Low Carbon Footprint Hybrid Battery Charger

Project Progress

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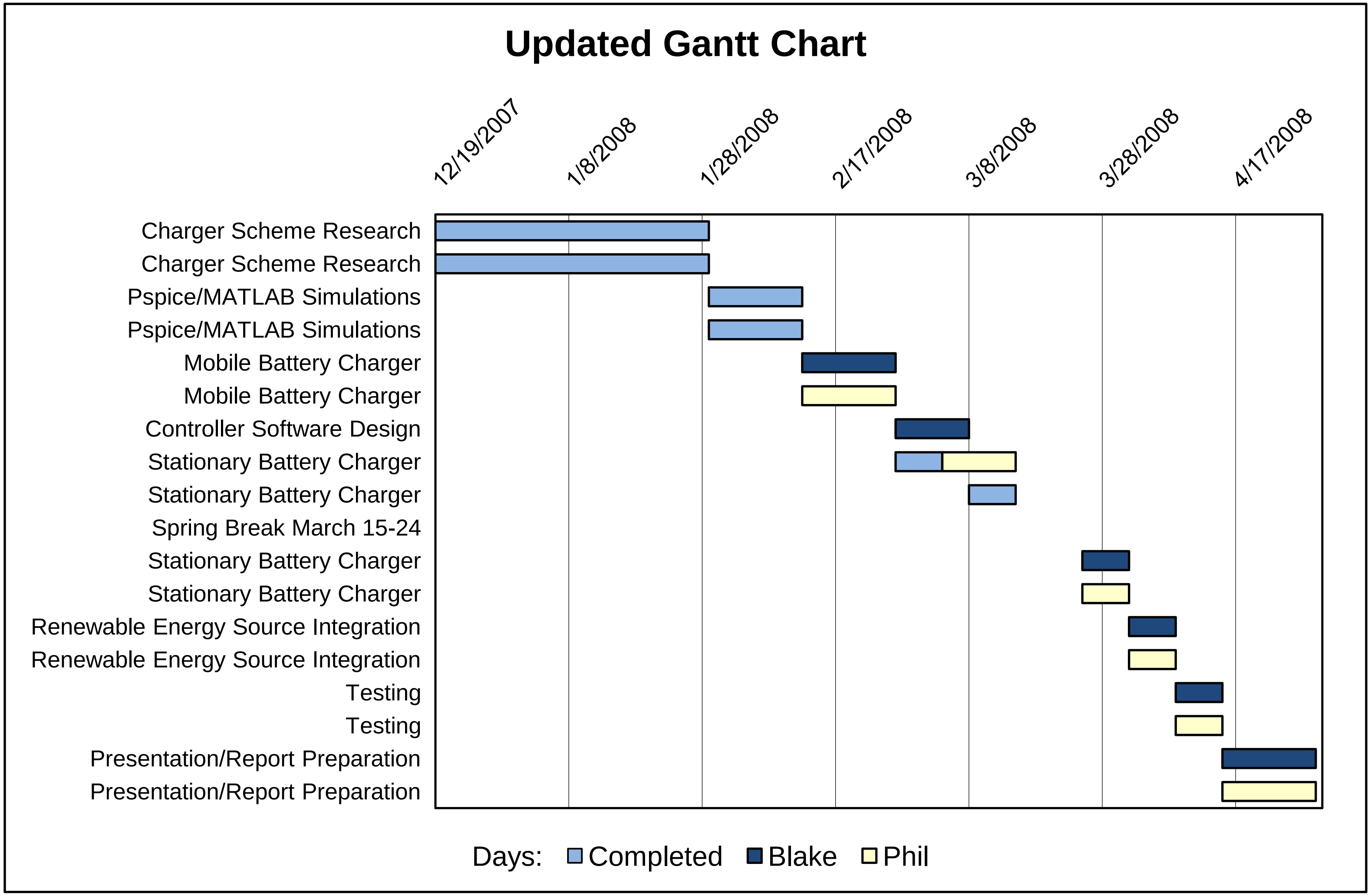
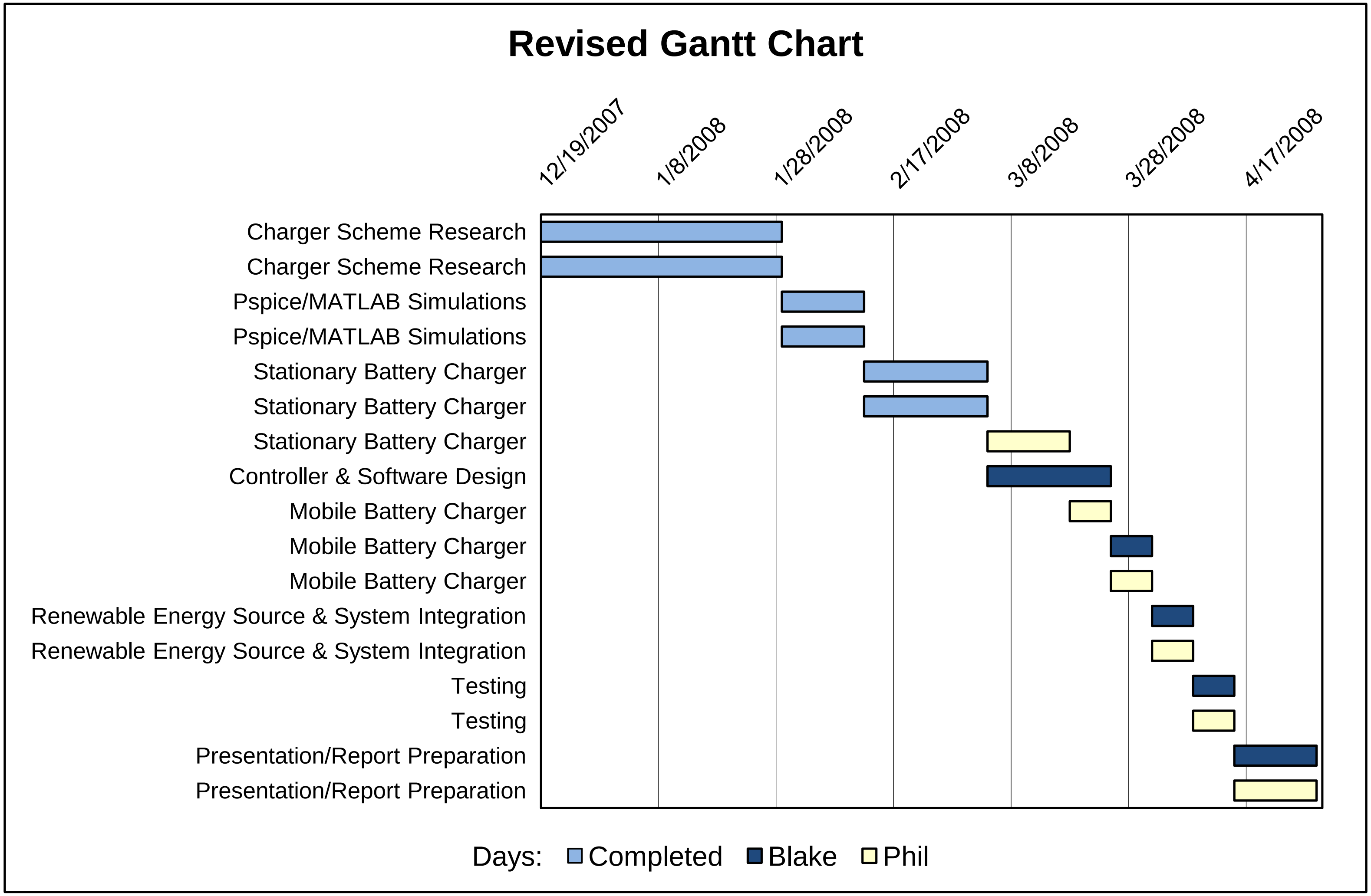
Presentation Outline

- Project Status
  - Time Management
  - Project Delays
  - Updated Flowchart
  - Updated Materials
- Project Updates
  - Buck-Boost Scheme
  - Charger Scheme
  - PSPICE Simulations
  - Controller & Software Design

Project Status

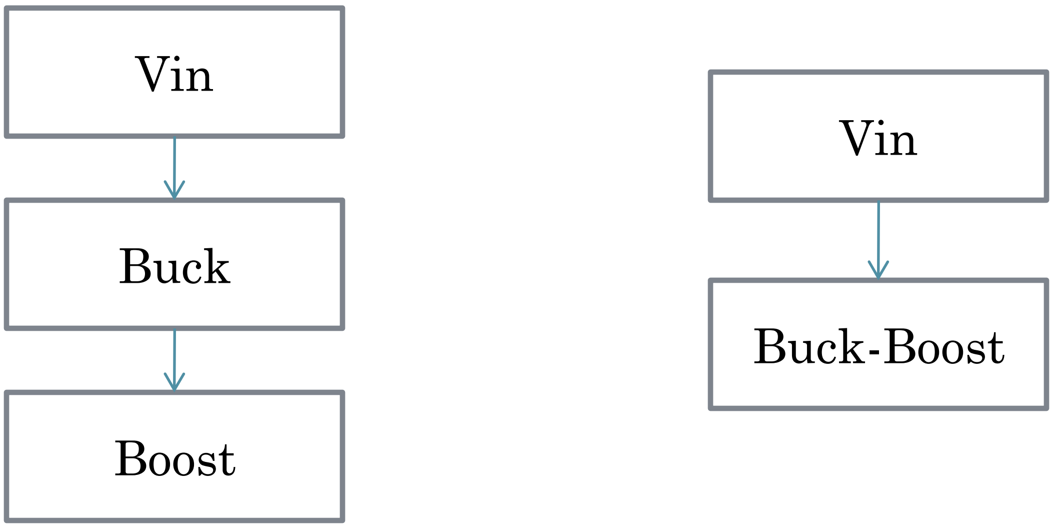


Project Status



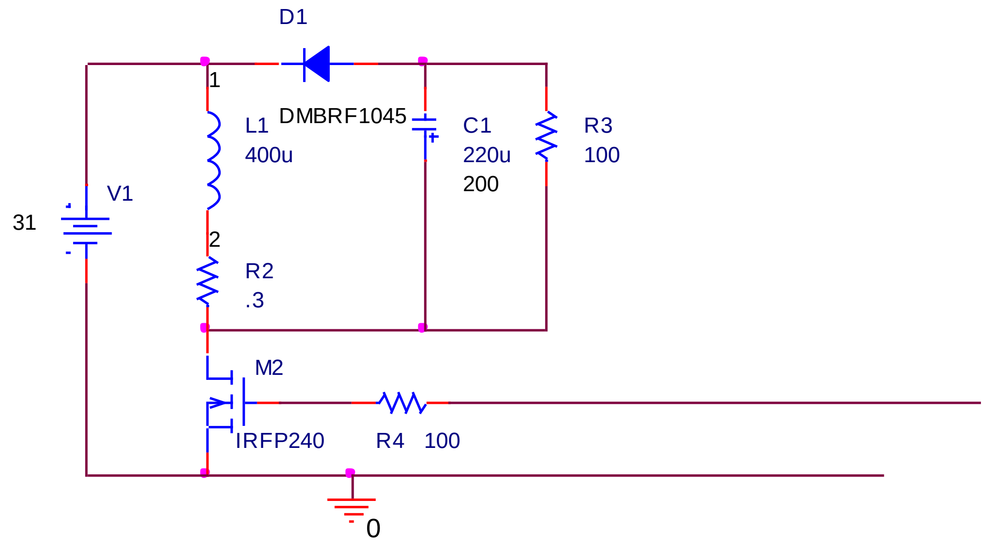
Project Delays

- Research
  - Major Setback
  - More research than anticipated
  - Probably should have taken EE430 last year
  - One week research spent on Buck then Boost topologies
  - Scraped plans and used Buck-Boost topology
    - Less parts needed
    - Simply makes more sense for this application



Project Delays

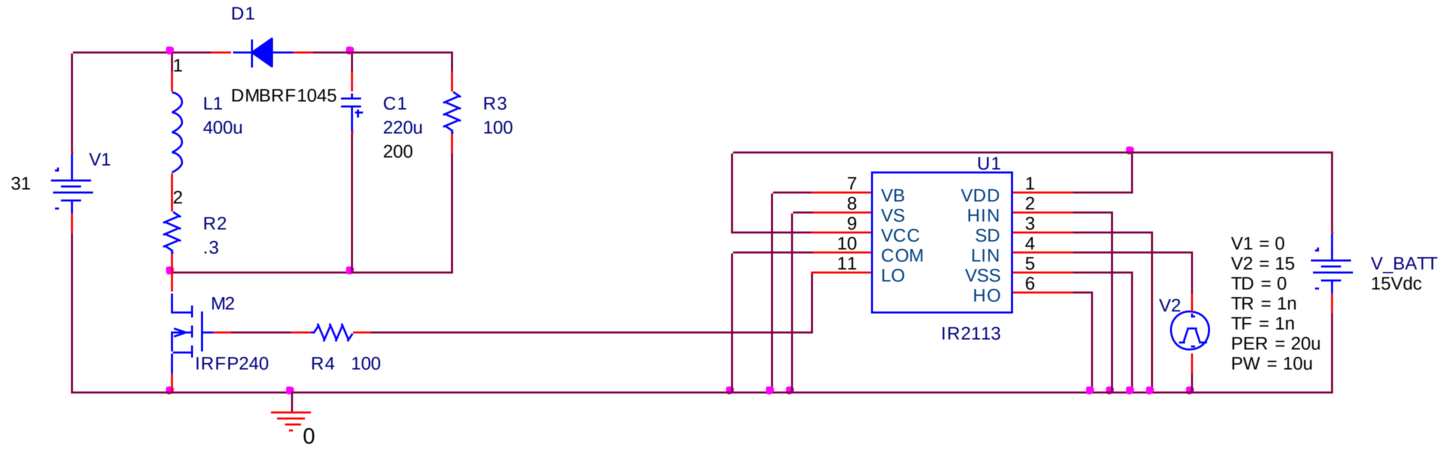
- Simulations Round I
  - About one day spent troubleshooting PSPICE
    - MOSFET switching
      - Initially, planned use of a p channel MOSFET
      - Switched to n channel
        - Lower Rds-On Value
        - Utilize mutual ground with source
        - Simpler topology



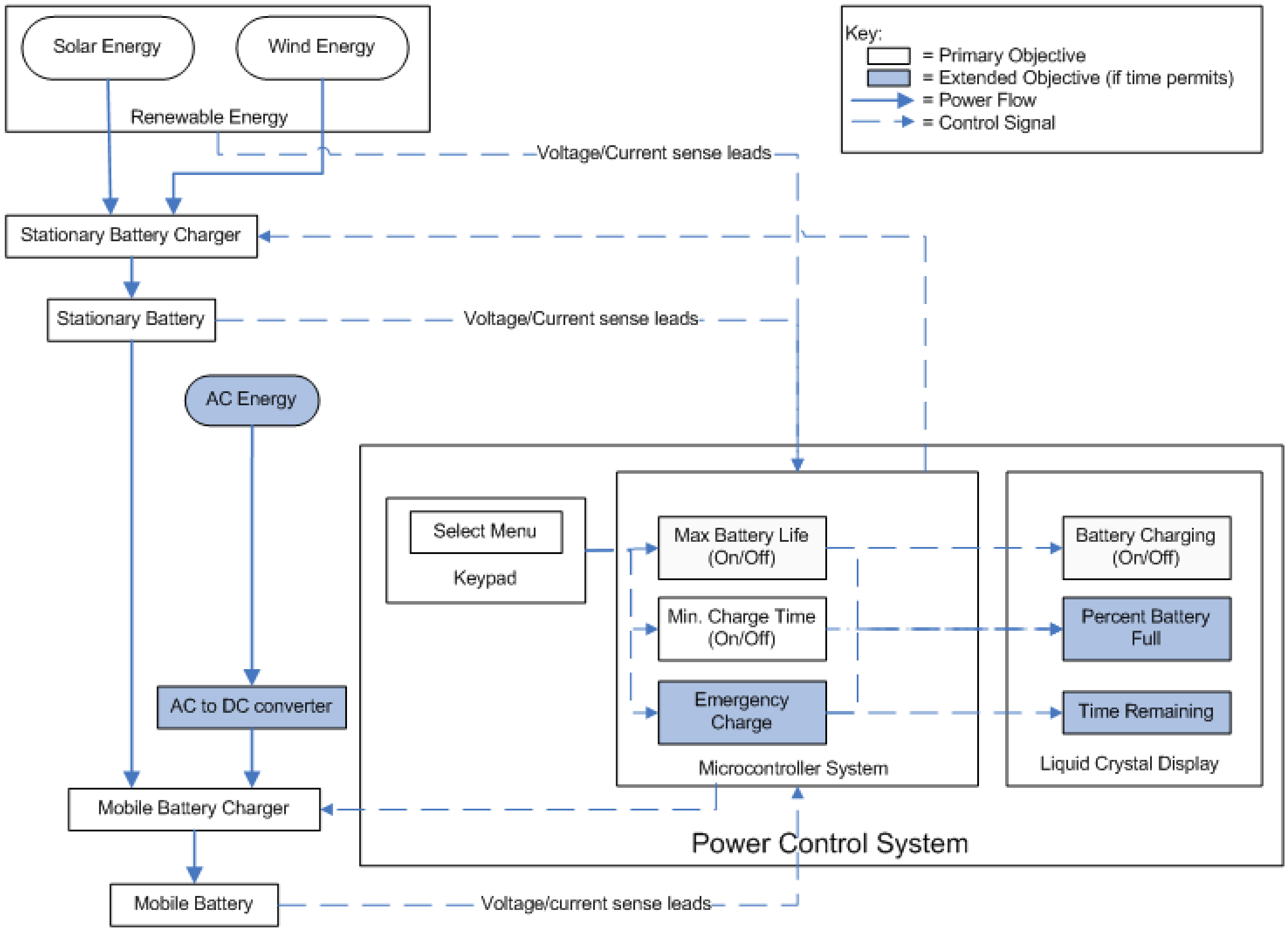
Project Delays

- Implementation Round I
  - MOSFET was stuck in linear mode
    - Gate driver needed

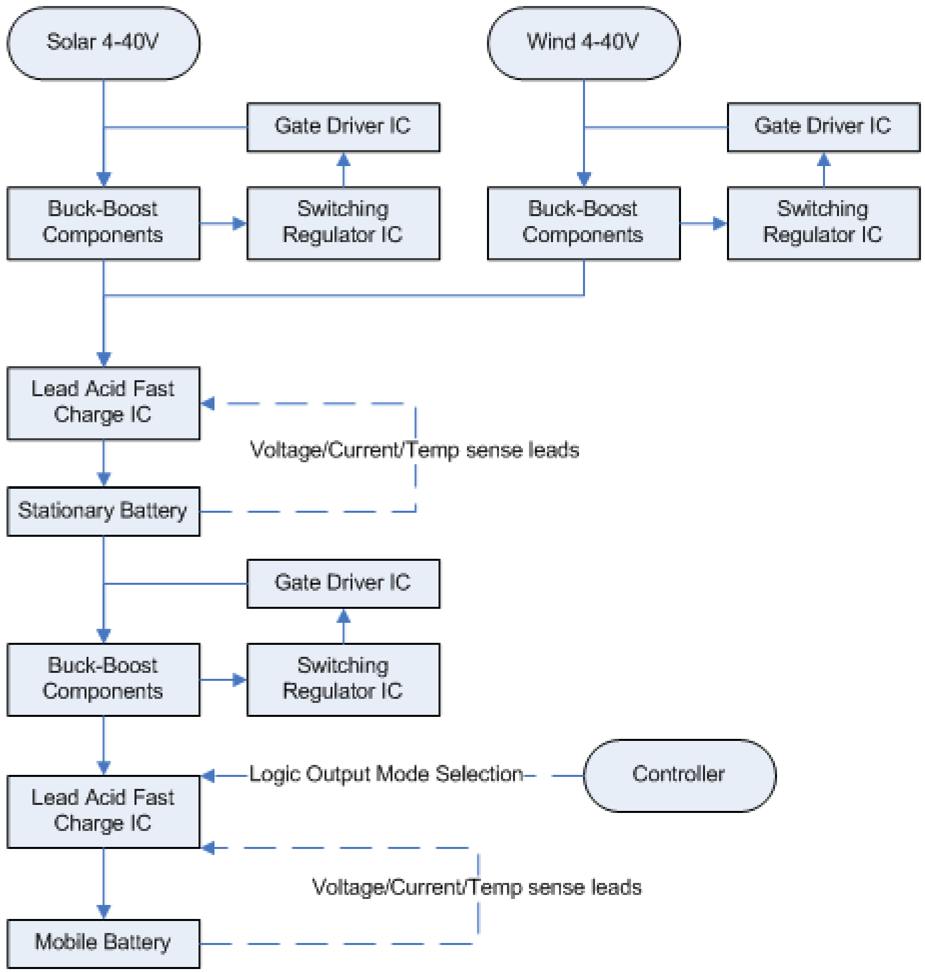
- Simulations Round II
  - Vout was stuck around 21 Volts for 40V input.
    - Vds was greater than maximum
    - Replaced MOSFET
  - Confirmed gate driver setup



Old High Level Flowchart



Low Level Flowchart



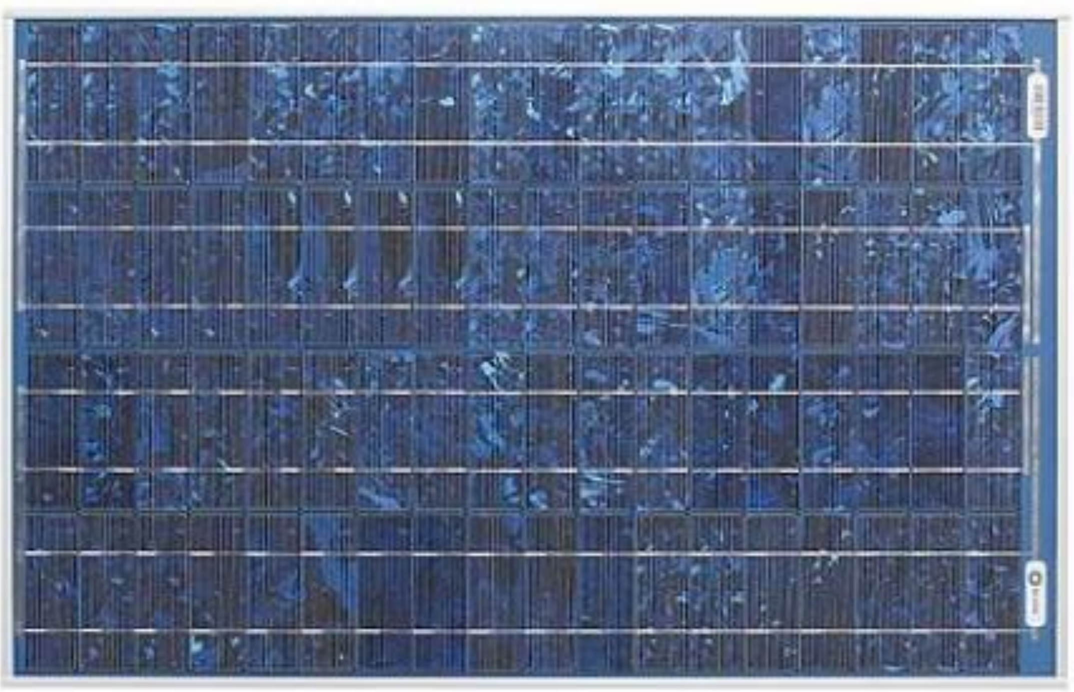
Updated Materials

- Stationary Battery
- Optima D31T
  - Lead Acid
  - 75 Ah,12V
  - Low cost
  - No Memory Effect

Battery Charger (Constant Voltage):	13.8 to 15.0 volts; 10 amps maximum; 6-12 hours approximate
Float Charge:	13.2 to 13.8 volts; 1 amp maximum (indefinite time at lower voltages)
Rapid Recharge: (Constant voltage charger)	Maximum voltage 15.6 volts. No current limit as long as battery temperature remains below 125°F (51.7°C). Charge until current drops below 1 amp.

Updated Materials

- Photovoltaic (P.V.) Array
  - Had planned to use Kyocera KC50T
  - Using BP 350J
  - 50W, 17.5V, 2.9A at max power



Updated Materials

- BP 350J Efficiency
- 72 modules (0.042m x 0.125m)
- Solar Panel Area = 0.378m^2
- Nominal Sun Power Density: 1kW/m^2
- Maximum Panel Power: 0.050 kW
- Efficiency: 0.050kW/(0.378m^2*1kW/m^2)

  = 13.22 %

Analytical Calculations

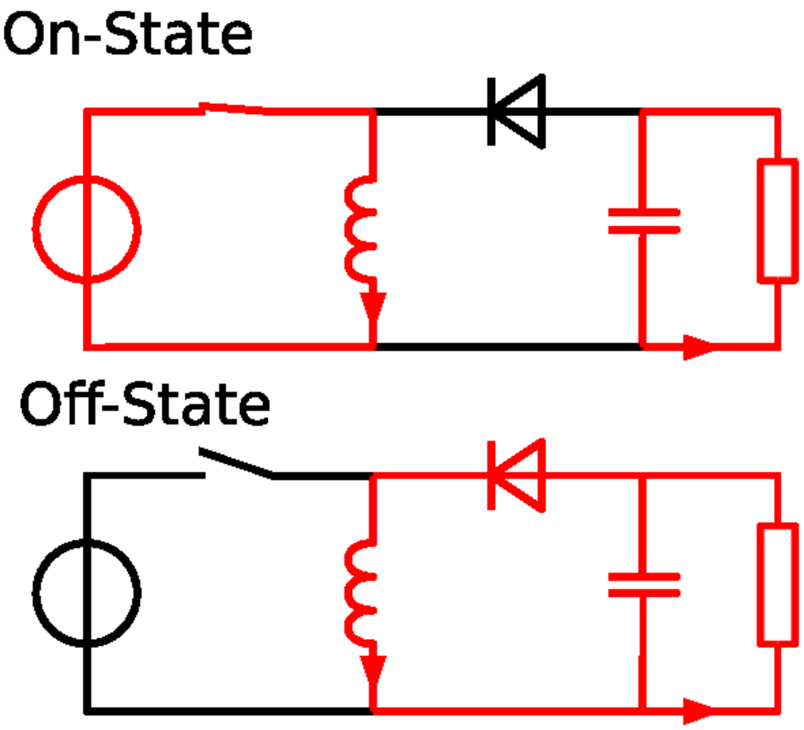
- Load Calculation
  - Capacity 12V*12Ah=144Wh
  - 144 W*3,600 sec*1.25 = 648,000 J

- Solar Power Calculation
  - Efficiency*Area*Sun hours*3,600 seconds
  - Maximum Spec 50W=180,000 J/hour / panel
  - Worst Case for Chicago = 206,449 J/day

- Worst Case Number of Solar Modules
  - 648,000 J/285,768 J= 2.45 P.V. Modules

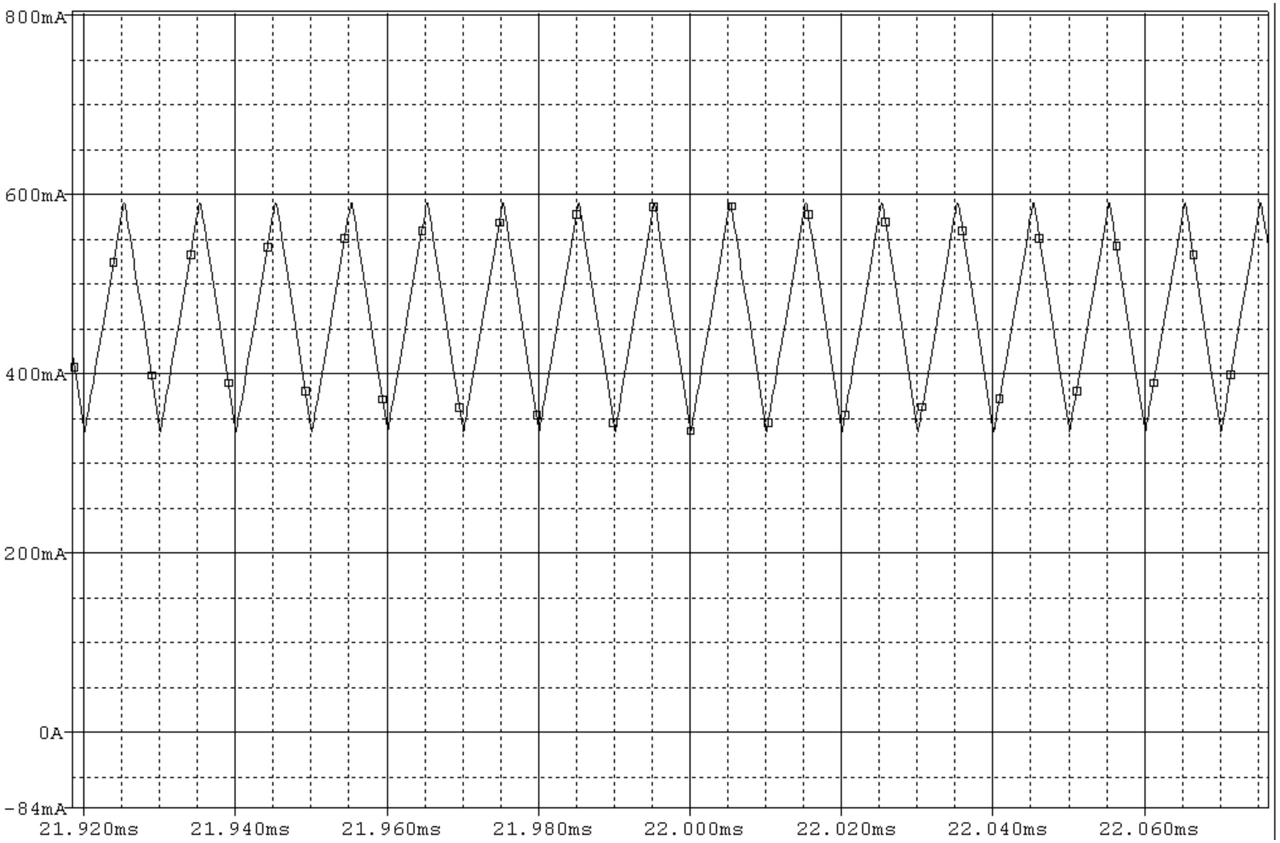
Buck-Boost Scheme

- Buck-Boost Voltage Regulator Topology
- Energy Stored in Inductor
- Inductor supplies energy to load
- Capacitor supplies energy to load when in the "on-state"
- Will operate in continuous mode



Buck-Boost Scheme

- Buck-Boost Voltage Regulator Topology
- Continuous mode- Inductor Current

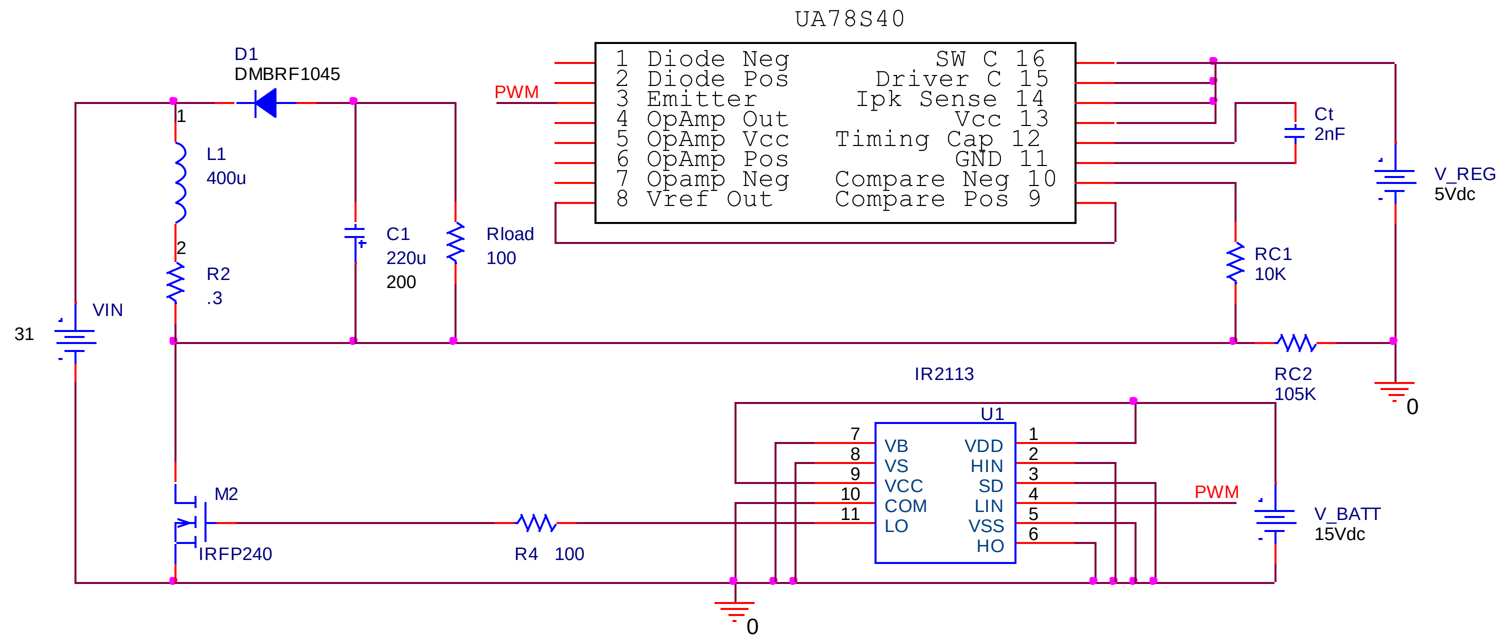


Buck-Boost Scheme

- Implementation Considerations
  - Inductor energy must be large enough to store required energy
  - Inductor must be large enough to be in continuous mode
  - Switching speed must be fast enough to remain in continuous mode
  - Capacitor must be large enough to supplement inductor when switch is closed
  - Diode must have:
    - high reverse bias ratings
    - low voltage drop
    - fast recovery
  - Inductor, FET, and Diode have high current

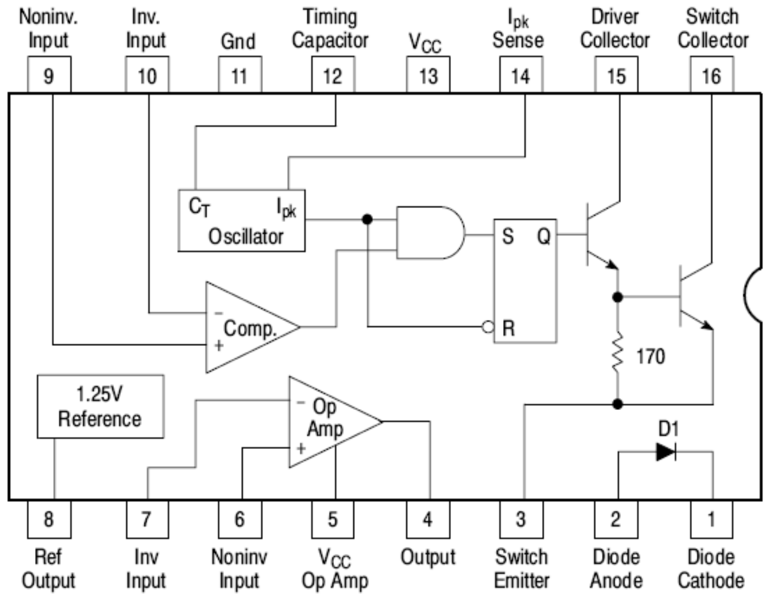
Buck-Boost Implementation

- Values determined from maximum and minimum Vin voltage simulations only
- Next step is to theoretically figure minimum values for Inductor and Capacitor



Buck-Boost Implementation

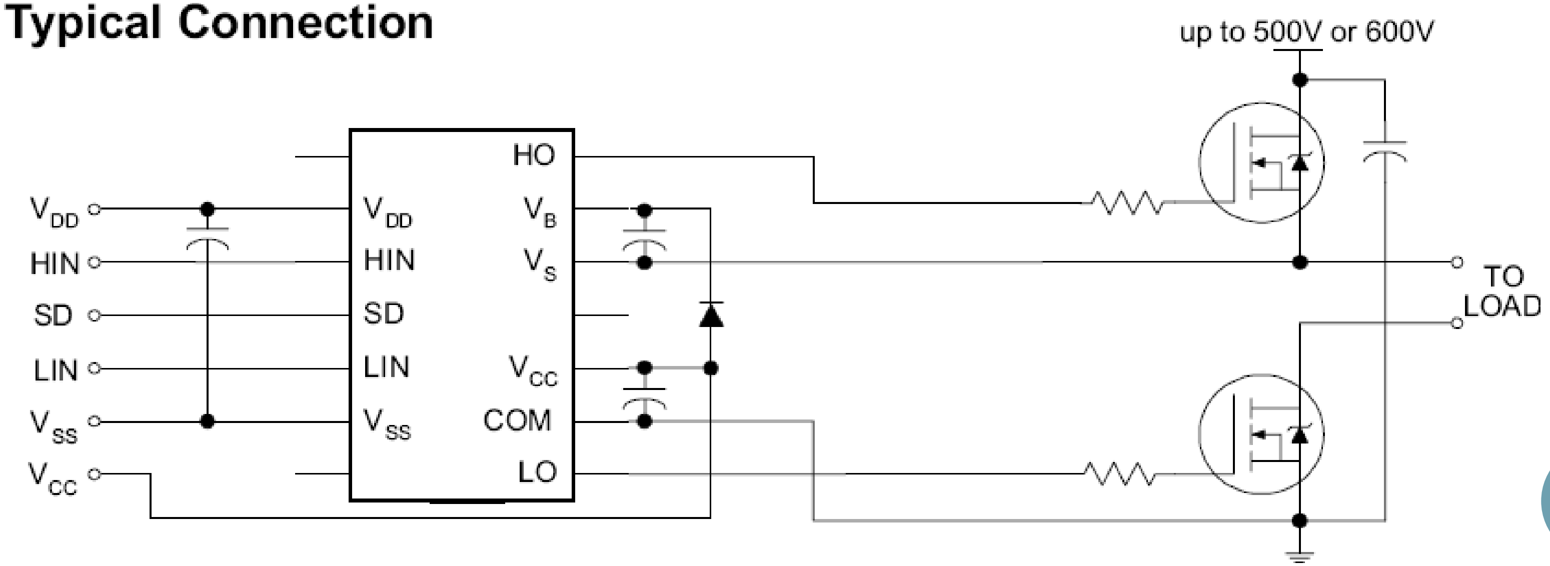
- UA78S40
- Universal Switching Regulator Subsystem
- Provides PWM Closed Loop Control
  - Scales down output voltage and compares to 1.25V
    - Voltage divider must have 1% resistor tolerance
  - Variable frequency range from 1Khz – 100Khz
  - Faster switching allows for lower inductance
  - Eliminates need for developing a stable control system in software
  - 0-40V PWM output
    - Vcc= 5V used



Buck-Boost Implementation

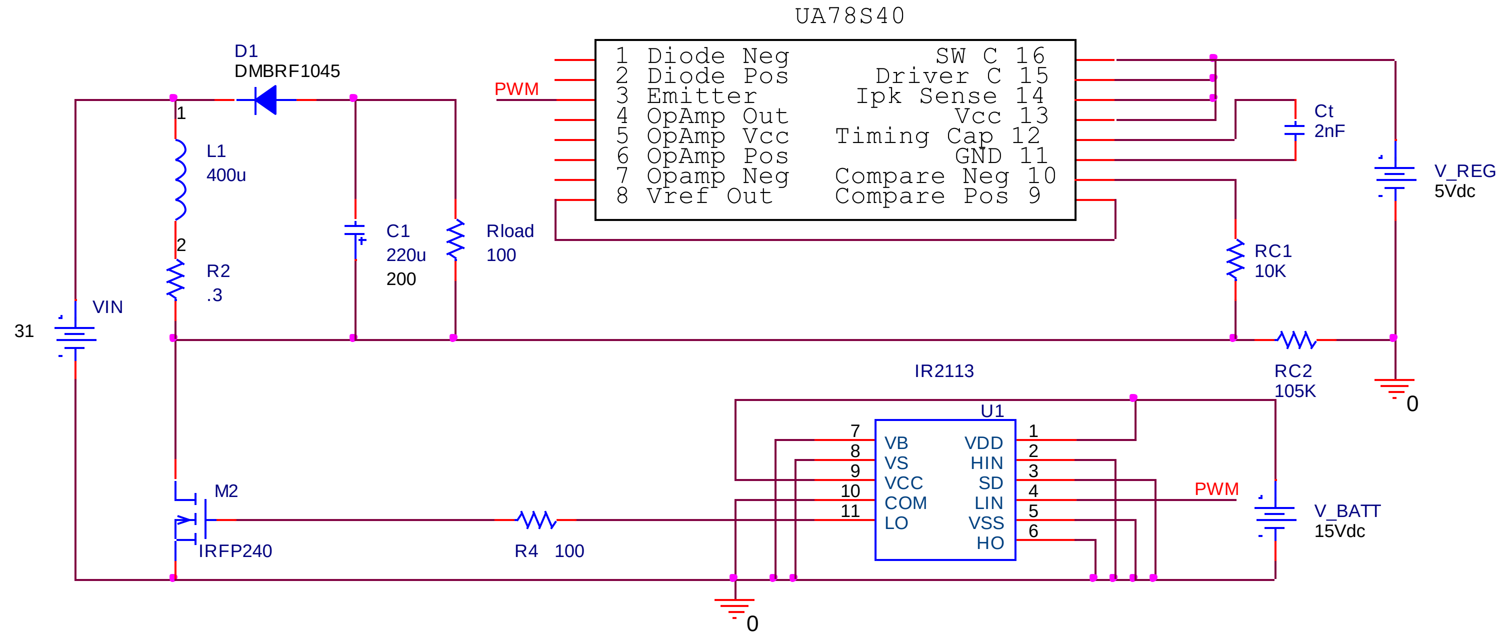
- IR2113
- High and Low Side Driver
- Ability to operate at 100KHz
- Separate logic supply range from 3.3V to 20V
- LO = Vdd = Vbatt = 12-13.5V

Typical Connection



Buck-Boost Implementation

- IR2113

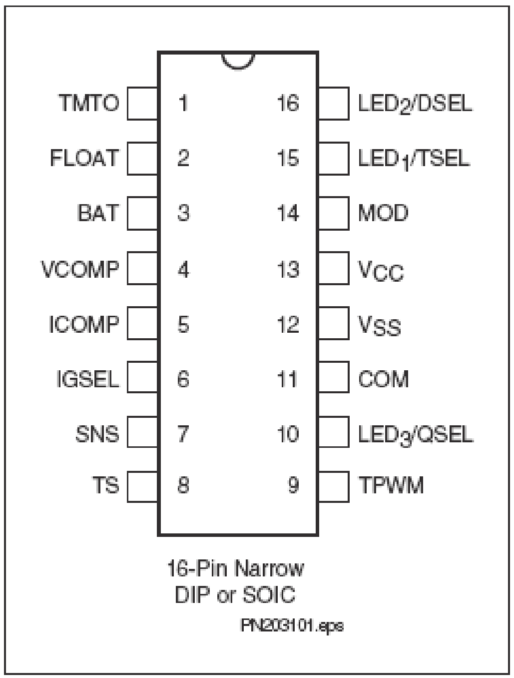


Stationary Charger Scheme

- BQ2031
- Lead Acid Fast Charge IC
- Two-Step Voltage Control
  - Automatically detects low current and switches to trickle charge
  - Temperature-compensated
  - PWM Control of output
  - Automatically detects shorted, opened, or damaged cells

Stationary Charger Scheme

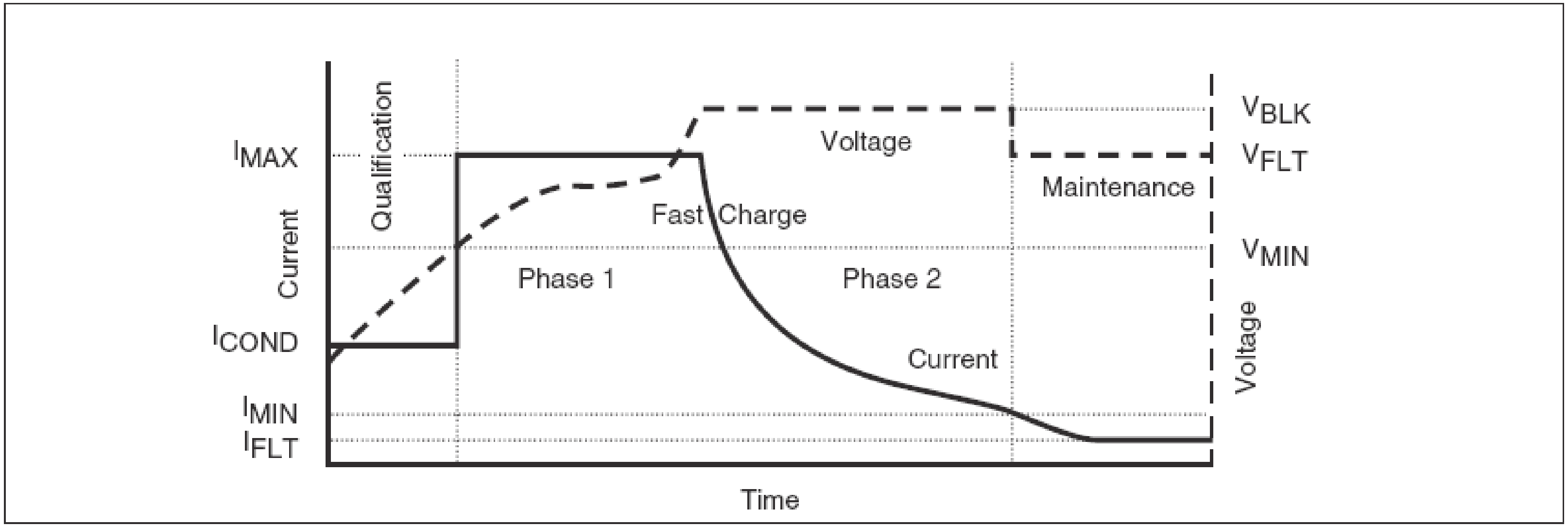
- BQ2031
- Lead Acid Fast Charge IC



TMTO	Time-out timebase input	LED3/ QSEL	Charge status output 3/ Charge algorithm select input 1
FLOAT	State control output	COM	Common LED output
BAT	Battery voltage input	V_{SS}	System ground
VCOMP	Voltage loop comp input	V_{CC}	$5.0V \pm 10\%$ power
ICOMP	Current loop comp input	MOD	Modulation control output
IGSEL	Current gain select input	LED1/ TSEL	Charge status output 1/ Charge algorithm select input 2
SNS	Sense resistor input	LED2/ DSEL	Charge status output 2/ Display select input
TS	Temperature sense input		
TPWM	Regulator timebase input		

Stationary Charger Scheme

- BQ2031
- Two-Step Voltage Charge



Stationary Charger Scheme

- BQ2031
- Configuring Charging Algorithm

Algorithm/State	QSEL	TSEL	Conditions	MOD Output
Two-Step Voltage	L	H/L Note 1	-	-
Fast charge, phase 1			while $V_{BAT} < V_{BLK}$, $I_{SNS} = I_{MAX}$	Current regulation
Fast charge, phase 2			while $I_{SNS} > I_{MIN}$, $V_{BAT} = V_{BLK}$	Voltage regulation
Primary termination			$I_{SNS} = I_{MIN}$	
Maintenance			$V_{BAT} = V_{FLT}$	Voltage regulation
Two-Step Current	H	L	-	-
Fast charge			while $V_{BAT} < V_{BLK}$, $I_{SNS} = I_{MAX}$	Current regulation
Primary termination			$V_{BAT} = V_{BLK}$ or $\Delta^2V < -8mV$ Note 2	
Maintenance			I_{SNS} pulsed to average I_{FLT}	Fixed pulse current
Pulsed Current	H	H	-	-
Fast charge			while $V_{BAT} < V_{BLK}$, $I_{SNS} = I_{MAX}$	Current regulation
Primary termination			$V_{BAT} = V_{BLK}$	
Maintenance			$I_{SNS} = I_{MAX}$ after $V_{BAT} = V_{FLT}$; $I_{SNS} = 0$ after $V_{BAT} = V_{BLK}$	Hysteretic pulsed current

STATIONARY CHARGER SCHEME

- BQ2031
- Voltage and Current Monitoring

The resistor values are calculated from the following:

Equation 1

$$\frac{RB1}{RB2} = \frac{(N * V_{FLT})}{2.2V} - 1$$

Equation 2

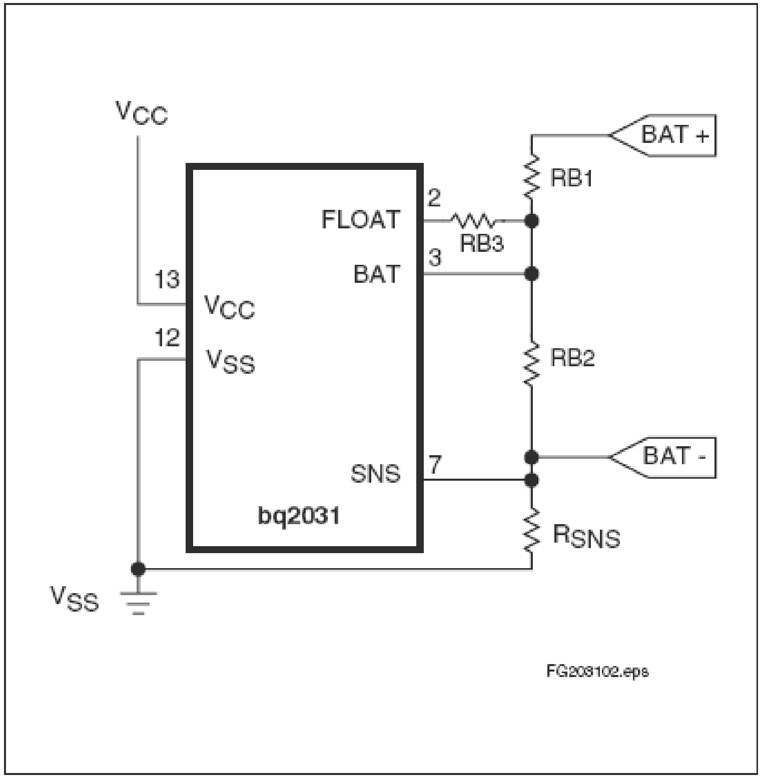
$$\frac{RB1}{RB2} + \frac{RB1}{RB3} = \left(\frac{N * V_{BLK}}{2.2}\right) - 1$$

Equation 3

$$I_{MAX} = \frac{0.250V}{R_{SNS}}$$

where:

- N = Number of cells
- V_{FLT} = Desired float voltage
- V_{BLK} = Desired bulk charging voltage
- I_{MAX} = Desired maximum charge current



STATIONARY CHARGER SCHEME

- BQ2031
- Voltage and Current Monitoring
  - N=6 cells
  - Vflt=13.3V
  - Vblk=14.0V
  - Imax=10A

  - Using Equations
  - RB1=130KΩ
  - RB2=50KΩ
  - RB3=620KΩ

The resistor values are calculated from the following:

Equation 1

$$\frac{RB1}{RB2} = \frac{(N * V_{FLT})}{2.2V} - 1$$

Equation 2

$$\frac{RB1}{RB2} + \frac{RB1}{RB3} = (\frac{N * V_{BLK}}{2.2}) - 1$$

Equation 3

$$I_{MAX} = \frac{0.250V}{R_{SNS}}$$

where:

- N = Number of cells
- V_{FLT} = Desired float voltage
- V_{BLK} = Desired bulk charging voltage
- I_{MAX} = Desired maximum charge current

Stationary Charger Scheme

- BQ2031
- Fast Charge cutoff to Trickle Charge
- IGSEL = 0
- $I_{min} = I_{max}/10 = 10A/10 = 1A$

IGSEL	I_{MIN}
0	$I_{MAX}/10$
1	$I_{MAX}/20$
Z	$I_{MAX}/30$

Stationary Charger Scheme

- BQ2031
- Temperature Sensing
- Thermistors have been ordered but calculations have not been done yet.

Equation 4

$$0.6 * V_{CC} = \frac{(V_{CC} - 0.250V)}{1 + \frac{RT1 * (RT2 + R_{LTF})}{(RT2 * R_{LTF})}}$$

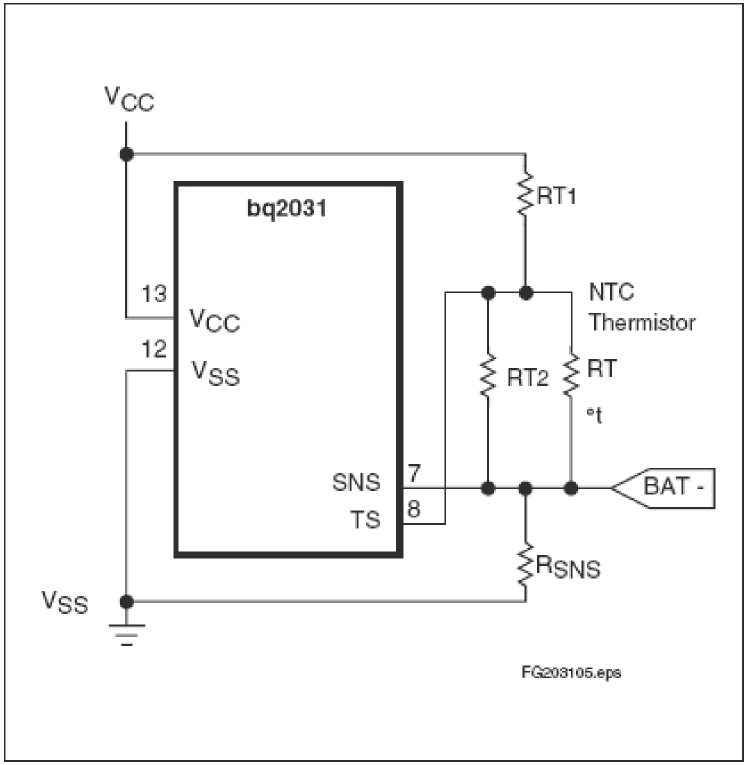
Equation 5

$$0.44 = \frac{1}{1 + \frac{RT1 * (RT2 + R_{HTF})}{(RT2 * R_{HTF})}}$$

where:

- R_{LTF} = thermistor resistance at LTF
- R_{HTF} = thermistor resistance at HTF

TCO is determined by the values of RT1 and RT2. 1% resistors are recommended.



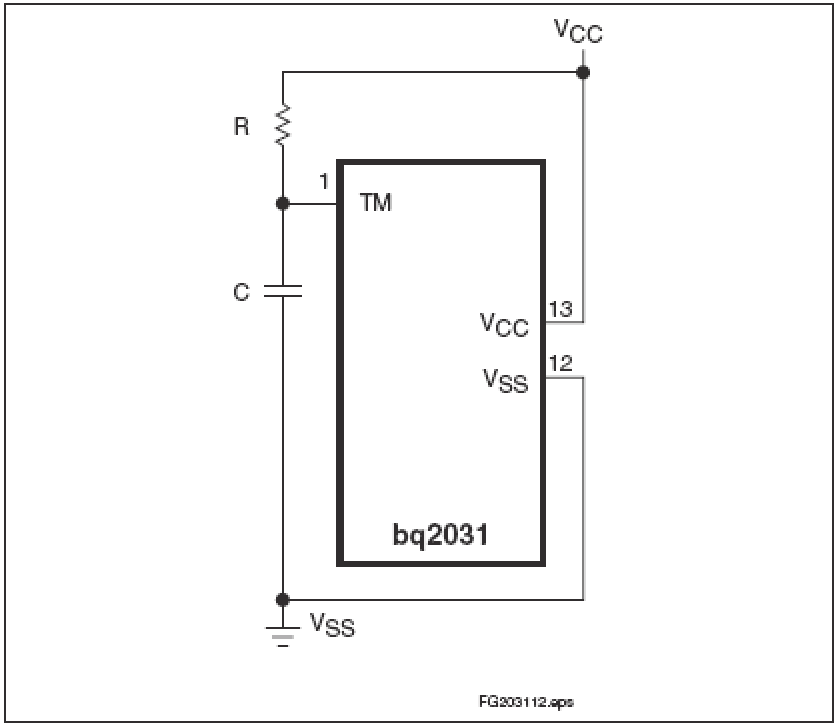
Stationary Charger Scheme

- BQ2031
- Setting Charging Maximum Timeout
- Tmto=24hours
- R=24hrs/(.5*.1uF)
-    = 480GΩ
- Use largest resistance possible or open circuit

Equation 6

$$t_{MTO} = 0.5 * R * C$$

where R is in kΩ, C is in µF, and t_{MTO} is in hours. Typically, the maximum value for C of 0.1µF is used.



STATIONARY CHARGER SCHEME

- BQ2031
- Set switching frequency
- Fpwm=100KHz

Equation 9

$$F_{PWM} = 0.1/C_{PWM}$$

where C is in µF and F is in kHz. A typical switching rate is 100kHz, implying C_{PWM} = 0.001µF. MOD pulse width is modulated between 0 and 80% of the switching period.

Stationary Charger Scheme

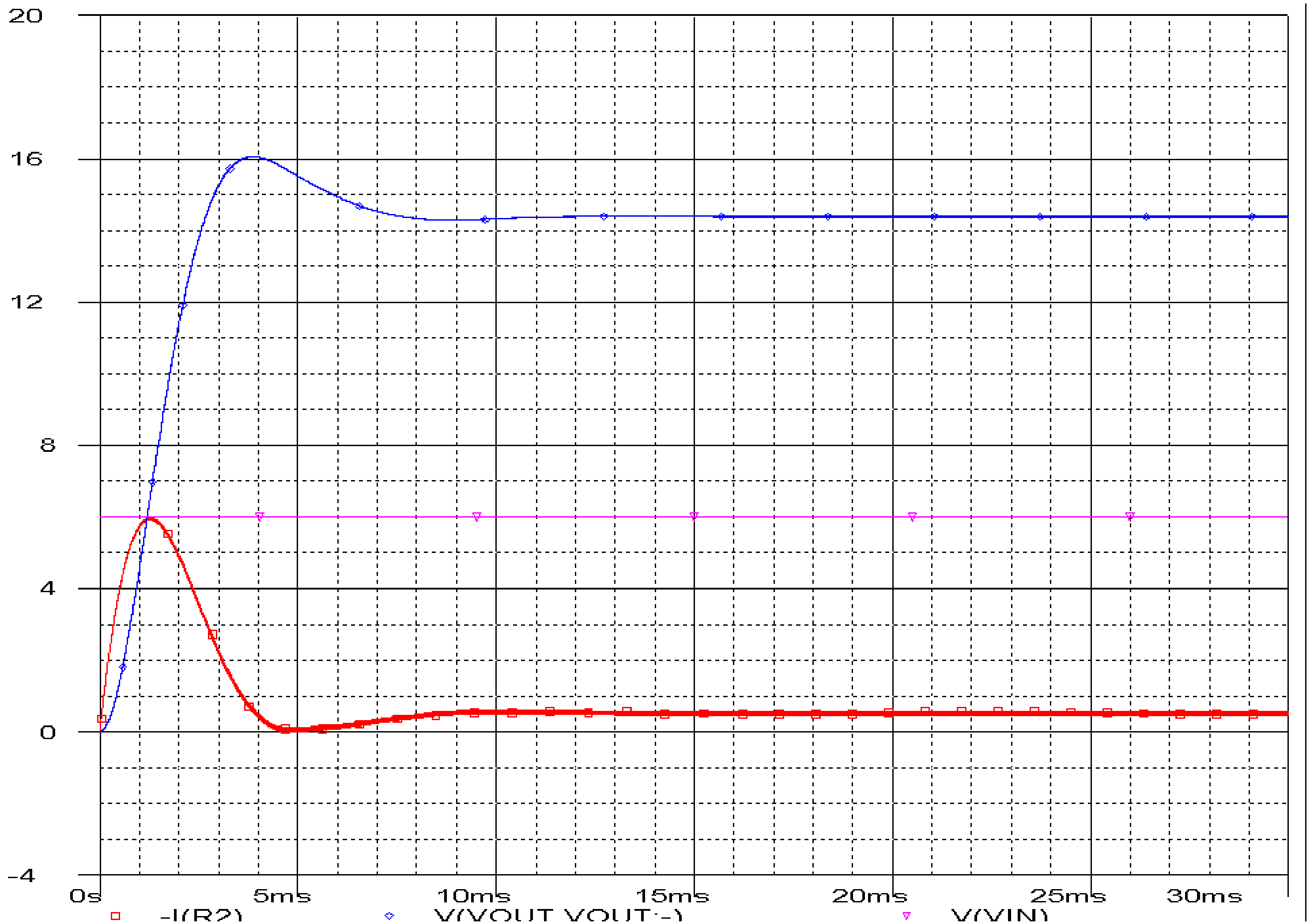
- BQ2031
- Voltage Loop stability
- Additional 17 page PDF explaining stability
- Adds external components to the IC
- Equations needed have been identified but will not be shown due to complexity and length
- We still need to determine exact values

Stationary Charger Scheme

- The same buck-boost process and fast charge IC will be used except with different values
- The same design process will be used
  - Have not started yet
- Will have 2 modes of operation
  - Fast Charge & Trickle
  - Modes switched via microcontroller digital output

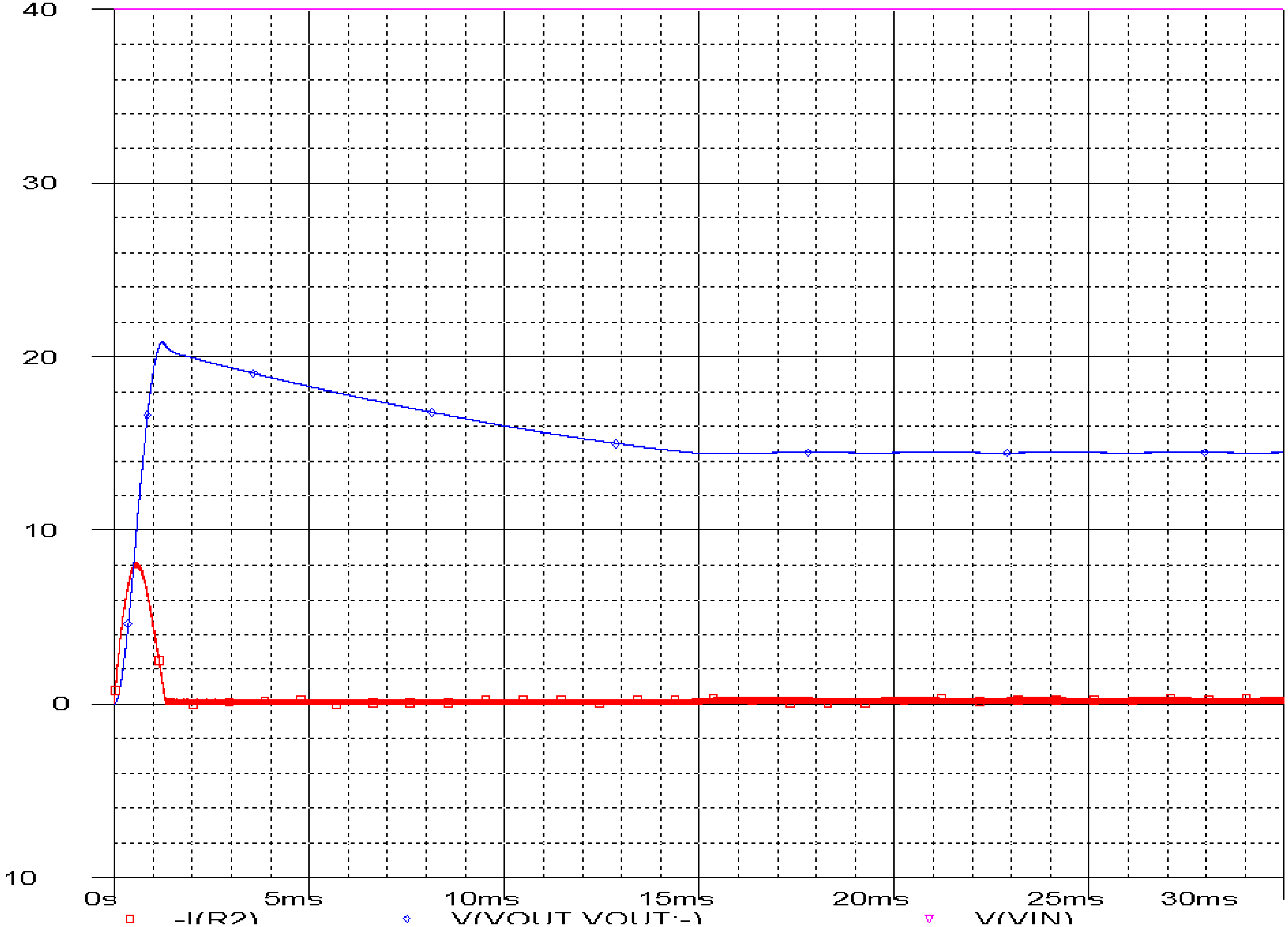
PSPICE Simulations- Buck Boost

- Minimum Input 6V with a 75% Duty Cycle



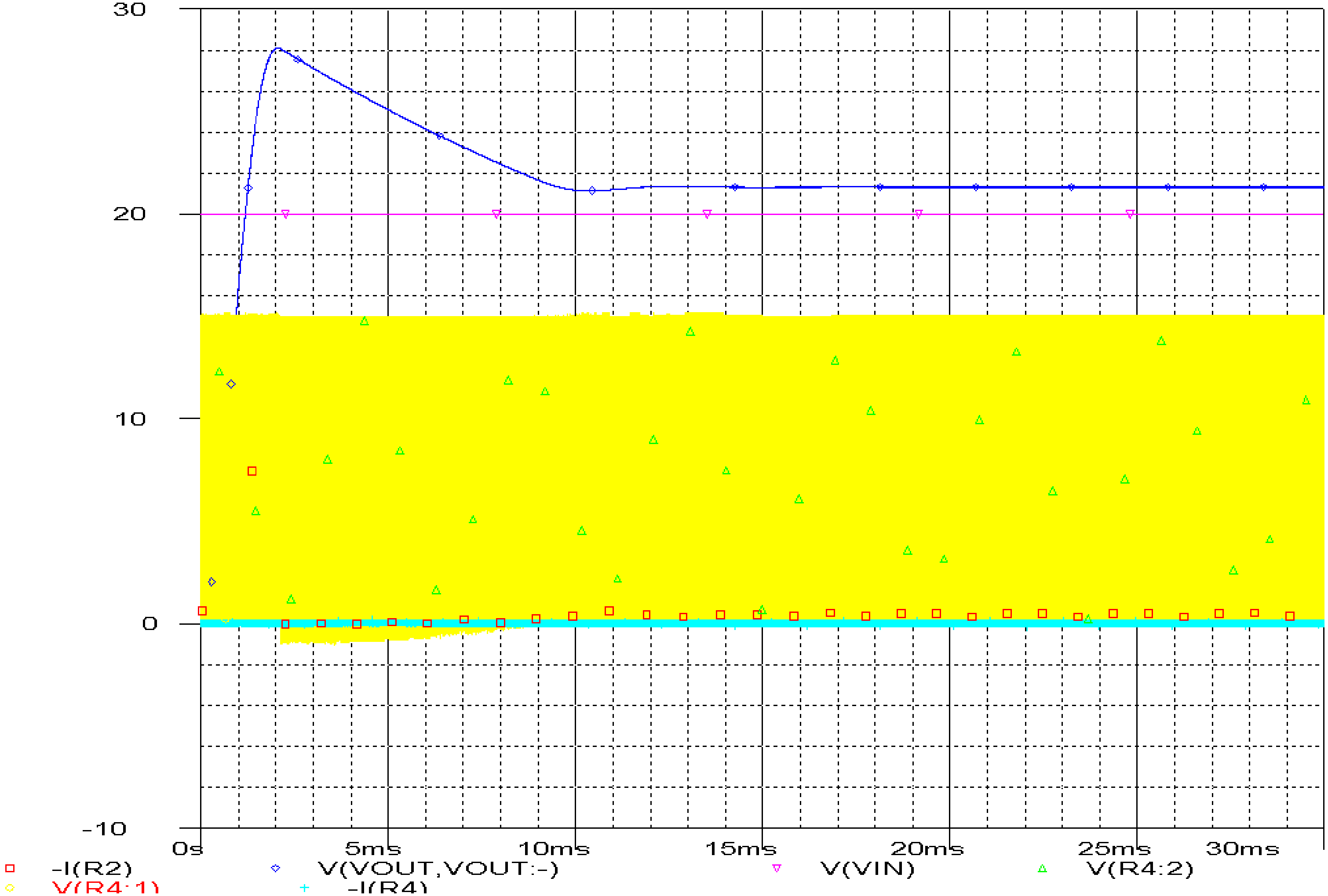
PSPICE Simulations- Buck Boost

- Maximum Input 40V with a 25% Duty Cycle



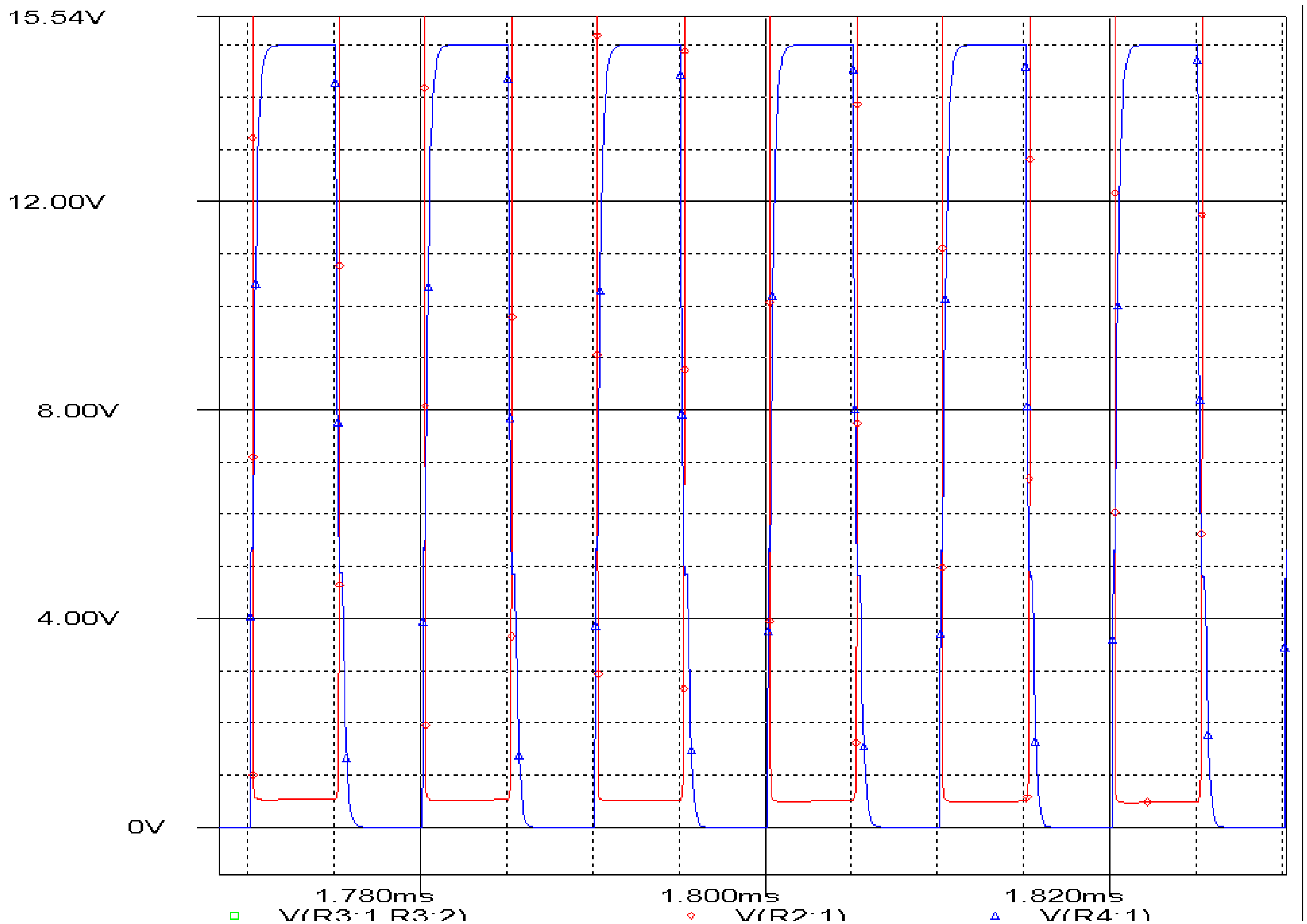
PSPICE Simulations- Buck Boost

- Input 20V with a 50% Duty Cycle



PSPICE SIMULATIONS- BUCK BOOST

- Switch Rate of 100KHz supported by IC model



Controller & Software Design

- Microcontroller switches IC charging mode
  - Feedback loop handled by IC
- Microcontroller Requirements
  - Keypad user input
    - 1 port needed
  - LCD user output
    - 1 port needed
  - Port pin IC input
    - 3 pins needed for status
  - Port pin IC output
    - 1 pin needed for switching modes

QUESTIONS?