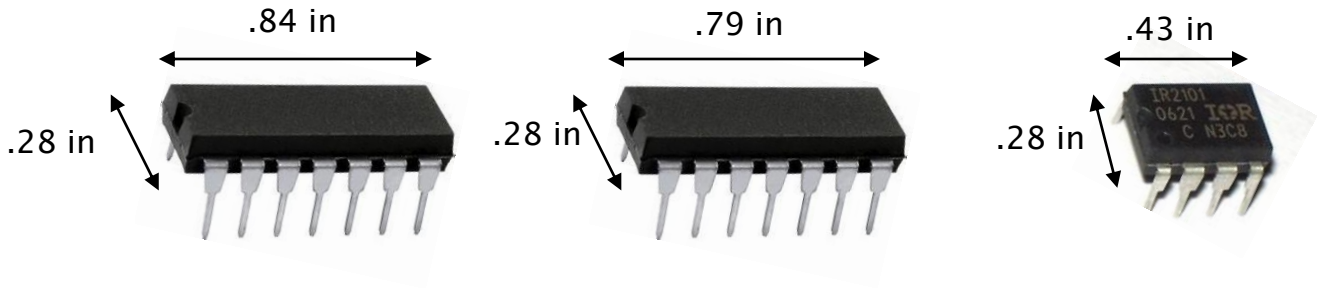
# MOSFET Driver

- $V_{DD} > 5V$, $V_{cc} > 12V$
- Low and high side driver
- Tolerant to negative transient voltage
- Fast on time
- Fast off dead time

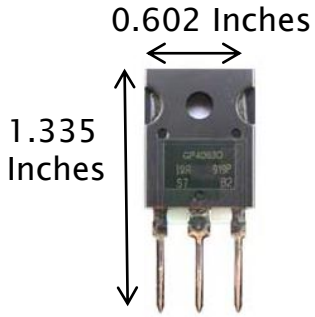


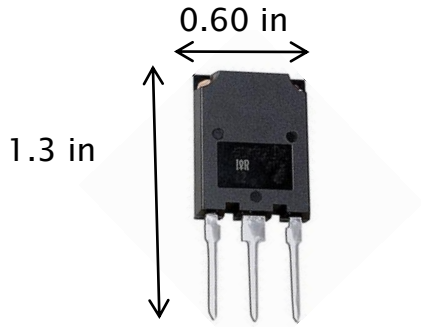
# MOSFET Driver Comparison

| | IR2110 | IR2112 | IR2101 |
|---|---|---|---|
| $V_{OFFSET}$ | 500V max | 600V max | 600V max |
| $I_{o+/-}$ | 2A/2A | 200mA/420mA | 130mA/270mA |
| $V_{OUT}$ | 10-20V | 10-20V | 10-20V |
| $t_{on}$ / $t_{off}$ | 160ns / 150ns | 125ns / 105ns | 160ns / 150ns |
| DELAY MATCHING | 10ns | 30ns | 50ns |
| COST | $1.88 | $1.55 | $1.18 |



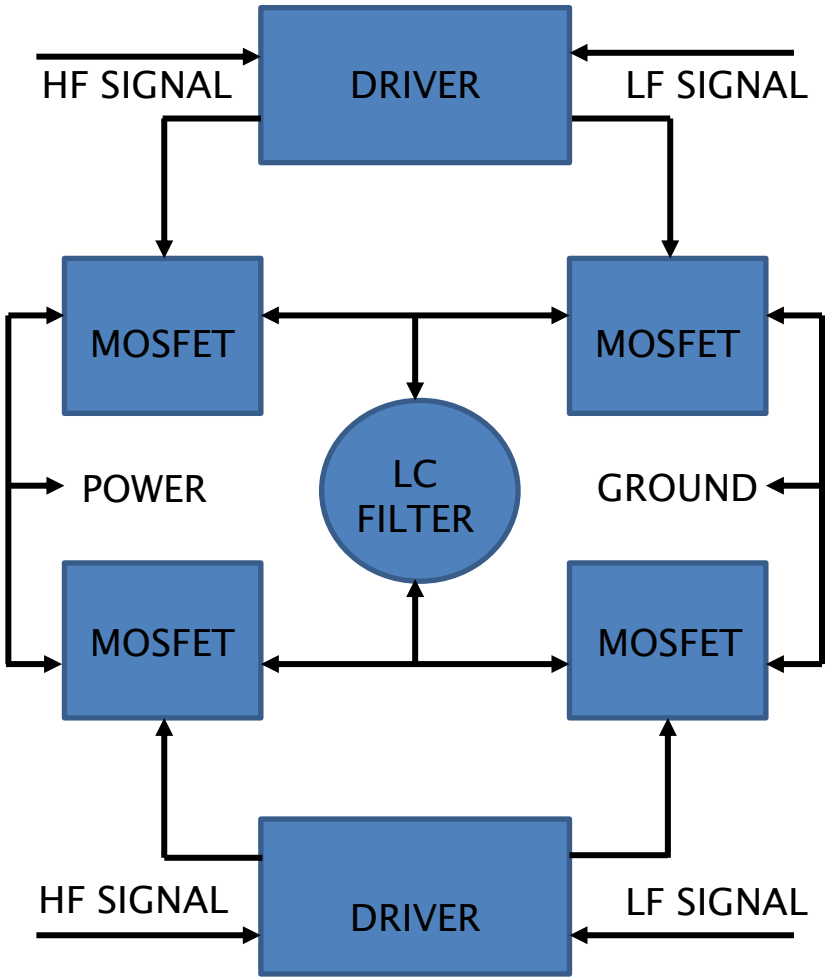
# IGBT/MOSFET Comparison



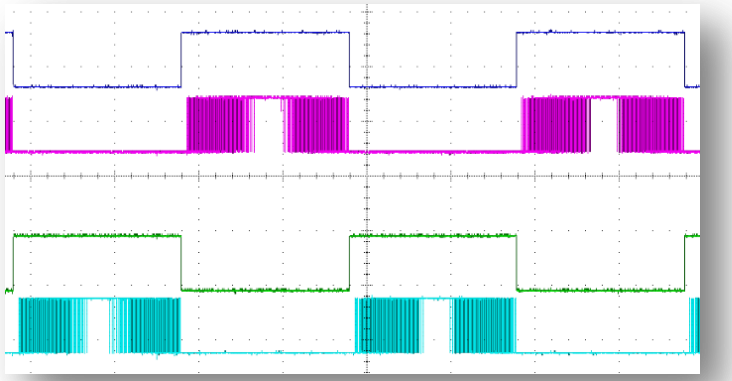




| | HIGH SIDE (Q1,Q3) | | LOW SIDE (Q2,Q4) | |
|---|---|---|---|---|
| | IRG4PC40UD | IRFPS3810 | IRG4PC40FDP | IRFPS3810 |
| POWER DISSIPATION | 8.7W | 12W | 7.53W | 12W |
| OPERATION FREQUENCY | 8-30KHz | 1MHz | <1KHz | 1MHz |
| TURN ON VOLTAGE | 1.7V | 3.0V | 1.5V | 3.0V |
| SPEED | ULTRAFAST | ULTRAFAST | FAST | ULTRAFAST |
| COST | $6.46 | FREE | $6.33 | FREE |

# MOSFET H-Bridge



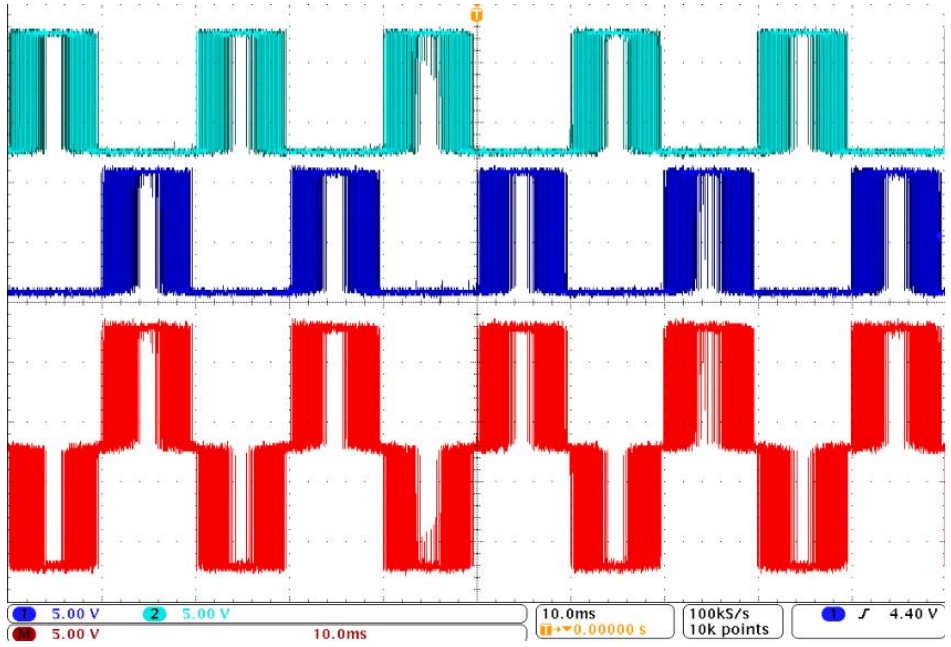

- Low Frequency & High Frequency signals from the microcontroller



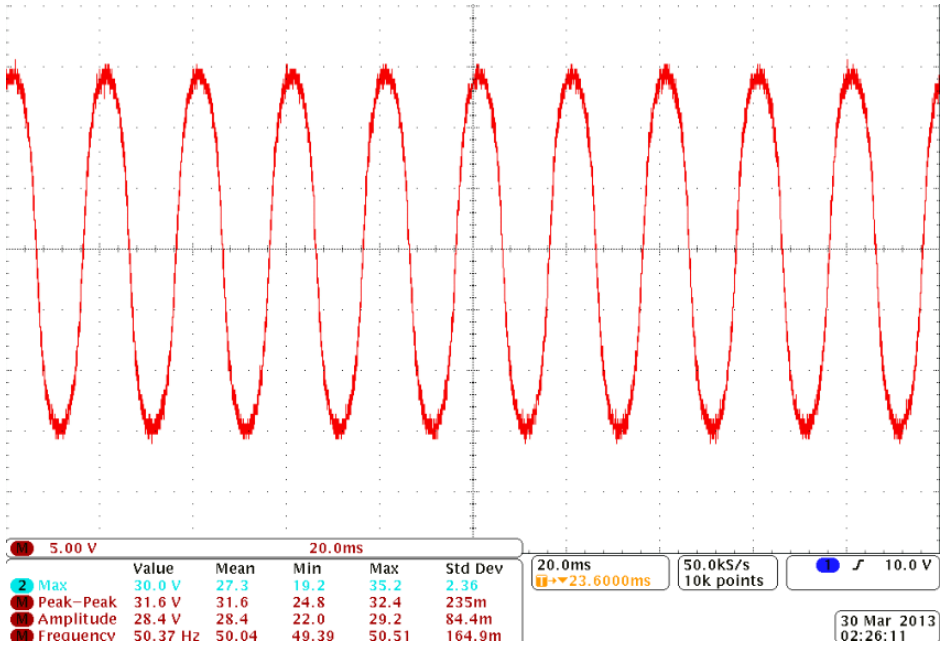
# LC Filter

- Filter frequencies above 50Hz
- Current rating of up to 42A

Unfiltered Output

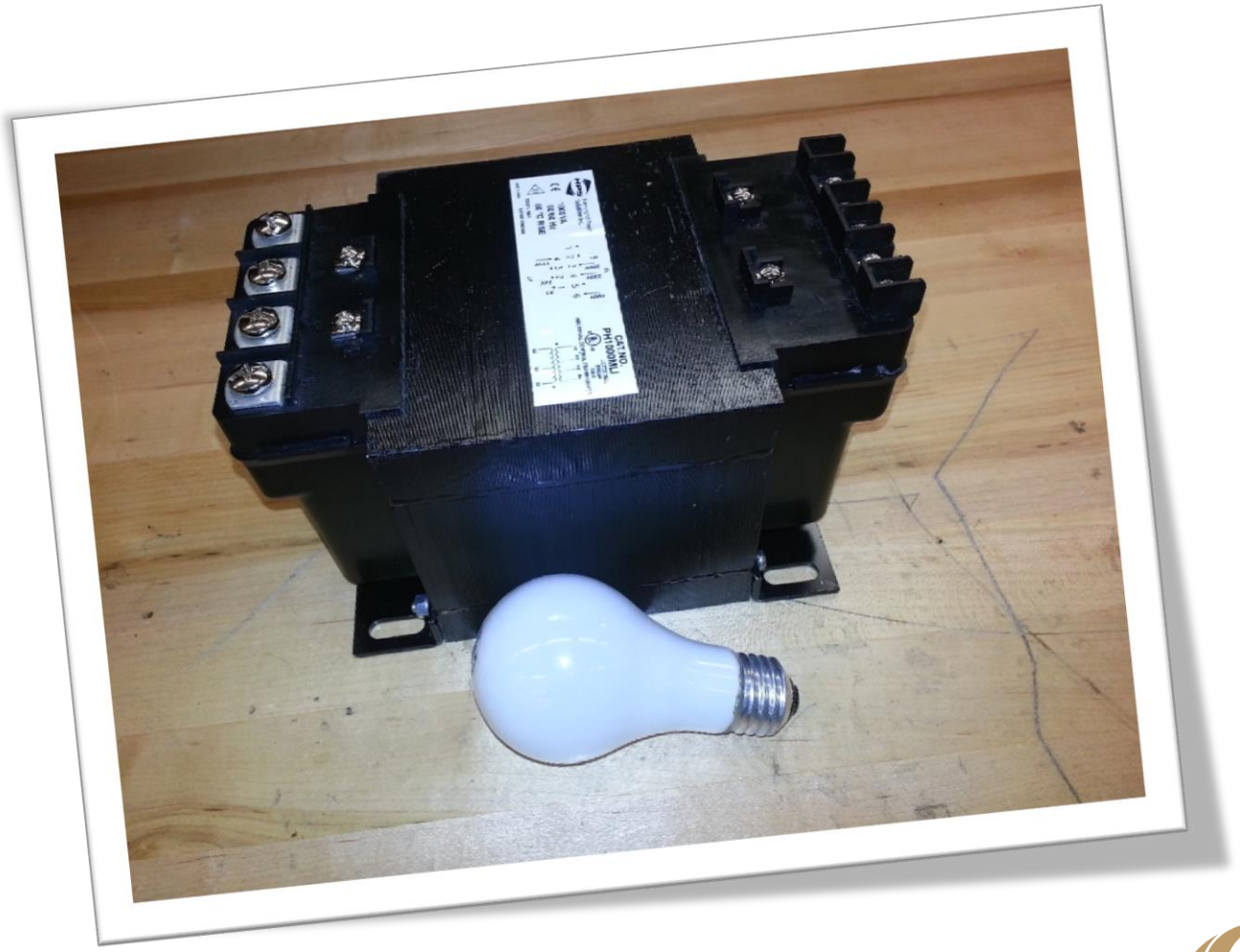



Filtered Output



# Transformer

- Input voltage 18V
- Output voltage 220V
- Frequency 50Hz
- Power rating 1000VA



# Problems

- INVERTER
  - IGBTs switching problems in the H-bridge
  - Transformer interference with the LC filter
  - Boost converter design difficulties

- CHARGE CONTROLLER
  - Driving the gates on the MOSFETs and IGBTs
  - Accuracy of the feedback

# Results

- Inverter Efficiency
  - Voltage Input: 18.36V
  - Current Input: 6.5A
  - Power Input: 119.34W
  - Voltage Output: 223.2V
  - Current Output: 0.406A
  - Power Output: 90.62W
  - **76% Efficiency**

# Work Distribution

| | PABLO | ESTEBAN | PATRICK | CORY |
|---|---|---|---|---|
| Solar Panels | | | X | X |
| Charge Controller | | | X | X |
| Battery Bank | X | X | | |
| Inverter | X | X | | |

# Budget

| COMPONENT DESCRTIPTION | TOTAL ITEMS | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|
| CAP CER 0.1UF 50V 5% RADIAL | 66 | $0.65 | $42.90 |
| DIODE FAST 1000V 1A DO-41 | 46 | $0.43 | $19.78 |
| CAP ALUM 47UF 50V 20% RADIAL | 54 | $0.25 | $13.50 |
| IC DRIVER HIGH/LOW SIDE 14DIP | 34 | $4.26 | $144.84 |
| RES 10 OHM 1W 1% WIREWOUND AXL | 34 | $0.44 | $14.96 |
| RES 1.0K OHM 3W 5% METAL OXIDE | 12 | $0.59 | $7.08 |
| CAP CER 15PF 50V 5% RADIAL | 14 | $0.29 | $4.06 |
| CAP CER 0.22UF 50V 10% RADIAL | 6 | $0.38 | $2.28 |
| CAP CER 0.1UF 50V 10% RADIAL | 12 | $0.20 | $2.40 |
| CAP CER 0.33UF 50V 10% RADIAL | 10 | $0.27 | $2.67 |
| 16MHz - 18PF | 50 | $0.35 | $17.50 |
| CONN IC SOCKET VERT 14POS TIN | 16 | $0.22 | $3.52 |
| HEATSINKS | 12 | $1.95 | $23.40 |
| ENCLOSURE | 1 | $35.00 | $35.00 |

# Budget

| DESCRTIPTION | TOTAL ITEMS | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|
| DIODE MBR1045 | 25 | $0.64 | $16.10 |
| LED STACK LIGHT | 1 | $6.92 | $6.92 |
| LED BLUE | 2 | $0.21 | $0.42 |
| RESISTOR 1K | 32 | $0.06 | $1.82 |
| CAP ELEC 1.5mF | 10 | $1.29 | $12.87 |
| INDUCTOR 120uH | 8 | $7.17 | $57.36 |
| SOCKET 40 PIN | 2 | $0.51 | $1.02 |
| TERM BLOCK 2POS | 3 | $0.63 | $1.89 |
| TERM BLOCK 4POS | 6 | $0.73 | $4.38 |
| HEATSINK AND CLIP FOR TO-247 | 12 | $2.07 | $24.84 |
| PIC 16F887 | 5 | $2.80 | $14.00 |
| SOLAR PANEL | 4 | $183.00 | $732.00 |
| BATTERIES | 4 | $85.00 | $340.00 |
| PCB INVERTER | 1 | $464.00 | $464.00 |
| PCB CHARGE CONTROLLER | 1 | $66.00 | $66.00 |
| EASYPIC 7 | 2 | $140.00 | $280.00 |
| CABLES | 1 | $140.00 | $140.00 |
| PIC 16F684 | 20 | $1.96 | $39.20 |
| | | **TOTAL** | **$2,536.71** |

# Sponsors

Progress Energy

UCF

College of Engineering & Computer Science

## Special Thanks:

- Dr. Richie
- CECS & EECS
- Mike Tullbane
- Honors College

# Questions??