Low Carbon Footprint Hybrid Battery Charger

Final Presentation

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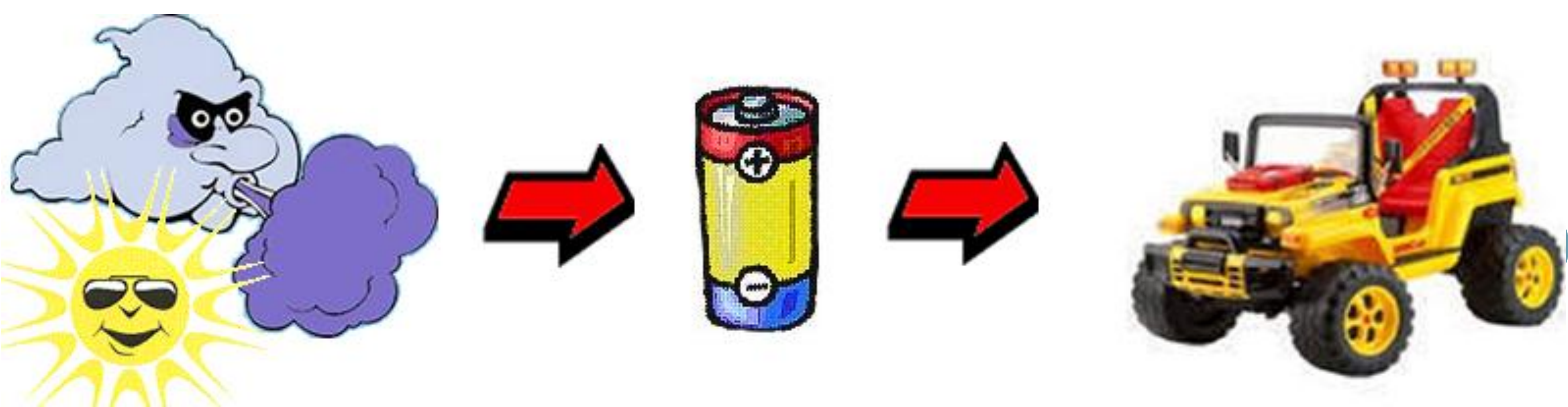
Presentation Outline

- Project Overview
- Design
  - Buck-Boost
    - Theory
    - Design Iterations
    - Closed Loop Control
  - Lead Acid Fast Charge IC
- Results
- Future Recommendations
- Questions

Introduction

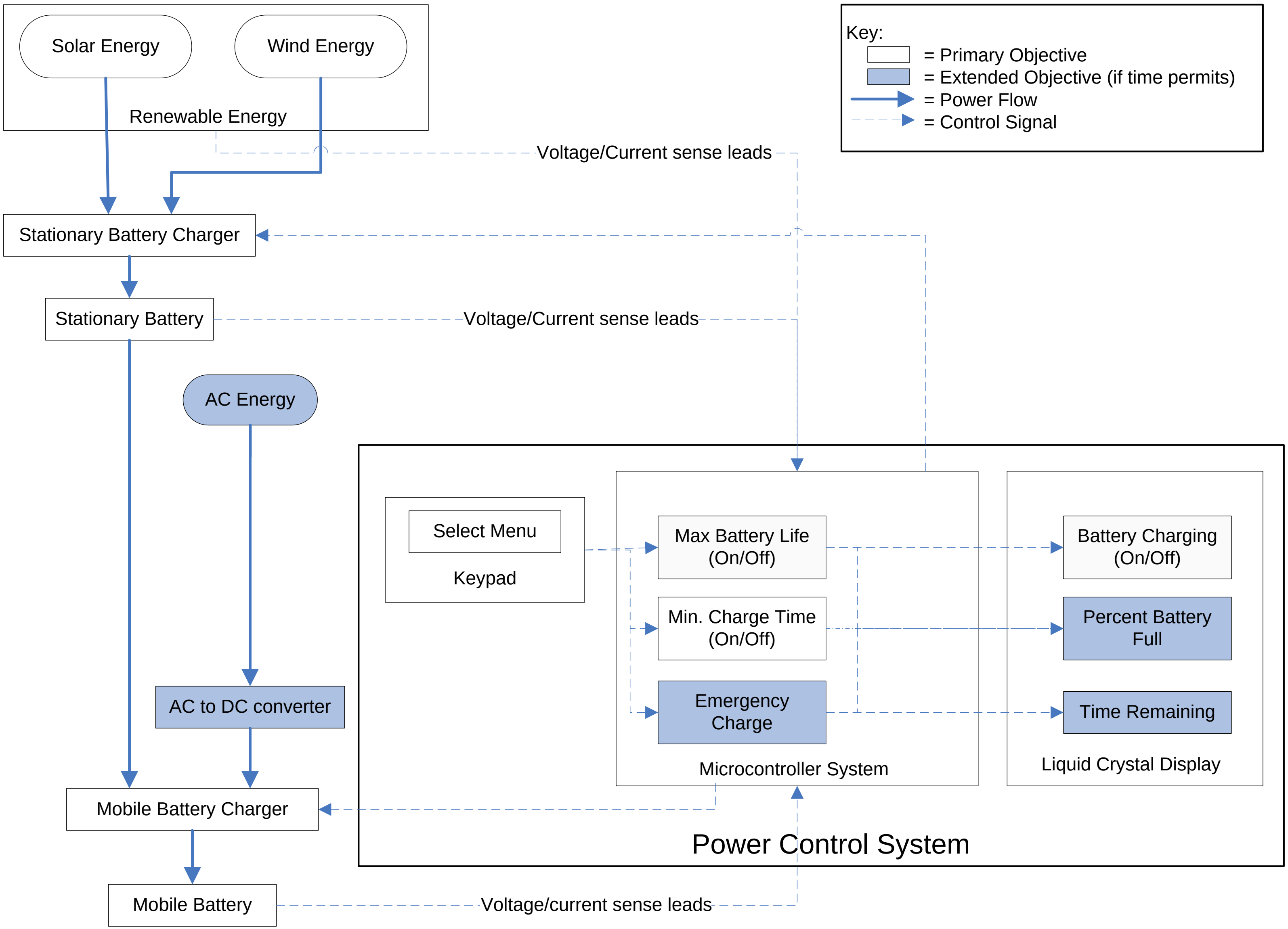
- Emphasize efficient energy collection
  - Photovoltaic arrays
  - Wind turbine
  - Minimize utility A.C. energy
- Store renewable energy
- Charge a mobile battery for vehicular applications using renewable energy



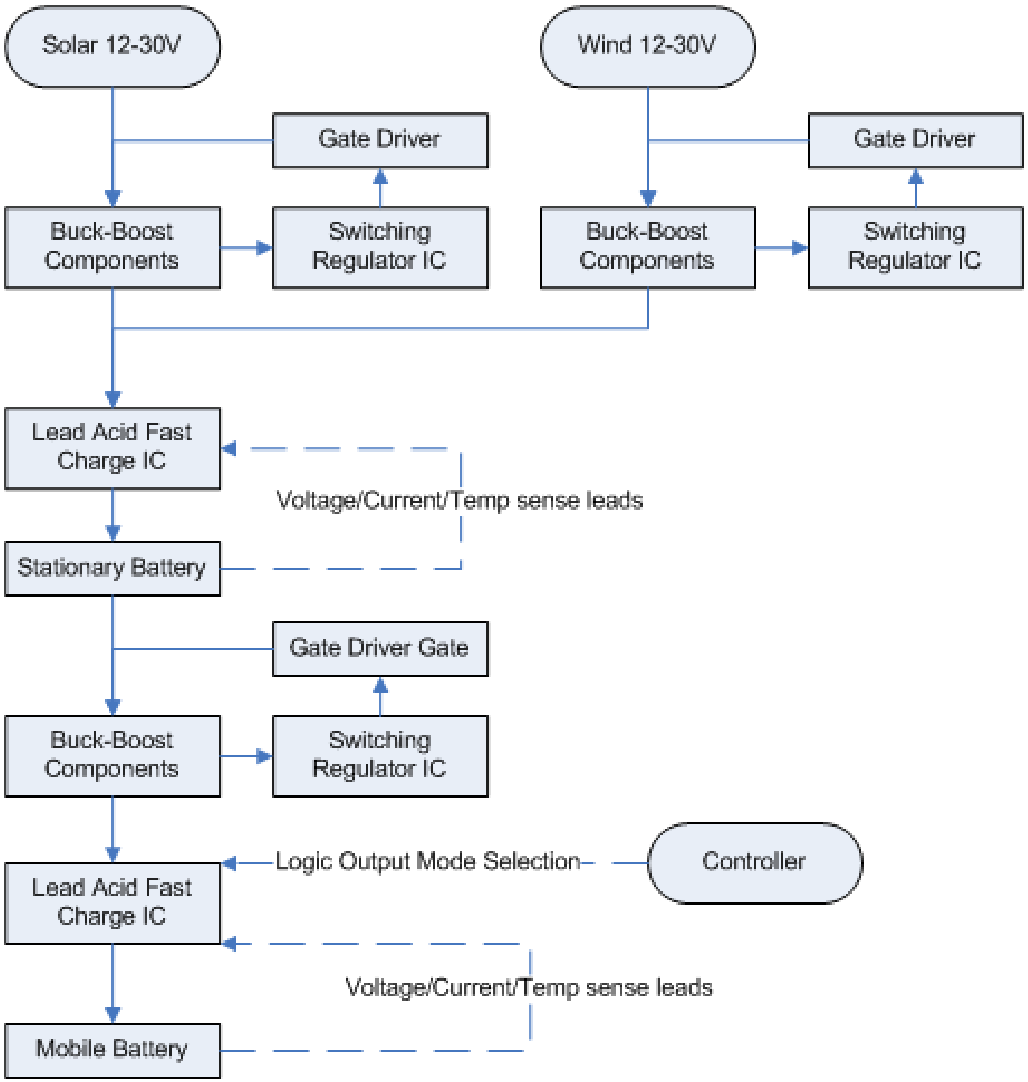
Previous Research

- What has been created by others?
- What is new with our project?
  - All systems combined to charge a vehicle battery
  - Utilization of battery to battery charging
- How can this be done?

High Level System Block Diagram

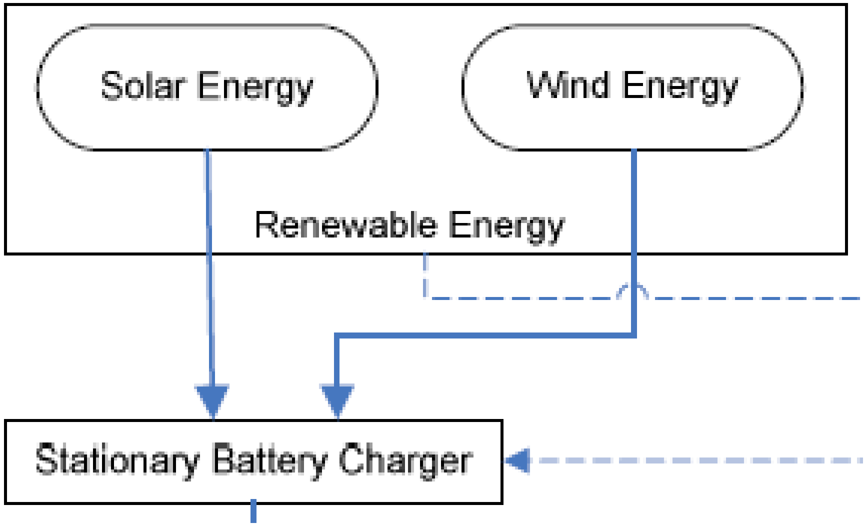


Low Level Flowchart



Renewable Energy

- Photovoltaic (P.V.) Array
  - BP 350J
  - 50W, 17.5V, 2.9A at max power
  - Provide sufficient energy to charge the mobile battery given worst case conditions



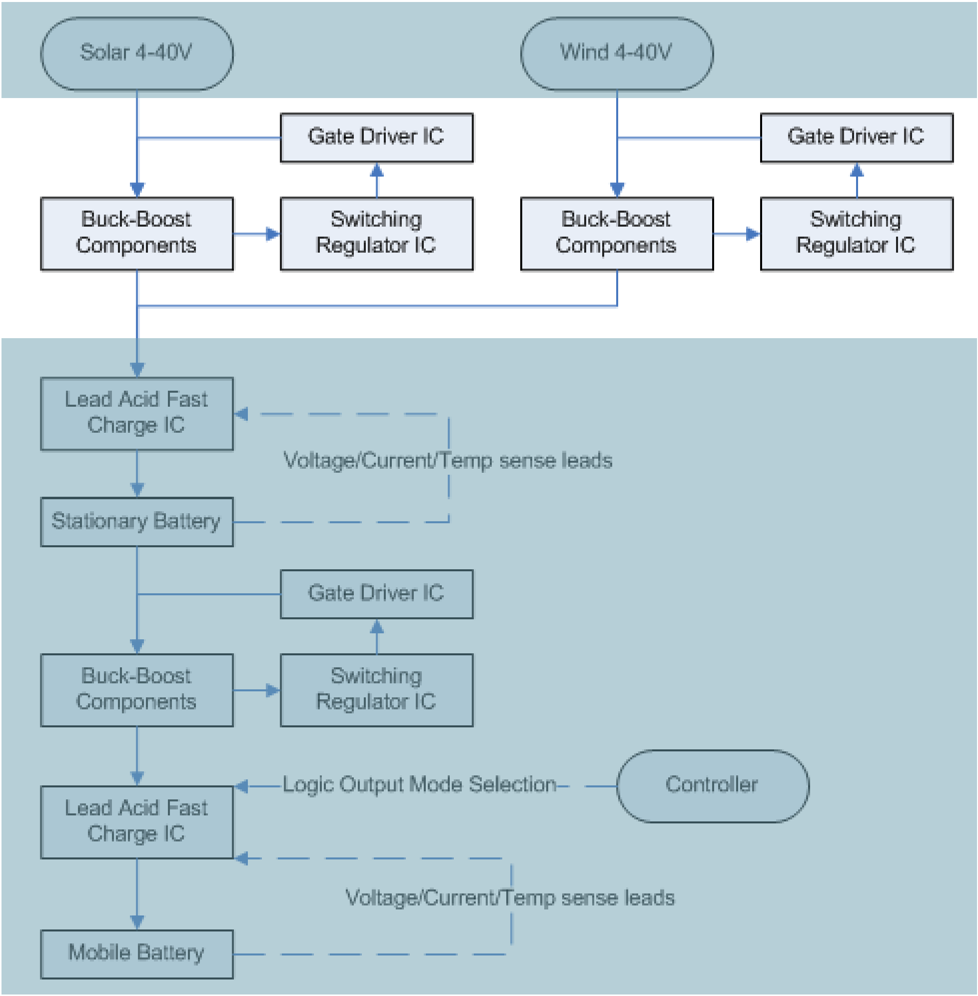
Renewable Energy

- Mobile Battery Load = 648 kJ
- BP 350J Efficiency = 13.22 %
- Worst Case: 1.470 sun hours per day
- Worst Case Solar Power Energy = 206,449 J/day
- Min Number of P.V. Arrays = 2.45 P.V. Arrays

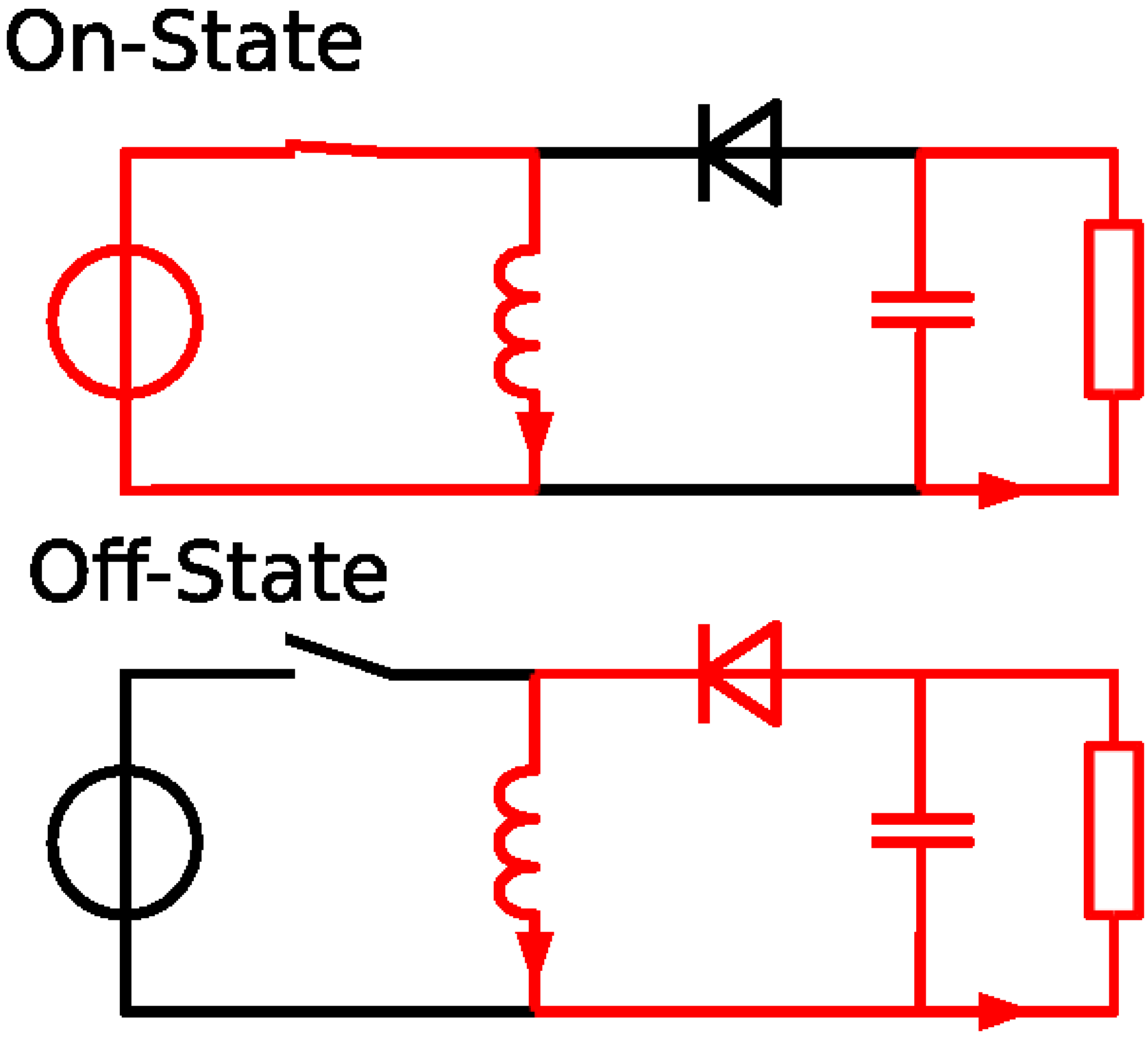
Renewable Energy

- Wind Energy
  - 1.2 kWh/day average at 50m
    - Simulated with D.C. power supply
  - Southwest Wind Power Air-X
    - Start up wind speed: 7 M.P.H.
    - Rotor Diameter: 46 in.
    - Max Power: 400W @ 28 M.P.H
    - Vout= 24VDC
    - Competitive Cost

Low Level Flowchart

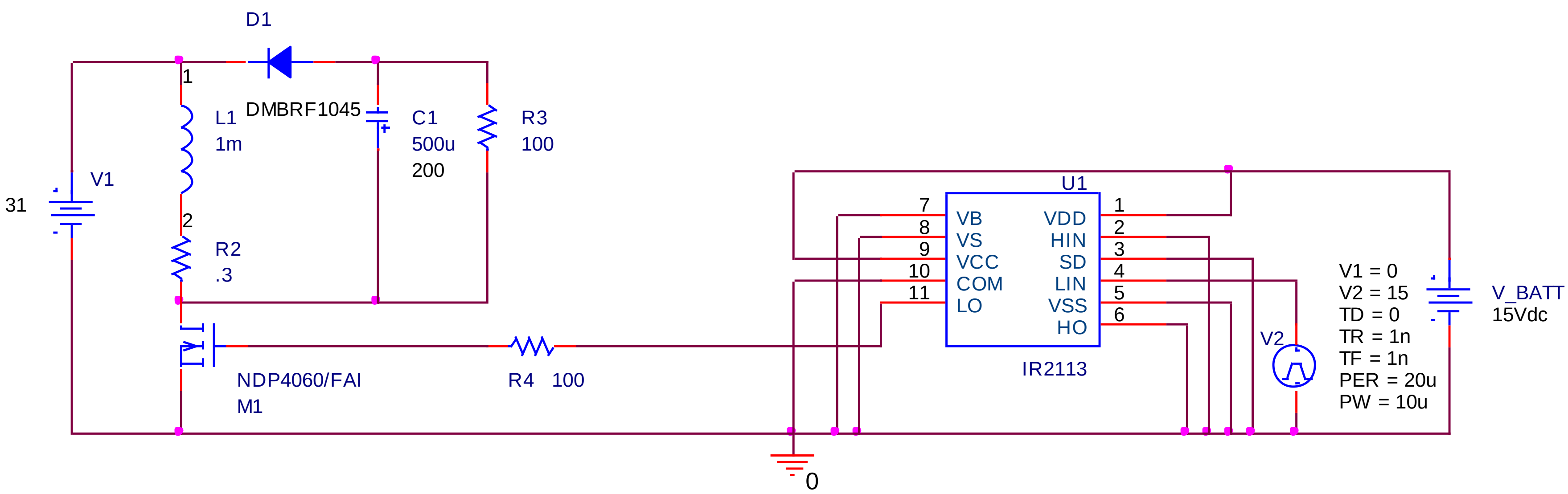


Buck-Boost Theory



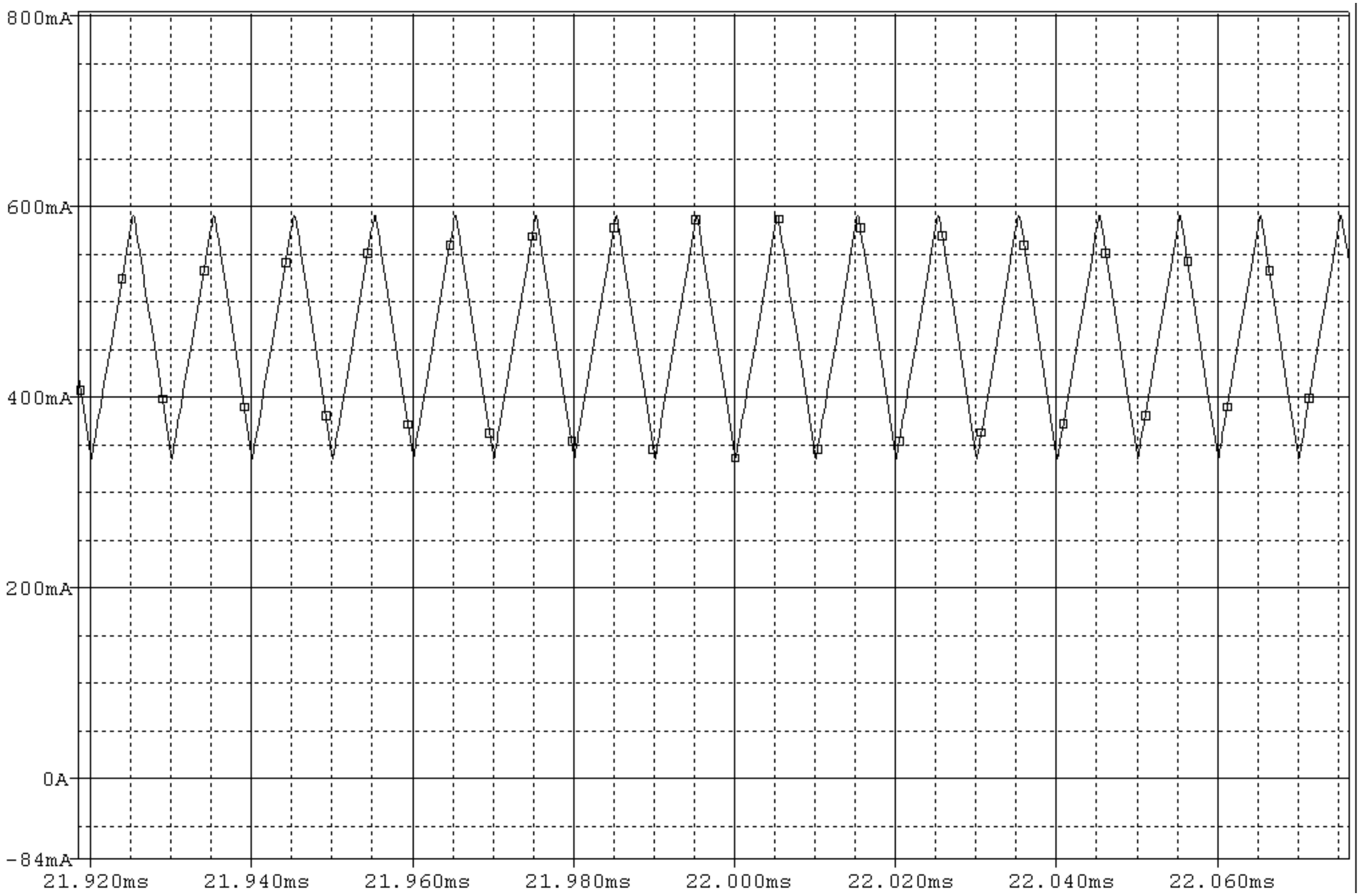
Buck-Boost Verification

- Simulated basic circuit using P-spice



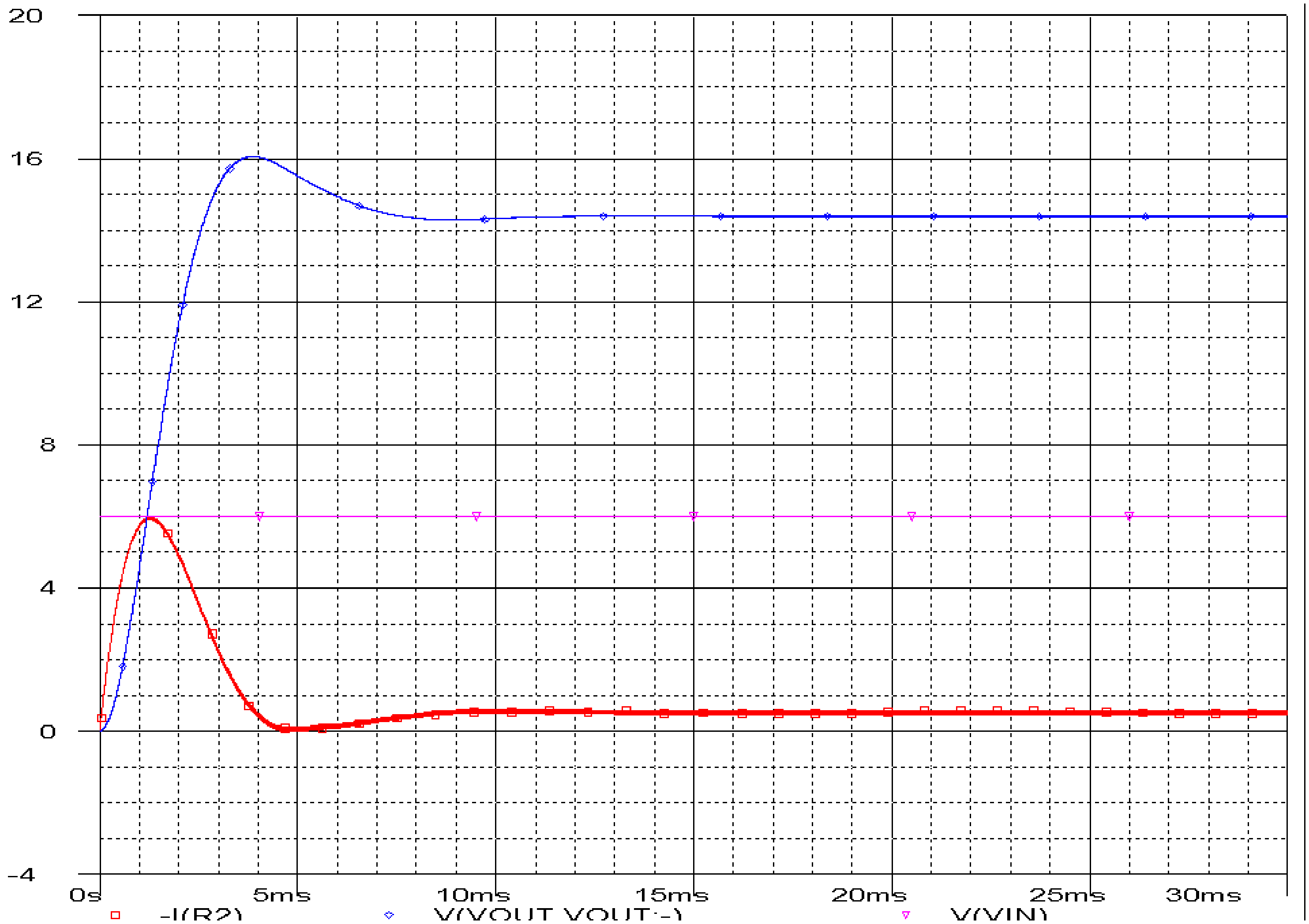
Buck-Boost Scheme

- Continuous mode- Inductor Current



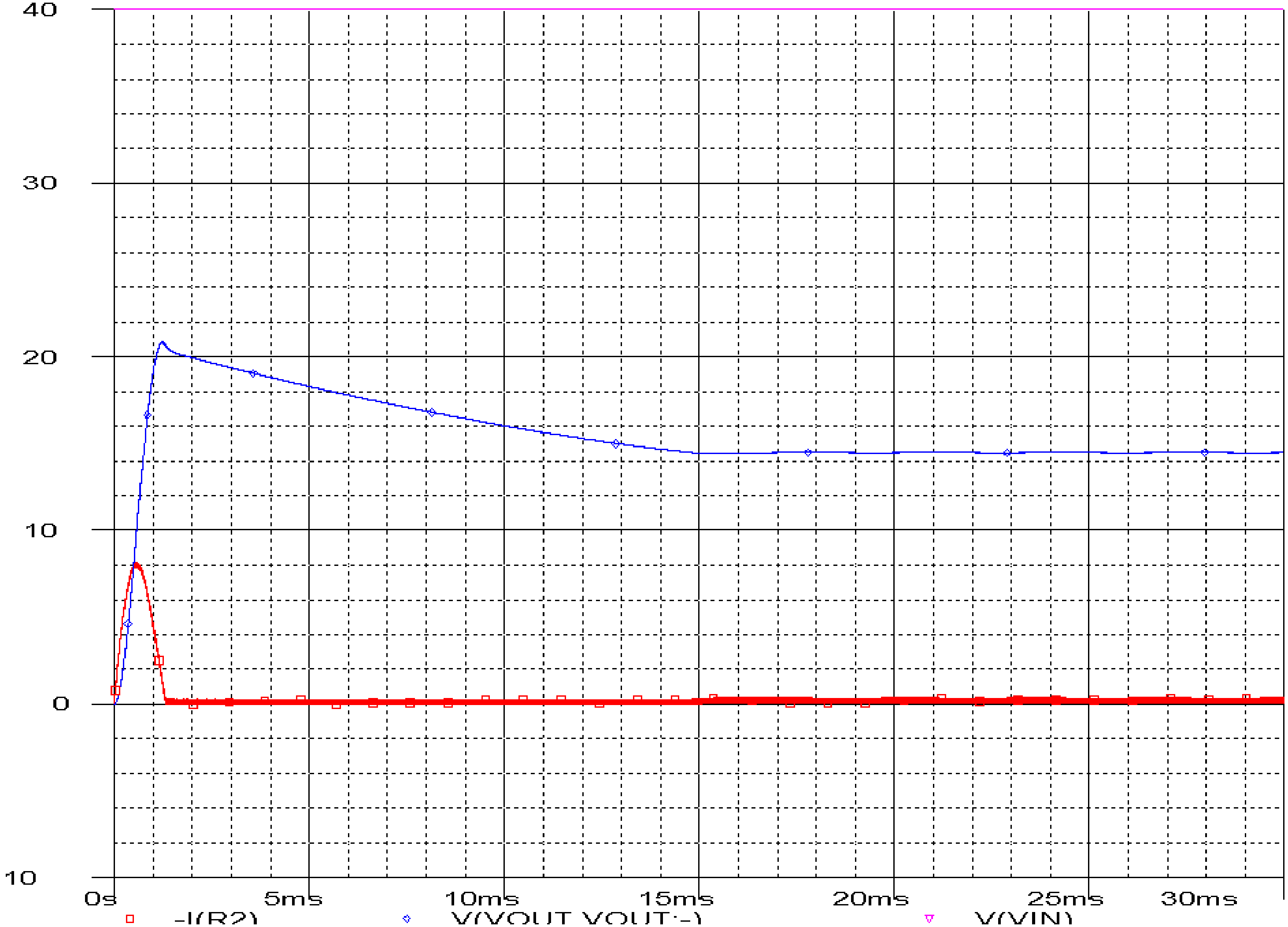
Buck Boost PSPICE Simulations

- Minimum Input 6V with a 75% Duty Cycle



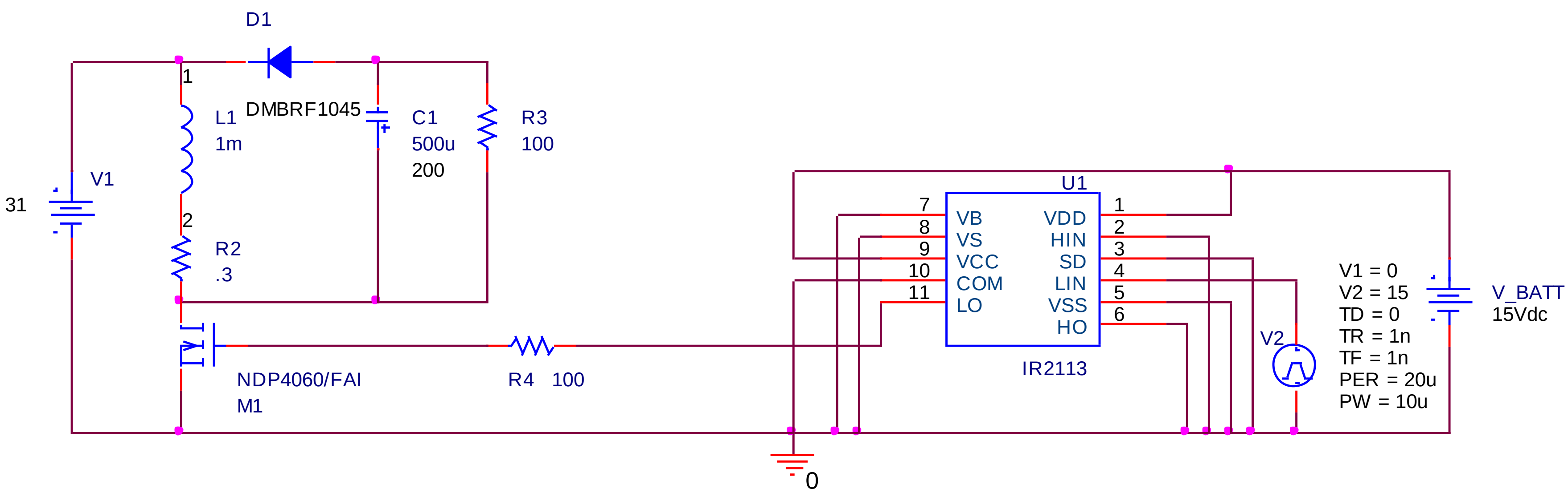
Buck Boost PSPICE Simulations

- Maximum Input 40V with a 25% Duty Cycle



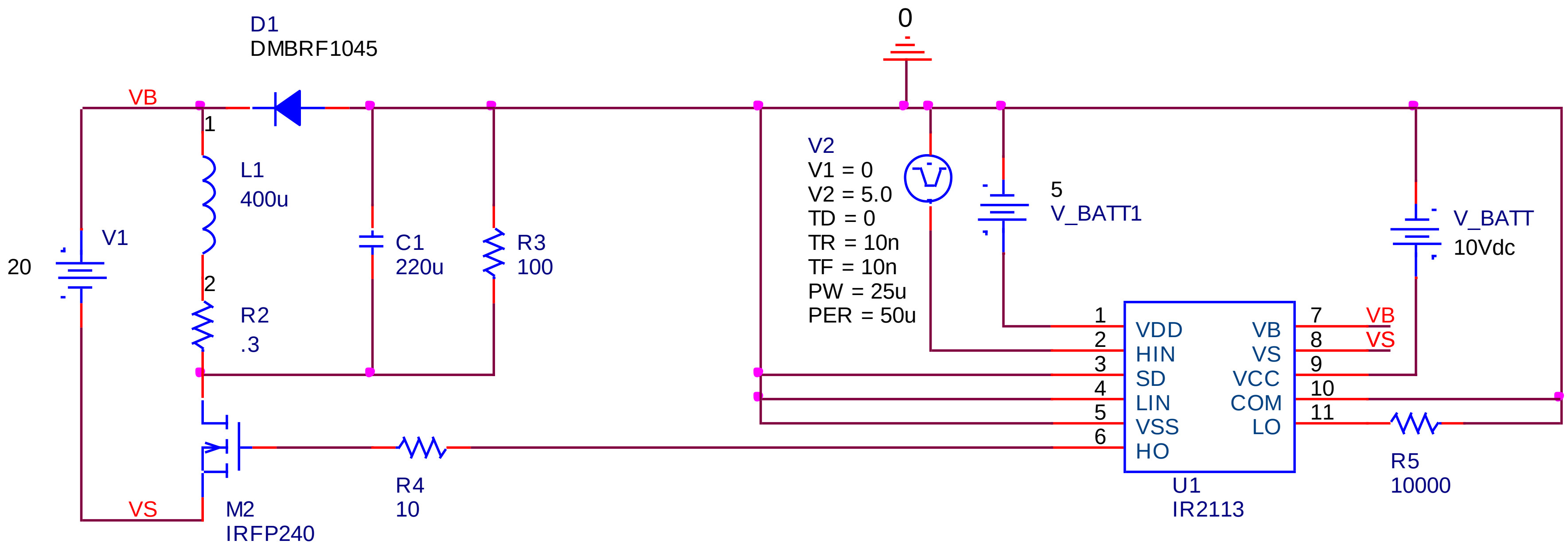
Buck-Boost Implementation

- IR2113 Low-side Driver



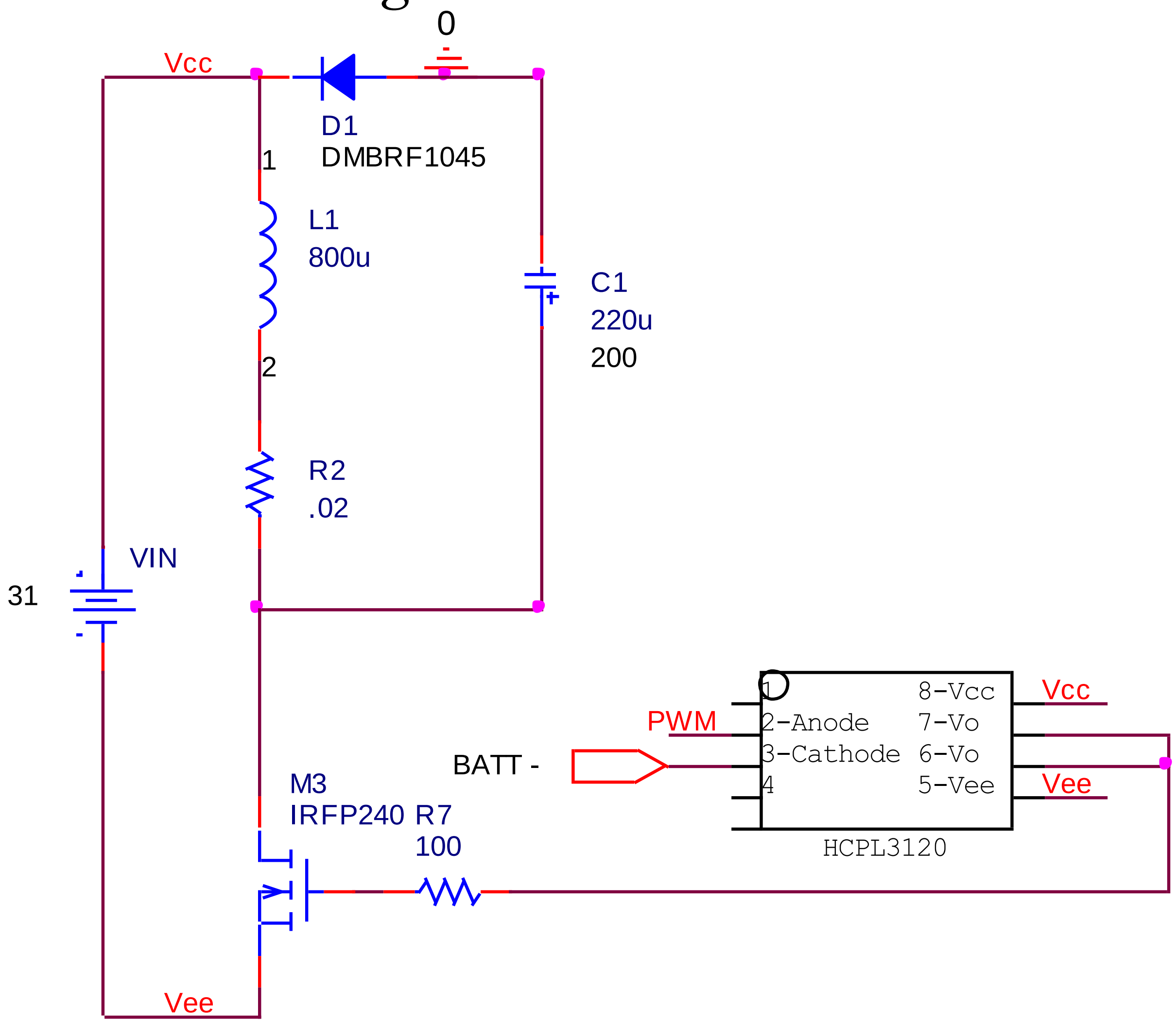
Buck-Boost Implementation

- IR2113 High-side Driver



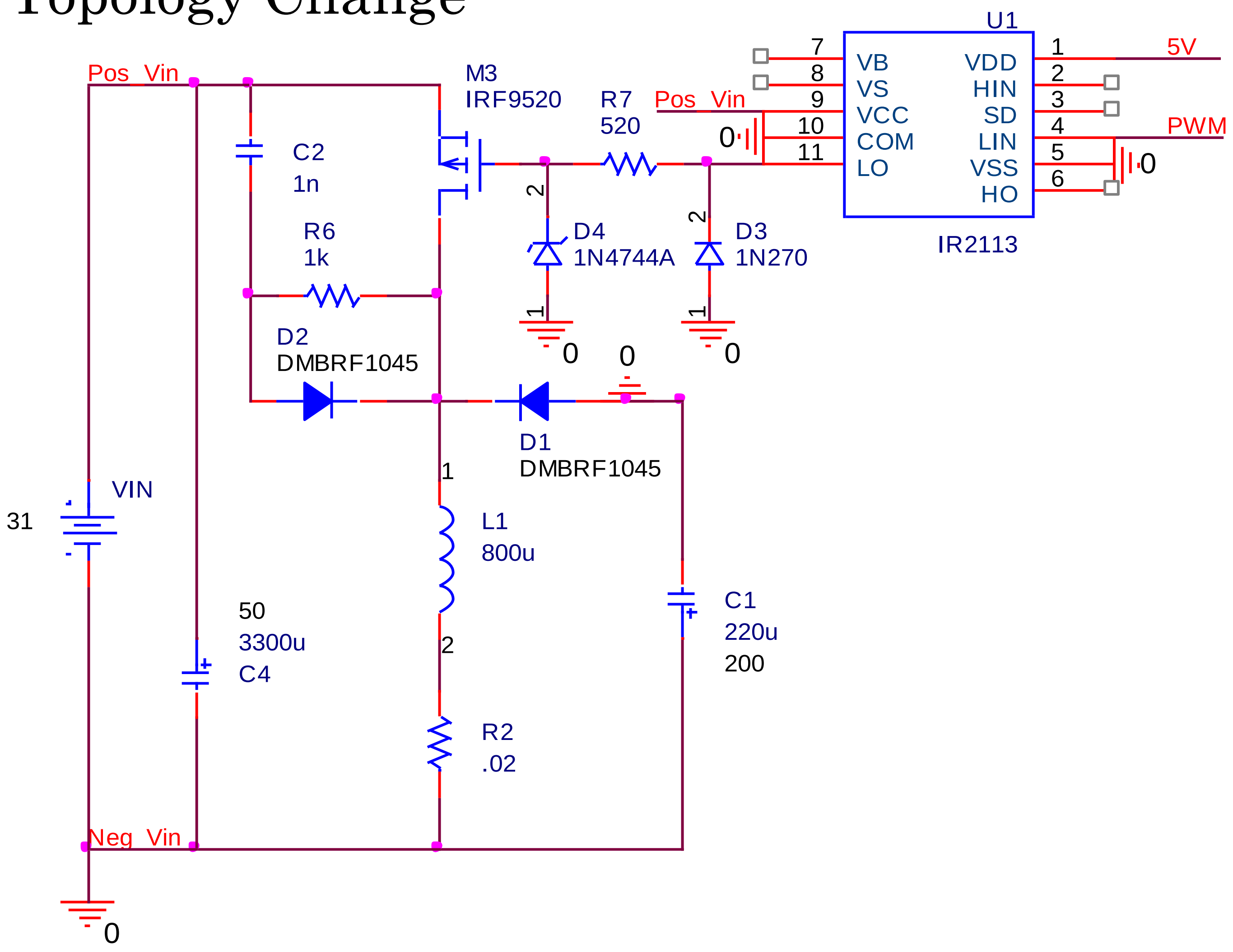
Buck-Boost Implementation

- HPCL-3120 High-side driver



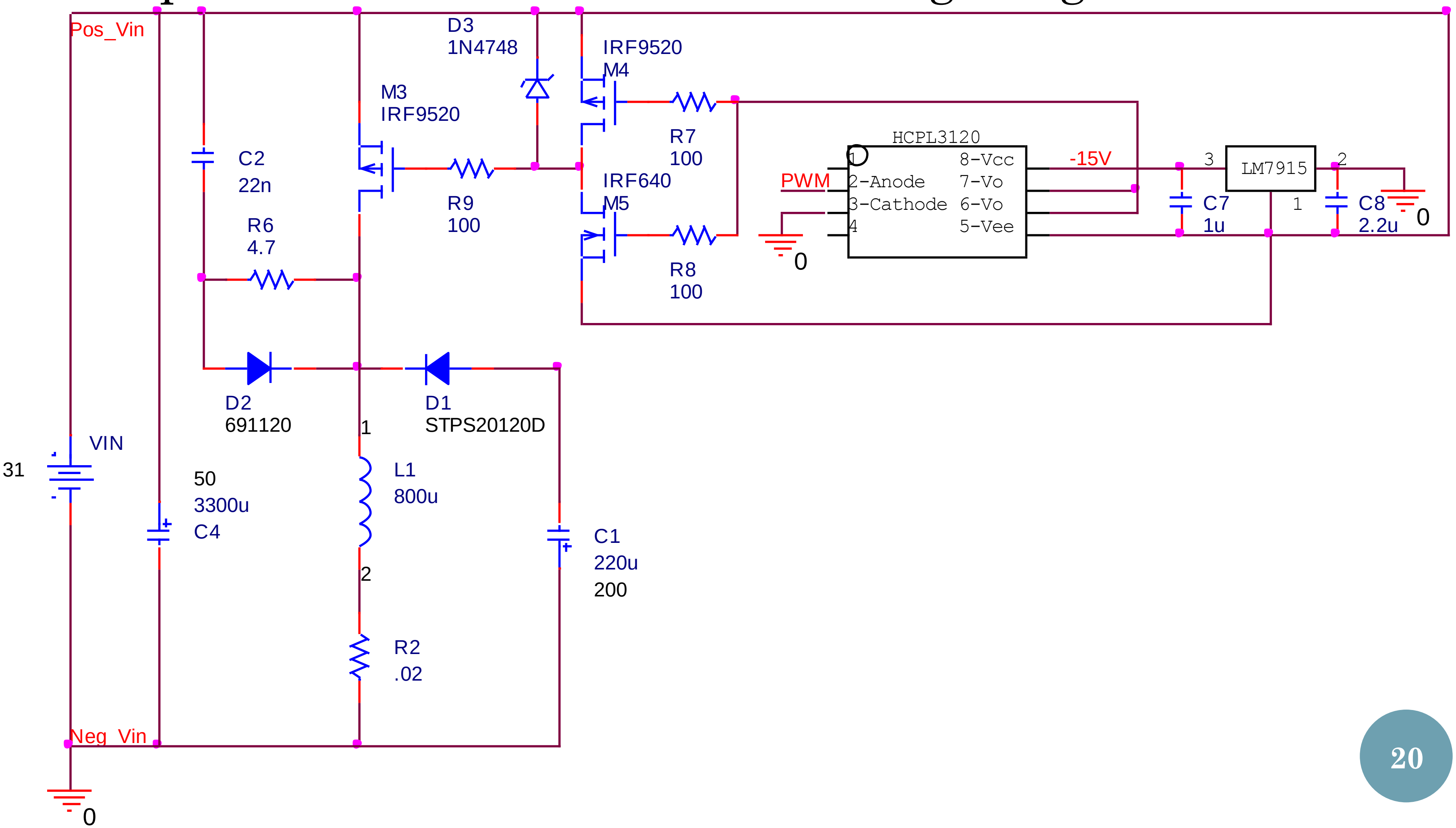
Buck-Boost Implementation

- Topology Change



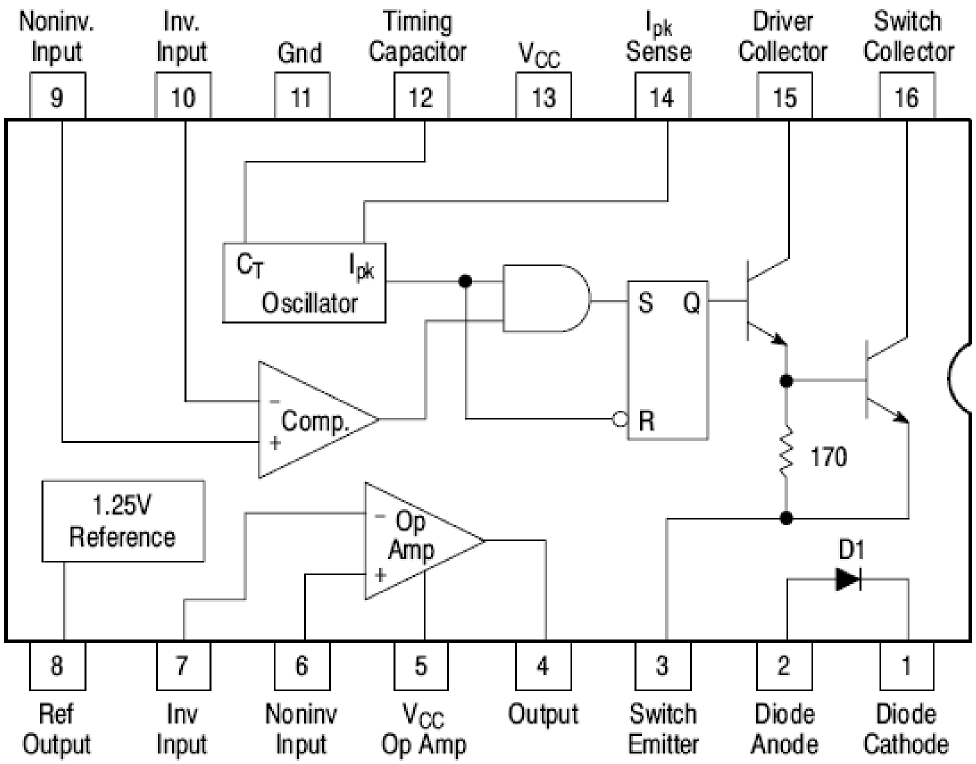
Buck-Boost Implementation

- Optical Isolator with Linear Voltage Regulator



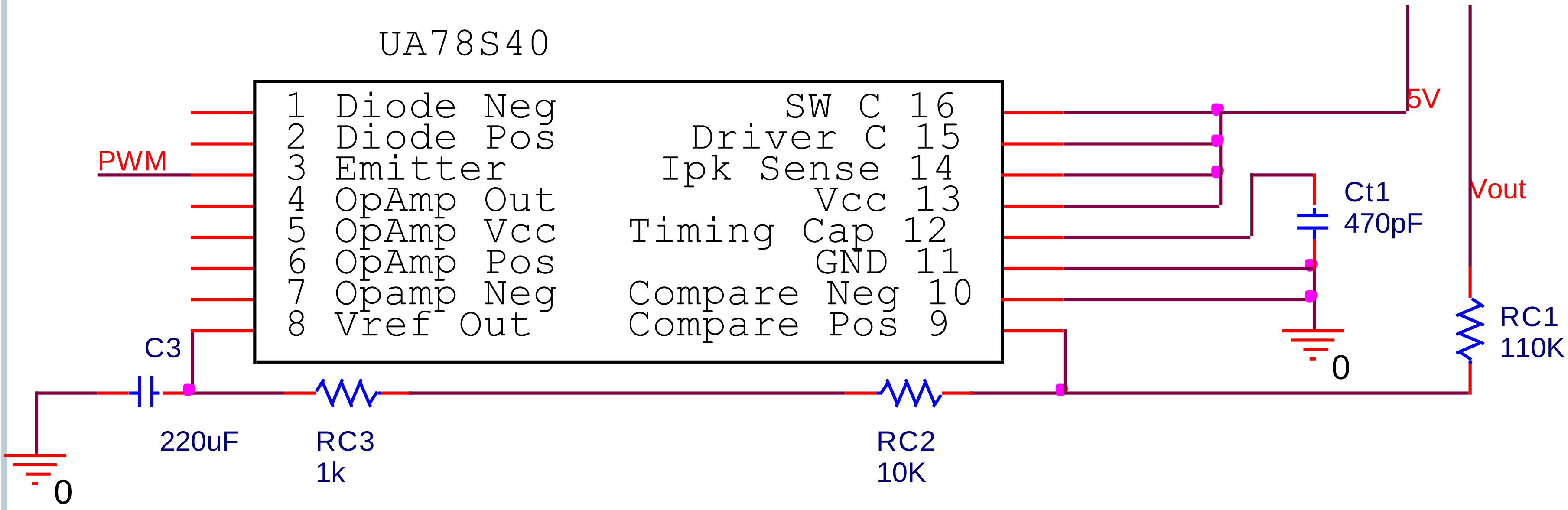
Buck-Boost Implementation

- UA78S40
- Universal Switching Regulator Subsystem
- Provides PWM Closed Loop Control

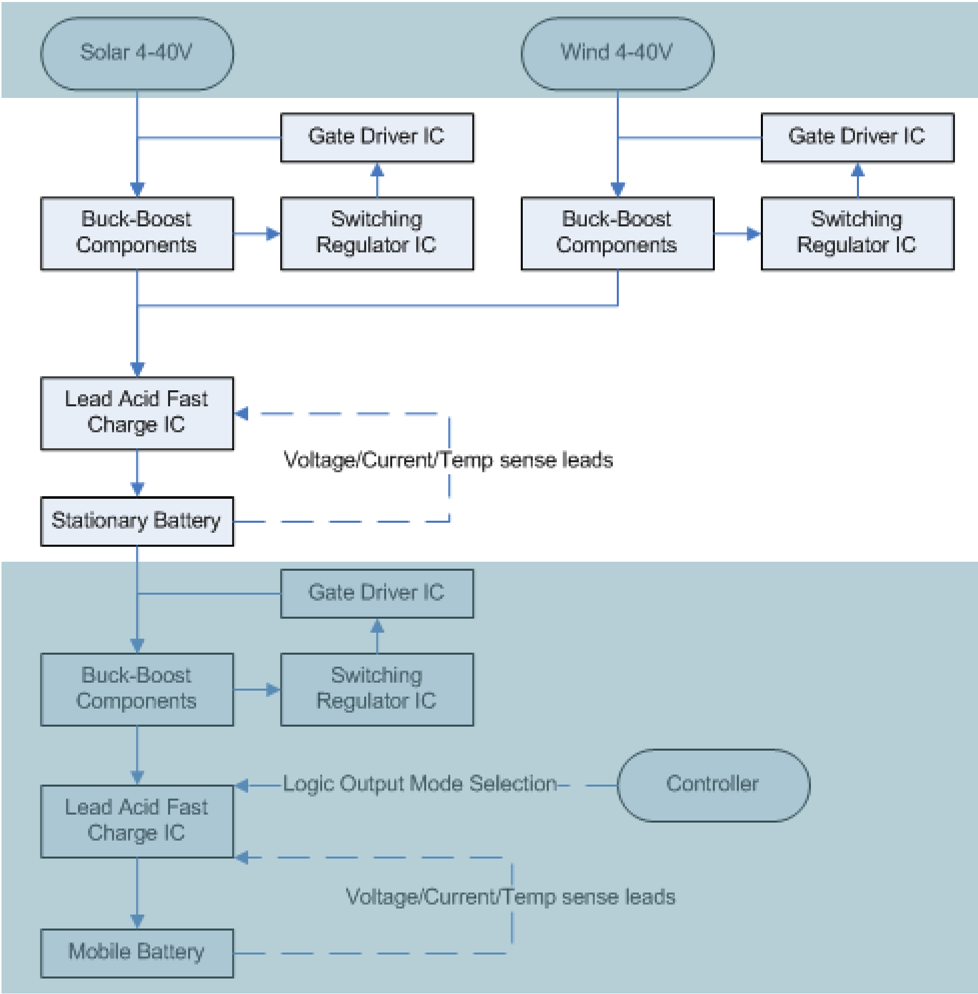


Buck-Boost Implementation

- Inverting Configuration
- Vout = 1.25 RC1/(RC2+RC3)

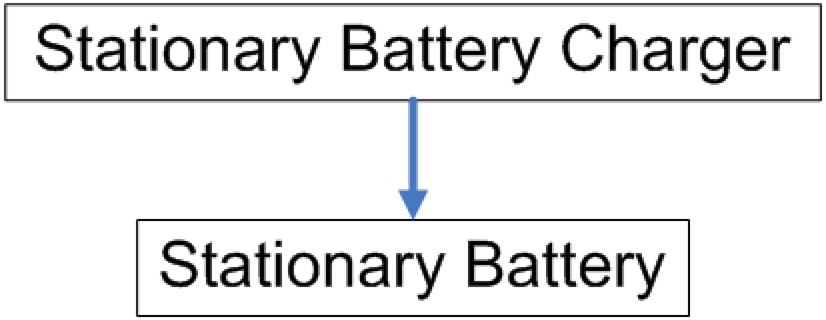


Low Level Flowchart



STATIONARY BATTERY

- Reduces mobile battery charge time
- Capacity needed determined by:
  - What is practical from cost standpoint
  - Stationary battery decay vs. mobile battery
  - Must be at least 180Wh



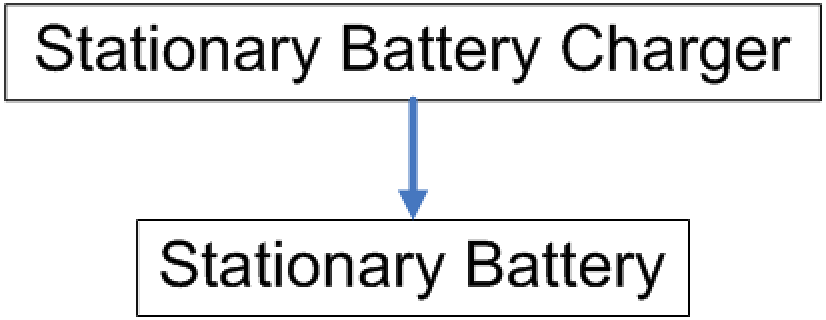
Stationary Battery

- 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.

Stationary Battery Charger

- Can accept max input values
  - Voltage: 30V (from renewable energy)
  - Current: 10A
  - Charges to maximize life
  - Provide over current / voltage protection to battery

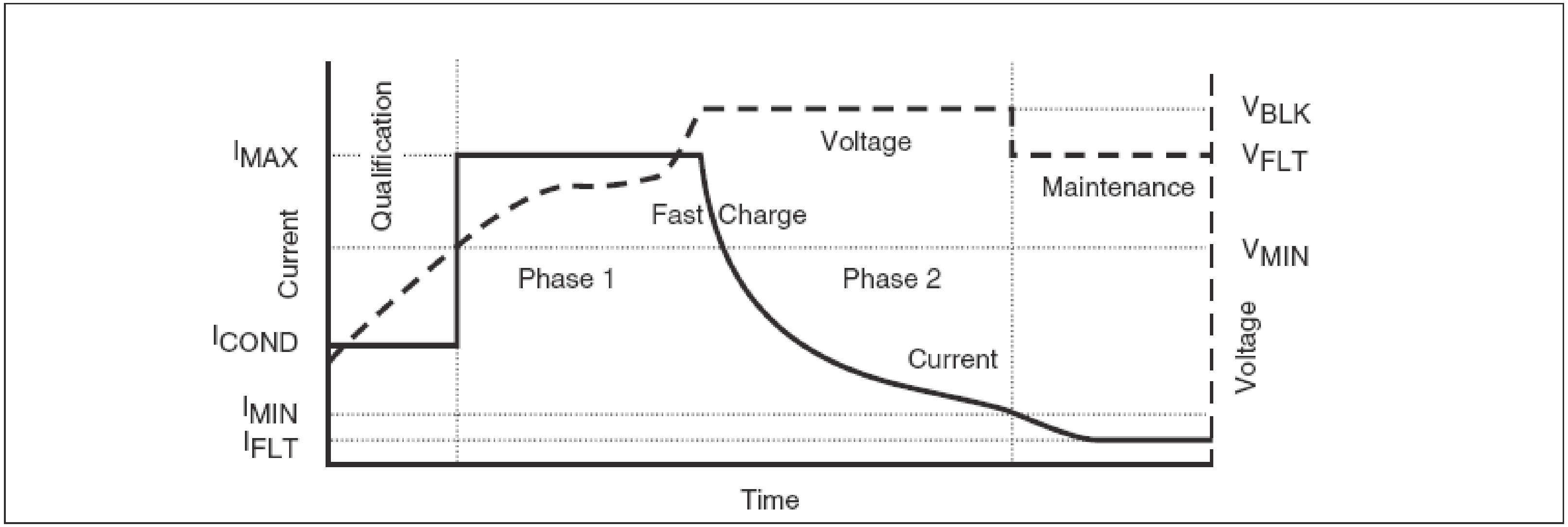


Stationary Battery Charger

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

STATIONARY CHARGER SCHEME

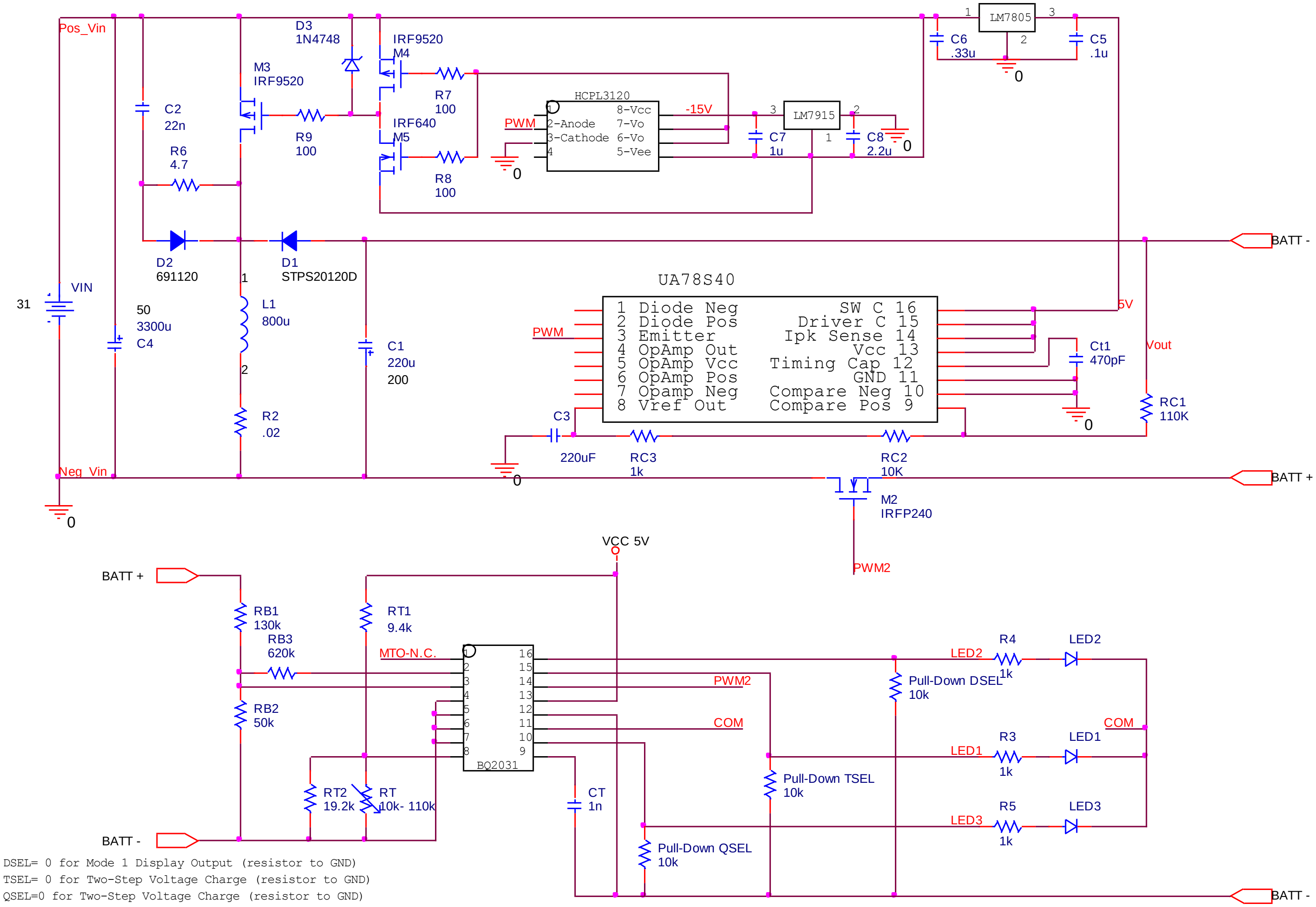
- BQ2031
- Two-Step Voltage Charge



Stationary Charger Scheme

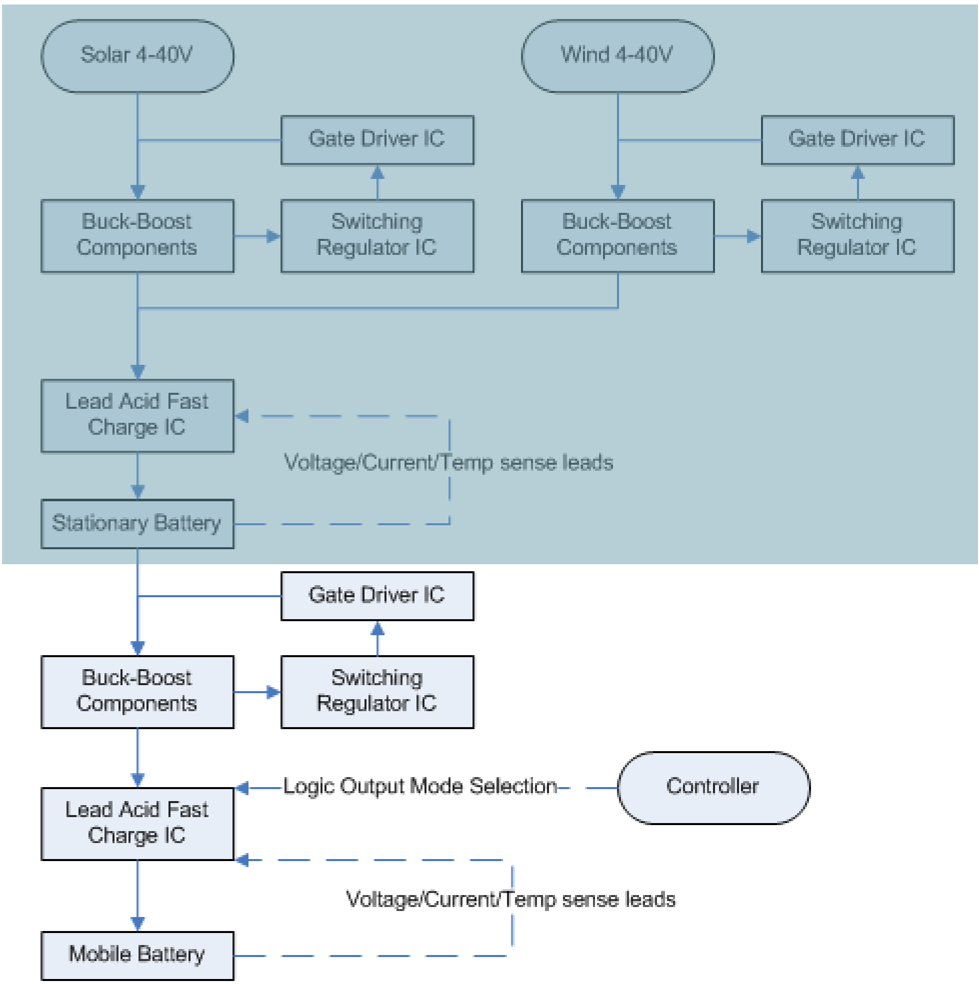
- BQ2031
- Stationary battery specific configuration
- Switching frequency = 100KHz
- Will charge between 32 ^{0} F and 106 ^{0} F
- Over current protection = 10A
- Voltage regulation = 14.3 V

Stationary Charger Scheme



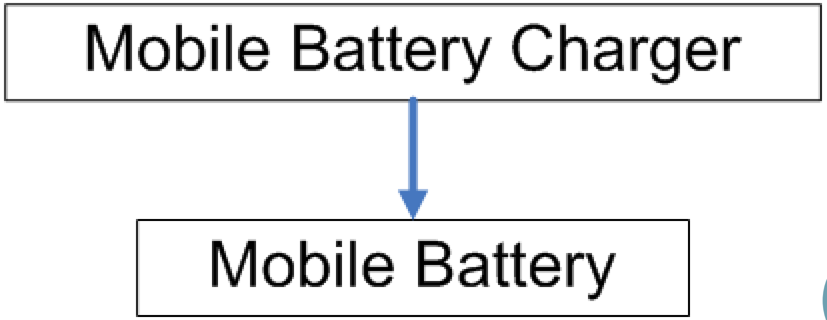
DSEL= 0 for Mode 1 Display Output (resistor to GND)
TSEL= 0 for Two-Step Voltage Charge (resistor to GND)
QSEL=0 for Two-Step Voltage Charge (resistor to GND)
IGSEL=0 for Imin= 1A
MTO=24hrs Open Circuit for Max
RT1, RT2= Charging stops when greater than 105F and restarts at 85F
RB1, RB2, RB3= Float Voltage=13.3V; IMax=10A; Battery charges at 14V

Low Level Flowchart



Mobile Battery Charger

- Accepts energy from stationary battery
- Must be capable of outputting
  - Voltage: 14.9V
  - Current: 4.8A
- The mobile battery charger shall be capable of charging the mobile battery within at least 12 hours

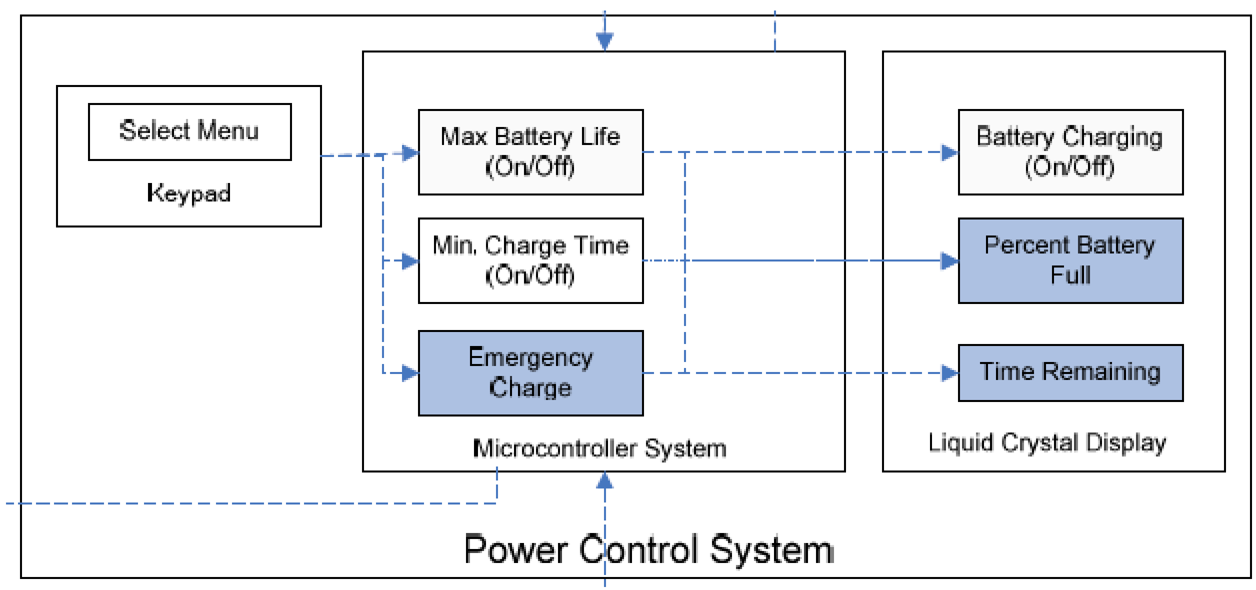


Mobile Battery

- Panasonic LC-RA1212P for Gaucho
  - 12V lead-acid battery
  - Rated capacity: 12Ah
- Minimal charge time
  - 2 hours 39 minutes
- Maximum battery life
  - 2-8 years
  - 250-500 charge cycles
- Constant Voltage Charge

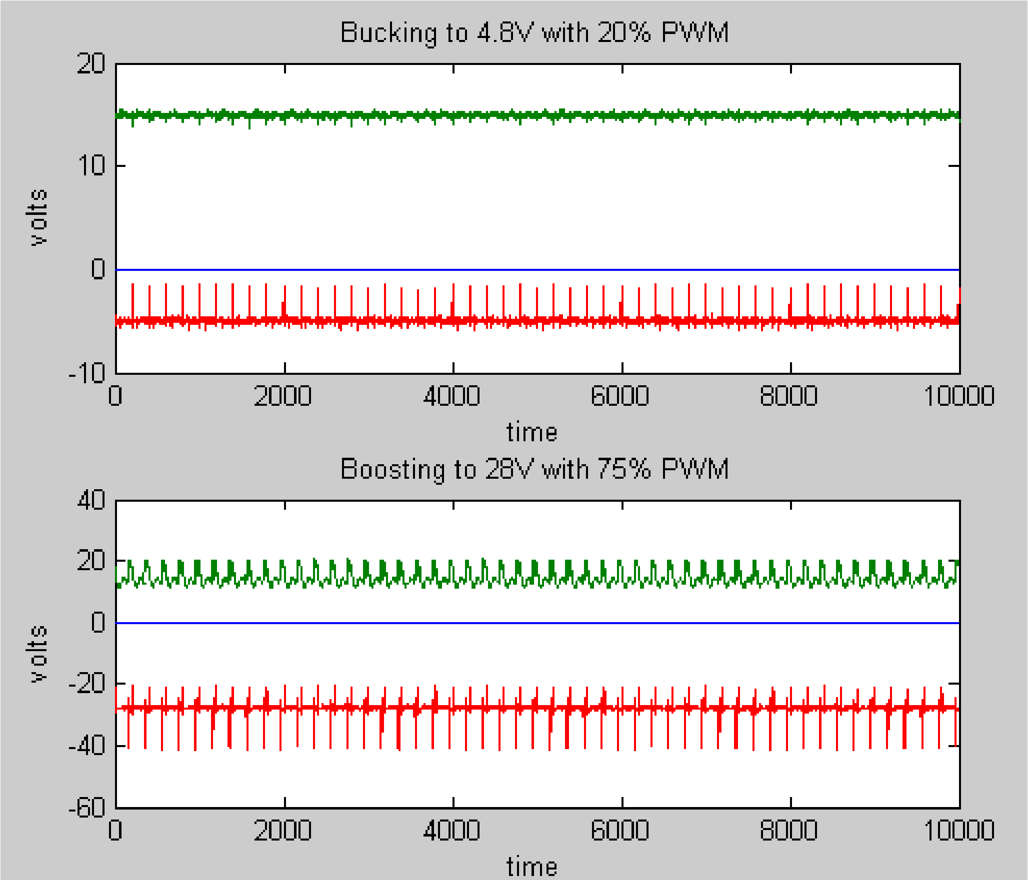
User Interface

- Keypad input
  - User selects mode of charge
- L.C.D. output
  - Battery charging indicator
  - Battery charge percentage indicator
  - Time remaining until battery charged indicator



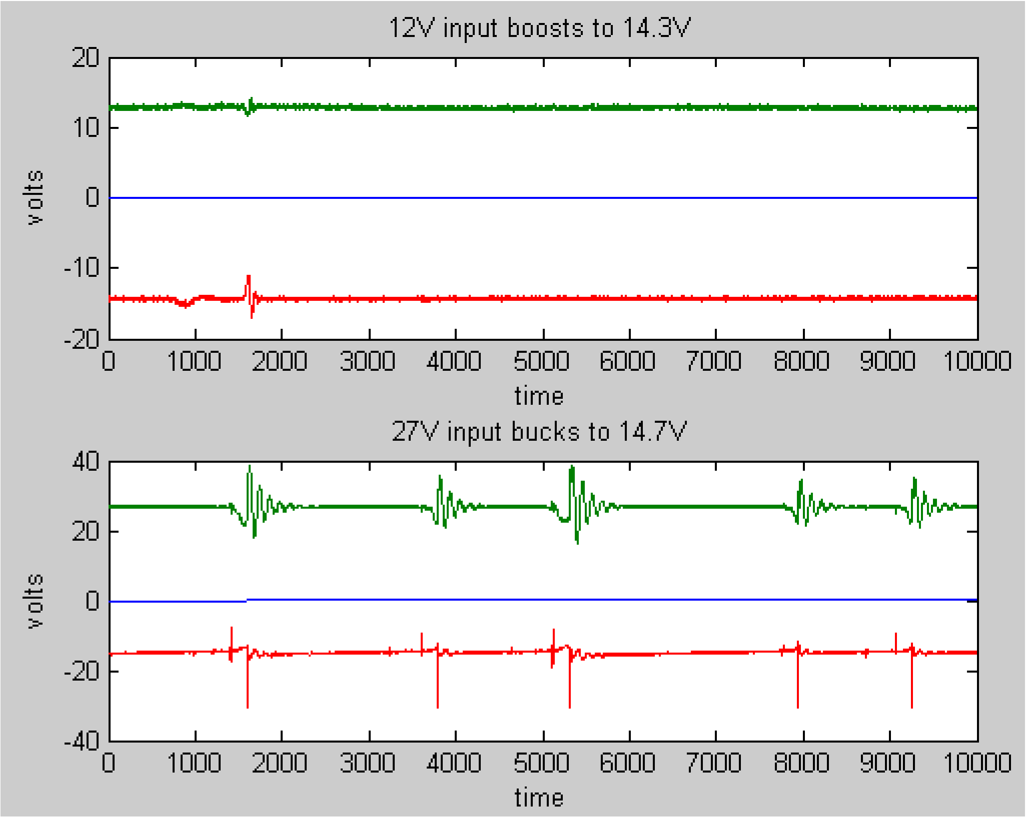
Actual Results

- Buck boost topology, gate drivers, and regulation works



Actual Results

- Buck- Boost Results with feedback



Actual Results

- BQ2031 Indicates it passes qualification tests
- Still need to implement gate driver and FET

Potential Improvements

- Implement
  - Mobile Battery Charger
  - Microcontroller Feedback
  - Use switching voltage regulators instead of linear
  - N-channel MOSFET with floating gate drive on buck-boost
  - Clean up noise in voltage regulation
  - Create more protection circuitry

QUESTIONS?

Stationary Battery

- Possible battery choices

	Optima Lead Acid	Li-Ion	Ni-CD	Ni-MH	Sealed Lead Acid
Temperature Range (C)	130 to -30	50 to -20	45 to -40	50 to -20	60 to -40
Calendar Life (years)	?	2 to 5	2 to 5	2 to 5	2 to 8
Max Charge Cycles	300+	1000+	300 to 700	300 to 600	250 to 500
Discharge Profile	Flat	Slope	Flat	Flat	Flat
Self Discharge Rate @ 20C (% /mo)	Very Low	2	15 to 20	15 to 25	4 to 8
Memory Effect	No	No	Yes	Yes	No
Ability to Trickle Charge	Yes	No	Yes	Yes	Yes
Charging Characteristic		2 stage			
Deep Discharge	Yes	Yes	Yes	Yes	No
Relatively Quick Charge	Yes	Yes	Yes	Yes	No
Constant Voltage Or Current Charge	Voltage	Voltage	Current	Current	Voltage
Relative Expense/ Capacity	Cheap	Expensive	Moderate	Moderate	Cheap
Approx Expense (dollars)	150	< 600	300	350	80

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 $\Delta^2 V < -8mV$[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

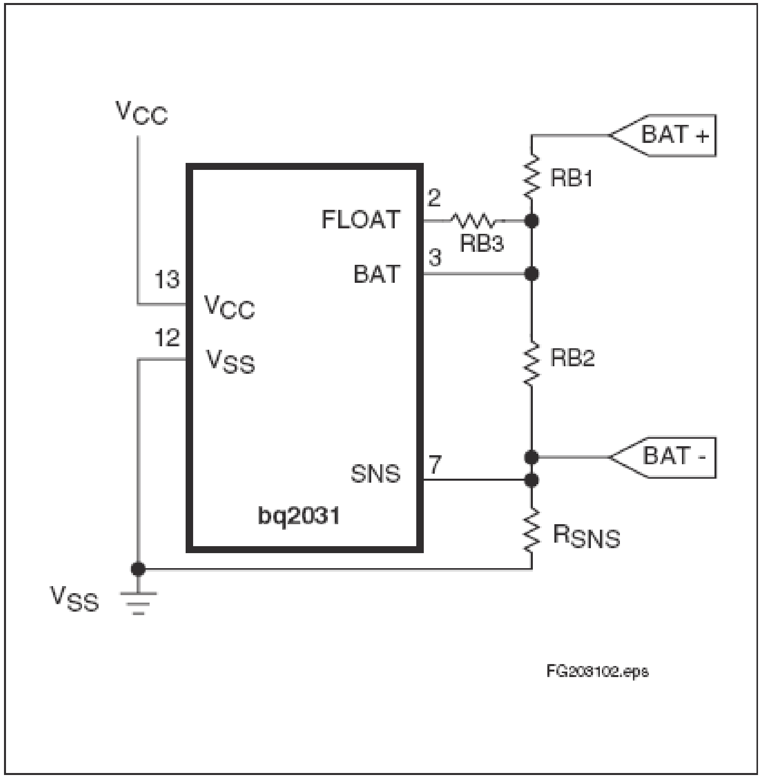
$$\frac{RB1}{RB2} + \frac{RB1}{RB3} = (\frac{N * V_{BLK}}{2.2}) - 1$$

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
- 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

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

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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
- Imin = Imax/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

Equation 4

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

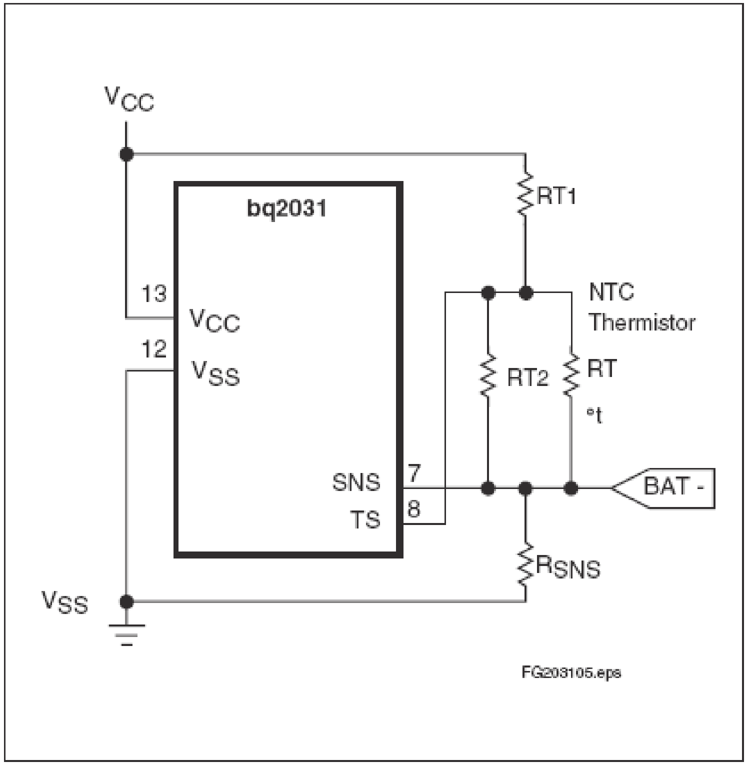
Equation 5

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

where:

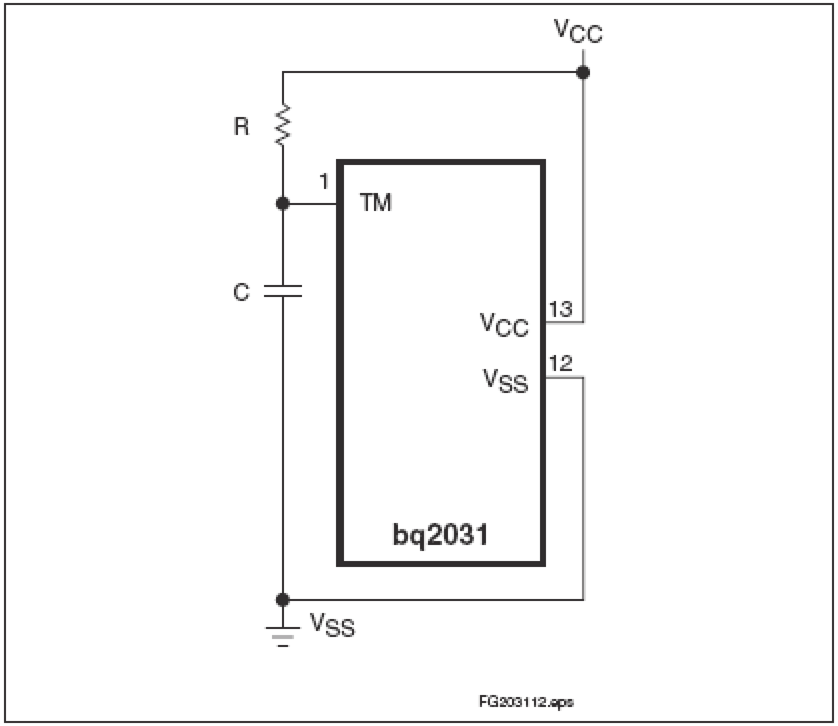
- R_{LTF} = thermistor resistance at LTF
- R_{HTF} = thermistor resistance at HTF

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.

Microcontroller Requirements

- Microcontroller switches IC charging mode
  - Feedback loop handled by IC
- 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

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