



Team Ultra-Charger

Design Report



Keith Leitner and Robert Prew

Executive Summary

This paper is written to represent Battery Ultracharger's senior design project, the Airport Battery Charger. The Airport Battery Charger is fast portable battery charger that can be used in any normal outlet. It takes two minutes to charge and can fully charge a cellular device. This report will cover the following topics:

- Background of the project
- Full project definition
- All concept designs for the entire project
- Final decision and design of project
- Future work for the project

Background

Motivation

Professor Herbert Hess wanted a solution to a constant problem that most airport travelers experience. When transferring from flight to flight you sometimes don't have enough time to fully charge your phone. This could be solved with a fast charging portable battery. This device would be able to charge within two minutes and be able to full charge a cellular device. Both the team members were very interested in this concept. Once we were accepted onto this project we got to work.

Who Would Benefit

This project would benefit anyone that has a mobile device that needs charging. The exceptional speed provided by this device would save the user countless hours that could be spent doing more important tasks. Having an on the go battery gets rid of the sitting next to a wall outlet conundrum that is regularly seen at airports.

Problem Definition

Goals and Deliverables

- The device must charge efficiently up to the required specifications
- The device must also store enough energy to charge a mobile cellular device
- Must fit in a carry-on item for airplane travel
- Must be safe to use

Based on these goal our team was able to develop a set of deliverables to have at the end of the project.

- Team Portfolio: A collection of notes, datasheets, minutes and other documents that have been made and collected for the purpose of this project.
- Logbooks: Our personal notes and research created over the entirety of the project.
- Poster Board: Shows a general overview of the entire project in an easy to read and understandable format.

- Final Design Report: A detailed paper created to convey the process and information gathered in the portfolio. The report will teach the reader how the team went about this project
- Hardware Prototype: A physical product that has been created over the course of the project timeline.

Specifications

Dr. Herbert Hess gave the team a set of specifications that this project should fit into. The list shown below changed over the course of time but the beginning set goes as follows.

- Should be able to fit into carry-on luggage
 - Length: 6"-8"
 - Width: 4"-6"
 - Thickness: up to .75" (Ipad thickness)
- Circuitry Parameters
 - Power Capacity: 5.33 Whr to 7.2 Whr
 - Charge Time: 2 minutes (± 30 seconds)
 - Plug into a standard household outlet
 - Capacitance 70 Farads
 - Max of 20 Amps

From these specifications, a tight constraint was created. To tackle this project, we needed a plan and we needed to catch up. This project was started by a previous team. Our team had to pick up where the previous team left off and see what could be improved.

Project Plan

Tasks and Schedule

This project was full of tasks to accomplish, with an overall goal of completing the prototype we were given at the beginning, and developing it into a fully functioning and marketable product. These tasks were varied, often changing according to how the needs of the project and other developments required them. For an overall forecast however, we produced a pair of Gantt charts at the start of each semester in order to detail our own goals and expectations, as well as mark down major dates and deadlines. These Gantt charts can be found within

Team Responsibilities

Initially our team consisted of more people, allowing a greater spread of the responsibilities for the project. With a shift in the overall members, duties were changed as well.

- Finances (Keith Leitner): In charge of budgeting and buying necessities during the life of the project.

- Primary Client Contact (Robert Prew & Keith Leitner): Primary contacts for our client, updating them on progress and addressing the needs and questions the client may have.
- Team Organizer (Robert Prew): Organizes meetings among team members and maintains all communications in order to ensure everyone is doing their part.
- Team Documentor (Keith Leitner): Records minutes of each meeting held, documenting any and all updates and information during them.
- Reflector (Robert Prew): Directs brainstorming of ideas and points the team in the correct direction to maintain progress of the project at hand.

Overall however, while duties were assigned and generally maintained, there was a sharing of some duties which occurred. With only two people on the project, maintaining general contact was made easy, as was meeting to research and develop the project. Meetings not involving the client were generally without much structure, merely updating each other on what had been done since the previous meeting, determining what needed to be done still, and proceeding to work on what both members decided was necessary for the time.

Concepts Considered

Client Interview

With the start of the project, our team turned to our client and department professor, and asked him about his desires for the project. While there was a prototype and notes on the project from the previous team, having the perspective of the client was important in kickstarting our work. For this, we developed a list of questions covering the previous team's work, specifics on the project such as desired components and results. Since the previous project was already available, a lot of what was asked was based on what the last team made. This was to learn from the mistakes of those before us, determining where they went wrong and what they had left to complete. Additionally, our questions were also to pick the client's brain and see their vision. Having his input allowed us to better visualize the expectations and what to look for when proceeding with the project.

The interview was productive as a result, allowing us to have a solid foundation upon which we could begin to move forward. There was still plenty to figure out, primarily based on what the previous team had left to evaluate, but the concept of the project and the desired end result were made clear enough. The main issues with the prototype were revealed at this point, allowing a good launching point from which the project could proceed.

Concept Development

As aforementioned, there was already a prototype [3] which had been created by the previous team. The prototype was deconstructed, requiring a process of reconstruction based on the varying images, diagrams, and explanations we could find from the

documentation we were given. This prototype was built within a buck converter layout, taking in AC voltage from a wall outlet, rectifying it into DC voltage, delivering it across a power MOSFET and a string of inductors and resistors before arriving into a “bank” of ultracapacitors as a storage medium. The stored power could then be output from the ultracapacitors, through a smaller buck converter device and out a USB interface through which a phone could be charged.

This prototype was unfinished and left with a variety of flaws in the design, the worst of which being that of the gate driver for the MOSFET. Originally, there was an isolated gate driver developed by International Rectifier which had been used in an attempt to flip the gate switch on the power MOSFET. The mistake in this turned out to be a complete failure to recognize the voltages required to flip the gate. Output from the original gate driver could reach a maximum of 18V. What the gate of the MOSFET required was a voltage approximately 10V to 20V less than the voltage going into the source. Since the source was receiving a rectified DC voltage of approximately 170V, their original gate driver was clearly unsuitable for the job. Knowing this, a variety of changes were suggested over the course of the year thanks to the general lack of availability of a single gate driver able to produce the necessary output.

With this in mind, the rest of the year followed with a constant stream of developing alternatives to the original buck layout. Much of this involved looking into various converter designs or other ways in which the prototype layout could work so as to avoid losing the work from the previous team. With such a high amount of power flowing through much of the project, finding components which handled the load cheaply and in small packaging proved to be a vexing issue.

Snapshot Day 1

The first Snapshot Day was preliminary of what to expect at the Engineering Expo a few months later. This event had each group set up a poster board explaining plans and expectations of the project, as well as any ideas and progress we had made. The poster board our team created covered several concepts:

- An abstract/problem statement for the project
- Specifications from our client for the final product
- Schematics and layouts of the prototype
- Examples of our research at that point
- A Gantt chart detailing our expected timeline for the spring semester
- Output diagrams of the capacitor bank’s charging capabilities

While it was not perfect, it was a good start. We received some level of feedback from peers, most expressing interest in what the project was looking to accomplish. Unfortunately, there was not much to be said in terms of helpful feedback for the project’s development, but this was not discouraging in and of itself.

Design Review 1

Around the end of the semester, the first design review took place. Our client as well as the course instructor attended and offered critique to the presentation our team gave. This presentation covered much of the same details as the Snapshot, only with

further detail provided on our progress and any developments on the project. Thus, we covered the specifications and vision of the project, as well as showing circuit diagrams, images of the project's sections, and some of our research into other layouts.

What we came away from during this review was a need to take another look at the project. A Cúk converter layout which had been suggested and looked into was determined to not be able to deal with the power we were working with, and so other suggestions were brought up. Flyback converters and Dickson charge pumps were mentioned as the next possible options, with both having slightly more complex layouts which could then be used to solve the issues of the power MOSFET by removing it entirely. Unfortunately, these ideas were dropped shortly after realizing the Dickson would provide high DC voltage outputs from lower voltage inputs and the Flyback didn't provide a high enough voltage. Additionally, the components to make even the Dickson charge pump work at the levels of voltage and power they would produce were found to be costly, if proper parts were sold to begin with.

Design Review 2

By the time the fall semester came around, it was time for another design review in order to pick up where things left off as well as leave a better impression than the previous time. By this time, the project had shifted yet again once it was clear finding a new converter layout was not going to work. The presentation covered much of the same material as the previous presentation, this time showing off the state of the working portions of the project and identifying MOSFET as the target issue of the prototype. With this in mind, a new look at the gate driver and finding a replacement was brought up. Another idea that was brought up to pursue was looking for parts which are specifically designed to charge super/ultracapacitors, though this was eventually dropped due to size concerns and the need for a very specific voltage and current range in order to hit the two minute timeframe necessary for charging. Aside from the shift in focus to go back to the original layout, there were other critiques which proved useful for the project. One such was to focus on the Arduino Uno and find a way to power it. Since it was pointless to have the Arduino power through a secondary cable, supplying power via the rectified input voltage was deemed the next best option. Using diodes to prevent backflow in case of failure and resistors to produce a voltage divider in order to scale down the voltage to a low enough level for the Arduino, it appeared to be a good plan to move forward from.

Snapshot Day 2

A second Snapshot was held around the same time as the design review, covering much of the same ideas as the previous one. This time we took our new research and brought up some of the ideas we were looking into, mainly in finding either a charging solution for the capacitor bank or finding a new driver. There was a fair amount of critique this time, though mostly it was involving the overall design and focus of the project. With little new information to go from after this review, we continued forward, eventually narrowing the focus onto finding a new driver for our MOSFET.

Snapshot Day 3

The final Snapshot Day was more along the lines of the Engineering Expo held back in May. There were more people and more critiques involved during this, including a presentation much akin to the design review. During the Snapshot portion, our group demonstrated the charging capabilities of the project and showed the current state of the project. While new parts had been secured to solve the previous issues, they had not been instituted into overall design just yet.

These components were shown off however and their purposes explained. The first was a DC/DC converter that had been brought in to drop the voltage going into the Arduino [16]. This in turn would solve the earlier issue brought up about powering the Arduino via the input from the outlet. This converter was able to reduce anywhere from 110V to 420V and bring it down to about 5V, all while producing a current of around .66A, much less than the 1A limit of the Arduino.

The other component was a new gate driver, based on discussions with our client and resulting research from these meetings. Instead of relying on a single gate, the design was altered to accommodate a dual-gate driver, utilizing the ideas of a motor driver [18]. With a second gate, a second MOSFET was needed to be added, this one connected between the output of the first MOSFET and ground.

Developmental Obstacles

It would be no exaggeration if the majority of this project was spent overcoming obstacles, primarily one key issue: the gate driver to the power MOSFET. This small part proved to be incredibly troublesome in replacing once it was determined to be the source of all the problems in the circuit. Researching a solution was what brought down the project for the majority of the time, as finding an exact solution became convoluted. Different converter layouts to either avoid using a MOSFET or ground the MOSFET were looked into, with a great deal of time and effort attempting to make any of them work. This time could have been spent finding the proper driver sooner, though early on it was unexpected to think a dual driver was to be necessary. Once the focus shifted onto the driver, even finding one was time-consuming. It was mentioned before, but the specifications of the project required a middle-of-the-road power rating that most components didn't work with. For the most part, voltage ratings on parts were either below 100V or well above it, and likewise current ratings rarely went above a few amps. Finding a driver which could not only handle the voltage range we required while outputting the right gate voltage, but also deal with the proper current was difficult. Had this focus been realized and the idea of using a motor driver as the inspiration come sooner, the project would have been far more successful, with more time being able to be spent on testing the final product once the parts were installed.

On that note however, one last setback that the project experienced was with the DC/DC converter that was brought in. While it appeared reasonable and just the kind of part needed, any attempts at testing the component were met with problems. The datasheet was obtuse to make sense, with very little direction on what view the pin layout was to be view from. Even with this sorted out and the proper load and layout

provided, the part refused to produce viable output, with results having the current rise too quickly and destroy a part in one instance, or simply having the current not rise much, if at all.

Concept Selection

Seeing as the previous team already had a prototype nearly built, developing a concept really was not much of a necessity. The buck converter layout was clearly one of the best suited designs for the purpose of the project thanks to its inherent process of ramping down voltages from high to low. It was also a simple overall layout and for the most part easy to understand. The changes made to the original idea in adding a dual gate driver and a second MOSFET as a result have not changed the main functionality of this layout thankfully, merely bolstered what is there already. In this regard, we have a new layout that can ramp down the voltage of the input and provide the system with enough power, all without worrying about too much or too little power at certain sections. The power MOSFET and its driver were again the primary issue in making this work, however a solution was able to be found, even if it took some time to find and develop it.

Most of the year was spend finding new concepts to, in a way, take the easy way out. Since working with a power MOSFET that wasn't grounded made the gate voltage incredibly high, it was originally thought finding an alternative layout would work. Through all of the design research and tests, it became obvious this was not a viable option. Time was being spent trying to make designs work that simply could not under the loads required of the project, whether it was simply too much or too little power. With that realization came the return to the original concept of a buck converter, this time approaching the initial problems brought on by the design and fixing them, finding the new dual gate driver and making the design still work with only a few minor alterations. No longer was an op amp needed to boost the Arduino signal into an isolated gate driver. Instead, the Arduino's output was just what the driver could use, reading the signal and then working to flip the gates of both MOSFETS, operating so one would open while the other was closed.

System Architecture

Buck Converter Background

Since the buck converter originally used by the previous team we took to using that as a solid base of our project. The buck convert is a step-down convert meaning it can step our voltage down while also increasing the current. The buck converter would swing the current as it ramped up until it got to a sufficient point that would charge the super capacitor bank. The buck converter would operate based on the supercapacitor bank. A microcontroller will operate the MOSFET as a switch until the supercapacitor bank reaches its max voltage.

Calculations (Energy Storage)

Our base energy storage is based off available technology for our team. We used an Iphone 4 battery in our testing and as a base for our supercapacitor bank. An Iphone 4s

has a lithium polymer battery has a storage capacity of 5.254 Whr. This is gathered from the fact that the voltage and current capacity of the battery is:

- 3.7 Volts
- 1420 milli-Amp hours

This will come in handy when trying to figure out how much storage our supercapacitor bank needs. Since 1 kWh is equal to 3600 kJ we can find how much storage is in an Iphone battery. An Iphone battery hold approximately 18,914 J. This 18 kJ is our base line for our capacitor bank.

We were provided with a set of twenty Maxwell BCAP350. These capacitors have 350 Farads at 2.7 Volts. We can use the Joules calculated earlier and this equation:

- $U(J) = \frac{1}{2} C * V^2$

Since we have twenty capacitors we can use a lot of different configurations to get the energy needed. If we take two of these capacitors in parallel and then ten of those two caps in series, we will get a voltage of 27 V [1]. Taking this voltage and using it in the equation we can find the Farads needed. We get around 50 farads but the closes capacitance we can get with these capacitors is 70 Farads. Plugging this capacitance back into the equation we get 25,515 Joules.

We need to know how much current will be required to charge the bank up in two minutes. Taking the 120 seconds we can figure out the wattage of our capacitor bank. $Watt = \frac{Joules}{Sec} = \frac{25515J}{120s} = 212.785W$. Taking that wattage we can figure out the current using the bank voltage. We get a current of 7.875 Amps. That's a pretty low current than what we initially thought. We are going to shoot for 12 amps so we can get in some more speed.

The pervious team went through and calculated the inductors also. The full wave rectifier at the beginning of the circuit takes 120 V ac and converts it to 169.7 V dc. The voltage of the inductors will be $169V - 28V = 141V$. The pervious team decided on a swing current of 10 Amps and a switching frequency of 500 kHz. Using the equation below we can calculate the inductance.

$$V = L * \frac{di}{dt}, 141V = L * \frac{10A}{\frac{1}{500kHz}}, L = 28.2uH$$

Using the Wurth 4.7uH inductors we will need 6 inductors to get the 28.2uH [20].

Controller and Gate Driver

To have the MOSFET switch to control the current we need something to do that automatically. Using an Arduino Uno we can set up a current sensor that will create a PWM to switch the MOSFET. Sensing the current can be accomplished by measuring the two sides of a power resistor after the inductors. As the current passes through the resistor two voltages will be on each end of the resistor. The microcontroller will sense the voltage at each end and then subtract one side from the other. This will supply the voltage difference which will be read by the code and then the controller will open or close the MOSFET.

The PWM output of the controller is only 5 V. Since the MOSFETs drain is not connected to ground there is no voltage difference across the MOSFET. This creates a problem because the controller won't be able to supply enough voltage to switch the MOSFET on and off. The previous team figured that an operational amplifier would fix the problem. The type of Op-Amp they planned to use would not supply enough voltage to get the MOSFET to switch. For the MOSFET to switch we need a voltage closer to the supply voltage. To fix this problem we went and got a gate driver (NCP5109A) [12]. This device takes a max of 200 V input and supplies a high voltage switching signal. This part will be able to supply the correct voltage to switch both MOSFETs. The microcontroller PWM can go directly into this part and be able to be received clearly.

Future Work

Unsolved Problems

- Housekeeping power supply for the microcontroller. We have a part that would take a portion of the input power and drop the voltage down to be able to keep the micro controller on. We were unsuccessful in getting this part to work though.
- Reduction: The biggest part of this project is the capacitor bank. As supercapacitor technology progresses we hope they get smaller and more efficient.
- Packaging: This device could use a more professional packaging situation and it could be more secure in this packaging.

State of the Prototype

As of the end of the timeframe for the project, it is not completely functional. While individual areas will activate and work on their own, there appears to be an issue with the new gate driver. This is not too terrible of a surprise seeing as the part was not discovered and tested until the final couple of weeks, so its ability to work immediately in the full circuit was not met with complete confidence.

Power does flow into the system and to the MOSFETs and the gate driver, but the driver fails to activate. After running tests across the voltage divider in place before the gate driver's Vcc and all around the driver itself, the cause seems uncertain for now. There's a possibility the gate driver is simply muting out the input into the Vcc, but this shouldn't be the case since the voltage divider was calculated to allow just enough voltage and current into the system. There are no signs of any damage to any part in the systems. As mentioned prior, the individual systems (capacitor bank, phone charging, rectified input, Arduino, etc) work just as needed. The gate driver performed exactly as expected during testing.

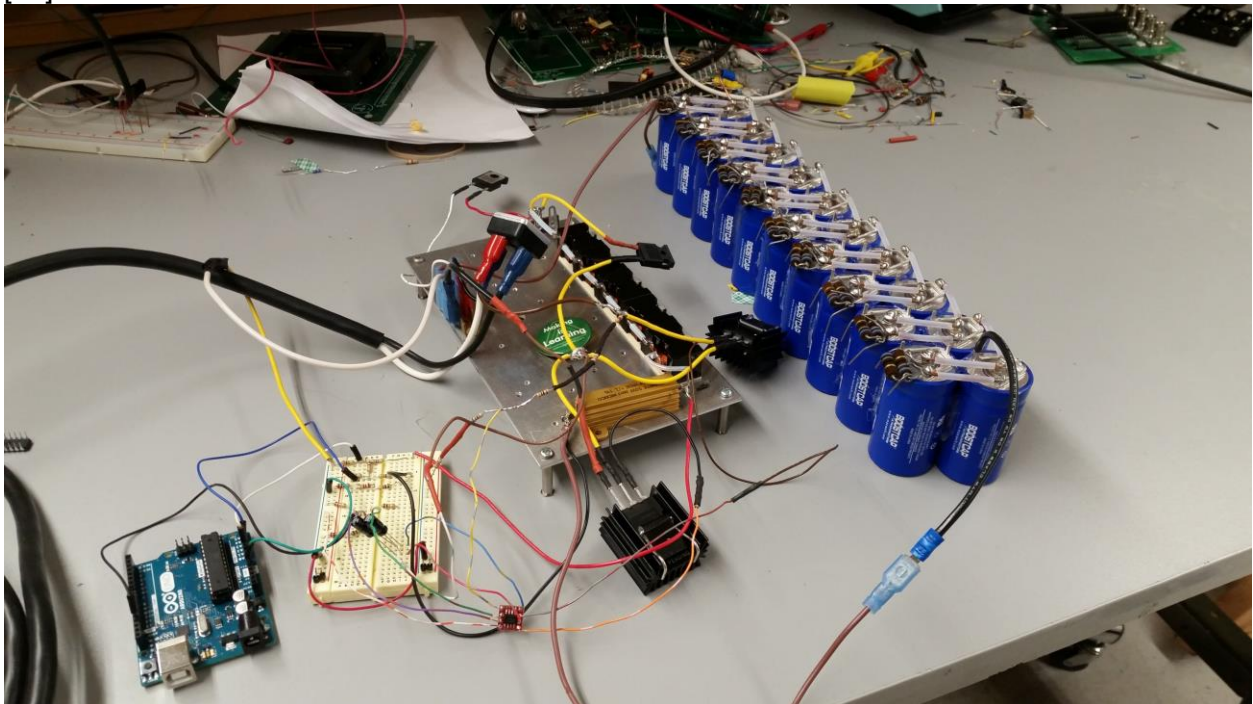
The cause behind this is likely a fairly simple fix, but due to the nature of how the project's progression went, solving this is not possible with the remaining time for our team. The project is nearly complete at this stage, but unfortunately it will remain without an absolute working system for the time being.

Appendices

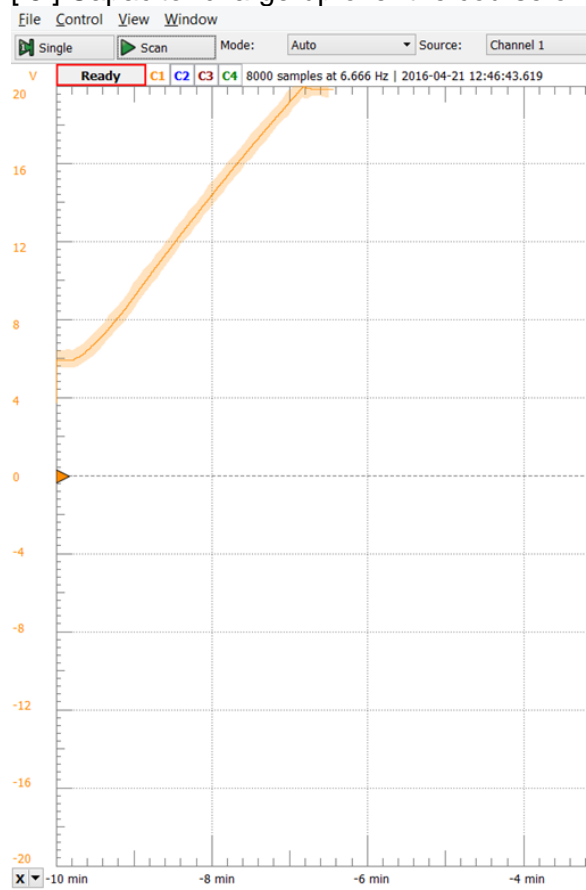
[1] Capacitor Bank



[2] Constructed Circuit



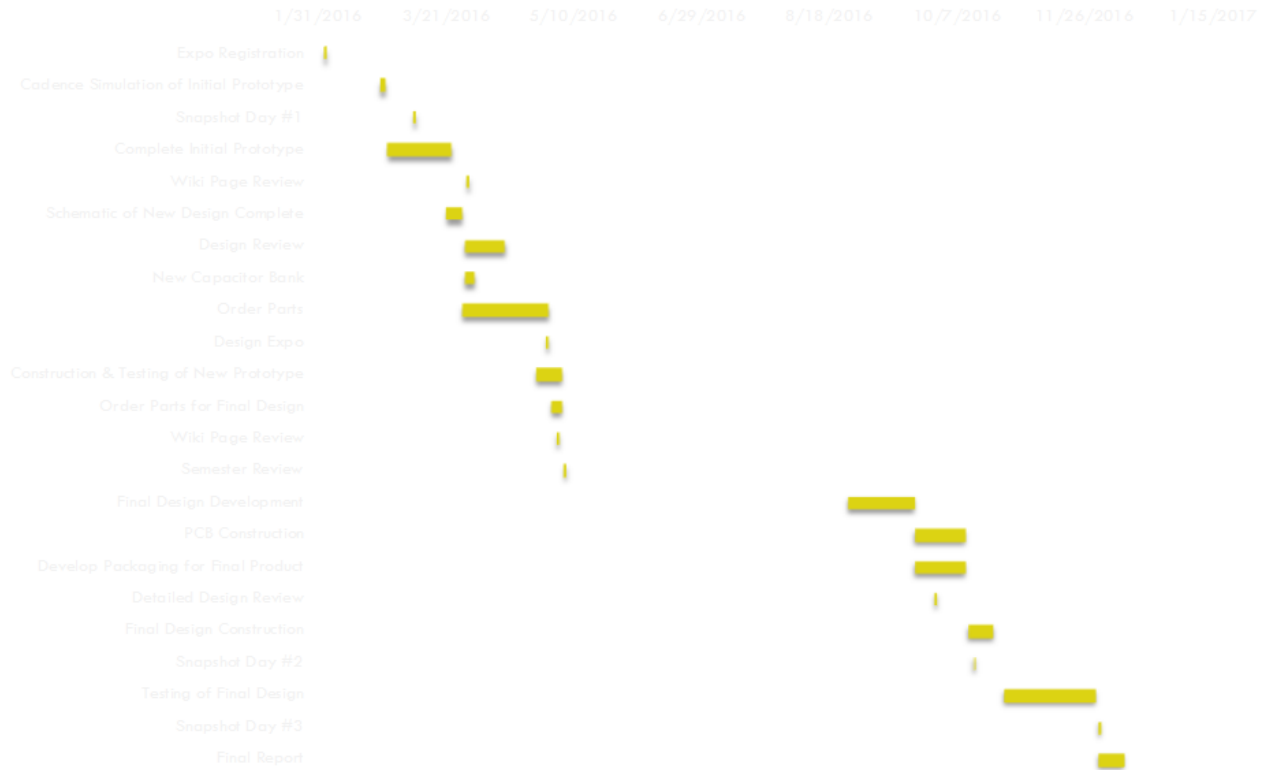
[5] Capacitor charge-up over the course of several minutes



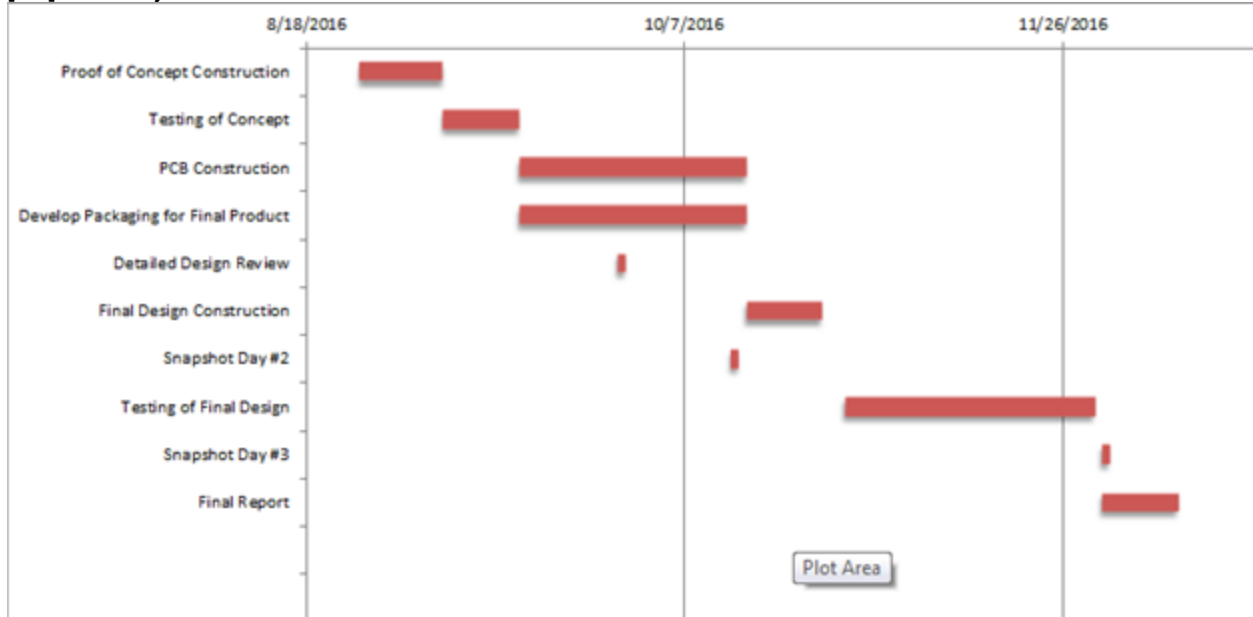
[6] Charging a phone from the capacitor bank



[7] Yearlong Gantt Chart Estimation



[8] Fall Adjusted Gantt Chart



[9] Expo Poster

Battery Ultracharger

Problem Statement

One of the constant issues with travel is running out of power for any of your electronic devices, especially your mobile phone, and not nearly having enough time to recharge before a traveler needs to get going again. Our team has sought to address this through a transportable battery charger.

Project Goals

We intend to create a device which can:

- Charge itself (not the phone) in two minutes or less
- Hold enough charge to a cellphone while also delivering it without damaging any recharging devices
- Fit in carry-on luggage

Project Learning

As there are countless ways to approach the problem, this project has involved learning about a variety of power converter types, including the components and math used to make a complete, functioning circuit.

Team Ultracharge:
Keith Leitner and Robert Prew
Client/Advisor: Dr. Herbert Hess

Schematic Design

Through a variety of simulation tools, we were able to both reflect upon the former project's prototype while also developing our new one. The schematic below represents the new design we plan to complete and test.

Determining a Solution



Given issues in the switching mechanism of the previous prototype, new design approaches are being developed. The current best candidate would be implementing a Cúk Converter between the AC/DC rectifier and the capacitor bank in order to bypass one of the primary issues regarding the switch.

Once this has been addressed the design works, plans for reducing the overall size will be implemented.

Capacitor bank voltage (orange) is brought down to 5 Volts to match the requirements of the phone charger (blue)

Charging process of capacitor bank up to 20V

[10] Maxwell Ultracapacitor Datasheet

FEATURES AND BENEFITS*		TYPICAL APPLICATIONS	
<ul style="list-style-type: none"> ➤ Up to 500,000 duty cycles or 10 year life ➤ Low internal resistance ➤ High power performance ➤ 310F and 350F capacitance values ➤ Radial terminals for PCB mounting 	<ul style="list-style-type: none"> ➤ Wind turbine pitch control ➤ Automotive subsystems ➤ Small UPS systems ➤ Consumer and industrial electronics ➤ Medical equipment ➤ Portable tools 		
PRODUCT SPECIFICATIONS			
ELECTRICAL	BCAP0310	BCAP0350	
Rated Capacitance ¹	310 F	350 F	
Minimum Capacitance, initial ¹	310 F	350 F	
Maximum ESR _{DC} , initial ¹	2.2 mΩ	3.2 mΩ	
Test Current for Capacitance and ESR _{DC} ¹	31 A	35 A	
Rated Voltage	2.70 V	2.70 V / 2.50 V	
Absolute Maximum Voltage ²	2.85 V	2.85 V	
Absolute Maximum Current	250 A	170 A	
Leakage Current at 25°C, maximum ³	0.45 mA	0.30 mA	
TEMPERATURE			
Operating temperature range (Cell case temperature)			
Minimum	-40°C	-40°C	
Maximum	65°C	65°C / 70°C	
Storage temperature range (Stored uncharged)			
Minimum	-40°C	-40°C	
Maximum	70°C	70°C	
PHYSICAL			
Mass, typical	60 g	60 g	
Terminals	Radial Tab	Radial Tab	
Vibration	IEC 60068.2.6, SAE J2380	IEC 60068.2.6, SAE J2380	
Shock	IEC 60068.2.27, SAE J2464	IEC 60068.2.27, SAE J2464	
POWER & ENERGY	BCAP0310	BCAP0350	
Usable Specific Power, P _d ⁴	6,600 W/kg	4,600 W/kg	
Impedance Match Specific Power ⁴	14,000 W/kg	9,500 W/kg	
Specific Energy, E _{max} ⁴	5.2 Wh/kg	5.9 Wh/kg	
Stored Energy ^{5,6}	0.31 Wh	0.35 Wh	
<p>*Results may vary. Additional terms and conditions, including the limited warranty, apply at the time of purchase. See the warranty details and enclosed information for applicable operating and use requirements.</p> <p>Page 1 ➤ Document number: 1017105.4 ➤ maxwell.com</p>			
			

[11] SPM0507SJ DC/DC Converter Datasheet



SPM0507SJ

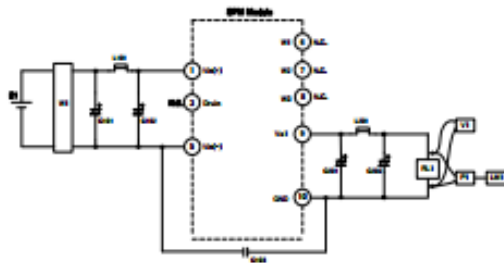
Input-output condition

Item	Specification
Input voltage range	DC110~420V
Rated input voltage	DC140V, DC340V
Rated output voltage	5V
Rated load current	0.66A

Electrical specification Tc=25°C

Item	Specification	Conditions · Note
Efficiency	70% or more (76% TYP)	Rated input voltage Rated output current
Output voltage tolerance	+12% / -10%	Rated input voltage Output current 0~0.07A
	±7.5%	Rated input voltage Output current 0.07~0.66A
No-load power	50mW or less (17mW TYP)	Rated input voltage
Ripple	150mVp-p or less	Rated input voltage
Ripple noise	200mVp-p or less	Rated output current
Lower limit of output undershoot during load step	3.7V or more	Rated input voltage Output current 0~0.66A Slew rate 10μS
	4.3V or more	Rated input voltage Output current 0.07~0.66A Slew rate 10μS
Upper limit of output overshoot during load step	5.7V or less	Rated input voltage Slew rate 10μS

Measurement circuit



- E1 : DC power supply
- W1 : Wattmeter WT210 (YOKOGAWA)
- EL1 : Electronic load
- V1 : Voltmeter Class 0.5
- PI : Differential probe DP-100 (GG)
- LM1 : Ripple noise meter RM-103 (GG)

- C101 : 450E0C6.8M (RUBYCON)
- C102 : 450E0C6.8M (RUBYCON)
- C103 : CD65XU2GA681M (TDK)
- C201 : 10ZLG1200M (RUBYCON)
- C202 : 10ZLG100M (RUBYCON)
- L101 : PJ5H-152M (KORIN)
- L201 : PJ5H-2R2M (KORIN)

TAMURA CORPORATION

Rev.B Nov, 2014

[12] NCP5109A Dual Gate Driver Datasheet

NCP5109A, NCP5109B

High Voltage, High and Low Side Driver

The NCP5109 is a high voltage gate driver IC providing two outputs for direct drive of 2 N-channel power MOSFETs or IGBTs arranged in a half-bridge configuration version B or any other high-side + low-side configuration version A.

It uses the bootstrap technique to ensure a proper drive of the high-side power switch. The driver works with 2 independent inputs.

Features

- High Voltage Range: Up to 200 V
- dV/dt Immunity ± 50 V/nsec
- Negative Current Injection Characterized Over the Temperature Range
- Gate Drive Supply Range from 10 V to 20 V
- High and Low Drive Outputs
- Output Source / Sink Current Capability 250 mA / 500 mA
- 3.3 V and 5 V Input Logic Compatible
- Up to V_{CC} Swing on Input Pins
- Extended Allowable Negative Bridge Pin Voltage Swing to -10 V for Signal Propagation
- Matched Propagation Delays Between Both Channels
- Outputs in Phase with the Inputs
- Independent Logic Inputs to Accommodate All Topologies (Version A)
- Cross Conduction Protection with 100 ns Internal Fixed Dead Time (Version B)
- Under V_{CC} LockOut (UVLO) for Both Channels
- Pin-to-Pin Compatible with Industry Standards
- These are Pb-Free Devices

Typical Applications

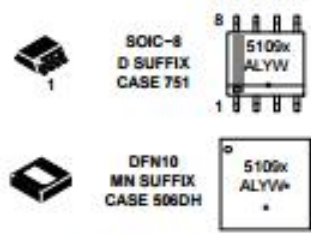
- Half-Bridge Power Converters
- Any Complementary Drive Converters (Asymmetrical Half-Bridge, Active Clamp) (A Version Only).
- Full-Bridge Converters



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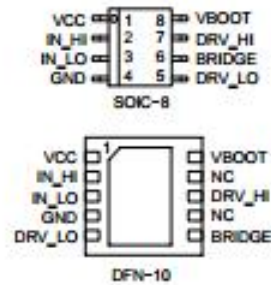
MARKING DIAGRAMS



5109 = Specific Device Code
 x = A or B version
 A = Assembly Location
 L = Water Lot
 Y = Year
 W = Work Week
 * = Pb-Free Package

(Note: Microdot may be in either location)


PINOUT INFORMATION



ORDERING INFORMATION


See detailed ordering and shipping information on page 16 of this data sheet.

[13] FDL100N50F Power Mosfet Datasheet



FAIRCHILD
SEMICONDUCTOR

November 2013



FDL100N50F

N-Channel UniFET™ FRFET® MOSFET

500 V, 100 A, 55 mΩ

Features

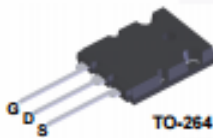
- $R_{DS(on)}$ = 43 mΩ (Typ.) @ $V_{GS} = 10\text{ V}$, $I_D = 50\text{ A}$
- Low Gate Charge (Typ. 238 nC)
- Low C_{iss} (Typ. 64 pF)
- 100% Avalanche Tested
- Improved dv/dt Capability
- RoHS Compliant

Applications

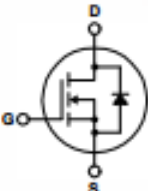
- Uninterruptible Power Supply
- AC-DC Power Supply

Description

UniFET™ MOSFET is Fairchild Semiconductor's high voltage MOSFET family based on planar stripe and DMOS technology. This MOSFET is tailored to reduce on-state resistance, and to provide better switching performance and higher avalanche energy strength. The body diode's reverse recovery performance of UniFET FRFET® MOSFET has been enhanced by lifetime control. Its trr is less than 100nsec and the reverse dv/dt immunity is 15V/ns while normal planar MOSFETs have over 200nsec and 4.5V/ns respectively. Therefore, it can remove additional component and improve system reliability in certain applications in which the performance of MOSFET's body diode is significant. This device family is suitable for switching power converter applications such as power factor correction (PFC), flat panel display (FPD) TV power, ATX and electronic lamp ballasts.



TO-264



MOSFET Maximum Ratings $T_C = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Parameter	FDL100N50F	Unit
V_{DSS}	Drain to Source Voltage	500	V
V_{GSS}	Gate to Source Voltage	±30	V
I_D	Drain Current	- Continuous ($T_C = 25^\circ\text{C}$)	100
		- Continuous ($T_C = 100^\circ\text{C}$)	60
I_{DM}	Drain Current	- Pulsed (Note 1)	400 A
E_{AS}	Single Pulsed Avalanche Energy	(Note 2)	5000 mJ
I_{AR}	Avalanche Current	(Note 1)	100 A
E_{AR}	Repetitive Avalanche Energy	(Note 1)	73.5 mJ
dv/dt	Peak Diode Recovery dv/dt	(Note 3)	20 V/ns
P_D	Power Dissipation	($T_C = 25^\circ\text{C}$)	2500 W
		- Derate Above 25°C	20 W/°C
T_J, T_{STG}	Operating and Storage Temperature Range	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering, 1/8" from Case for 5 Seconds	300	°C

Thermal Characteristics

Symbol	Parameter	FDL100N50F	Unit
$R_{\theta JC}$	Thermal Resistance, Junction to Case, Max.	0.05	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient, Max.	30	

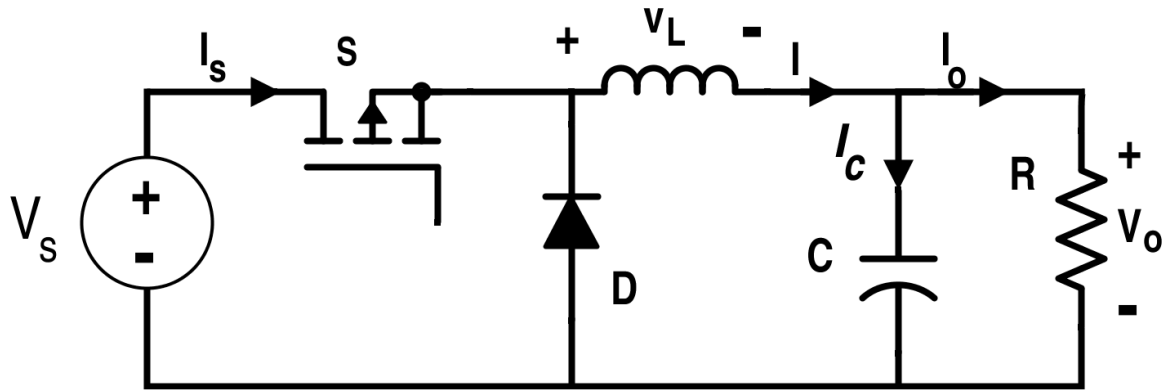
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FDL100N50F Rev. C1

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FDL100N50F — N-Channel UniFET™ FRFET® MOSFET

[14] Buck converter general circuit



[15] NCP5109A Resonant Converter

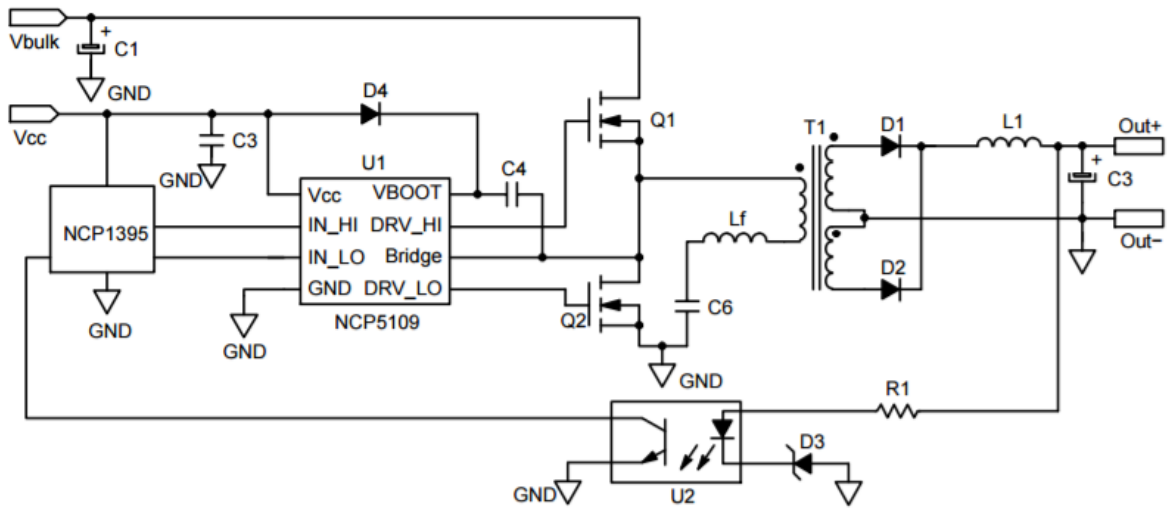
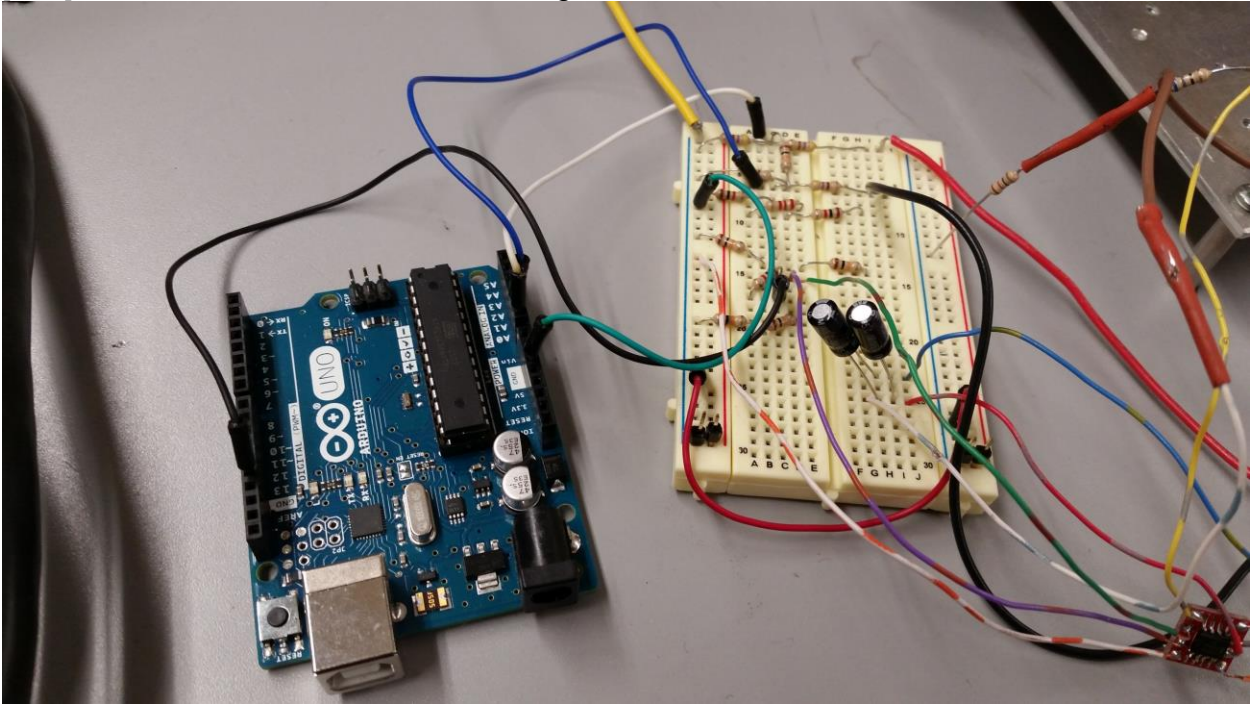
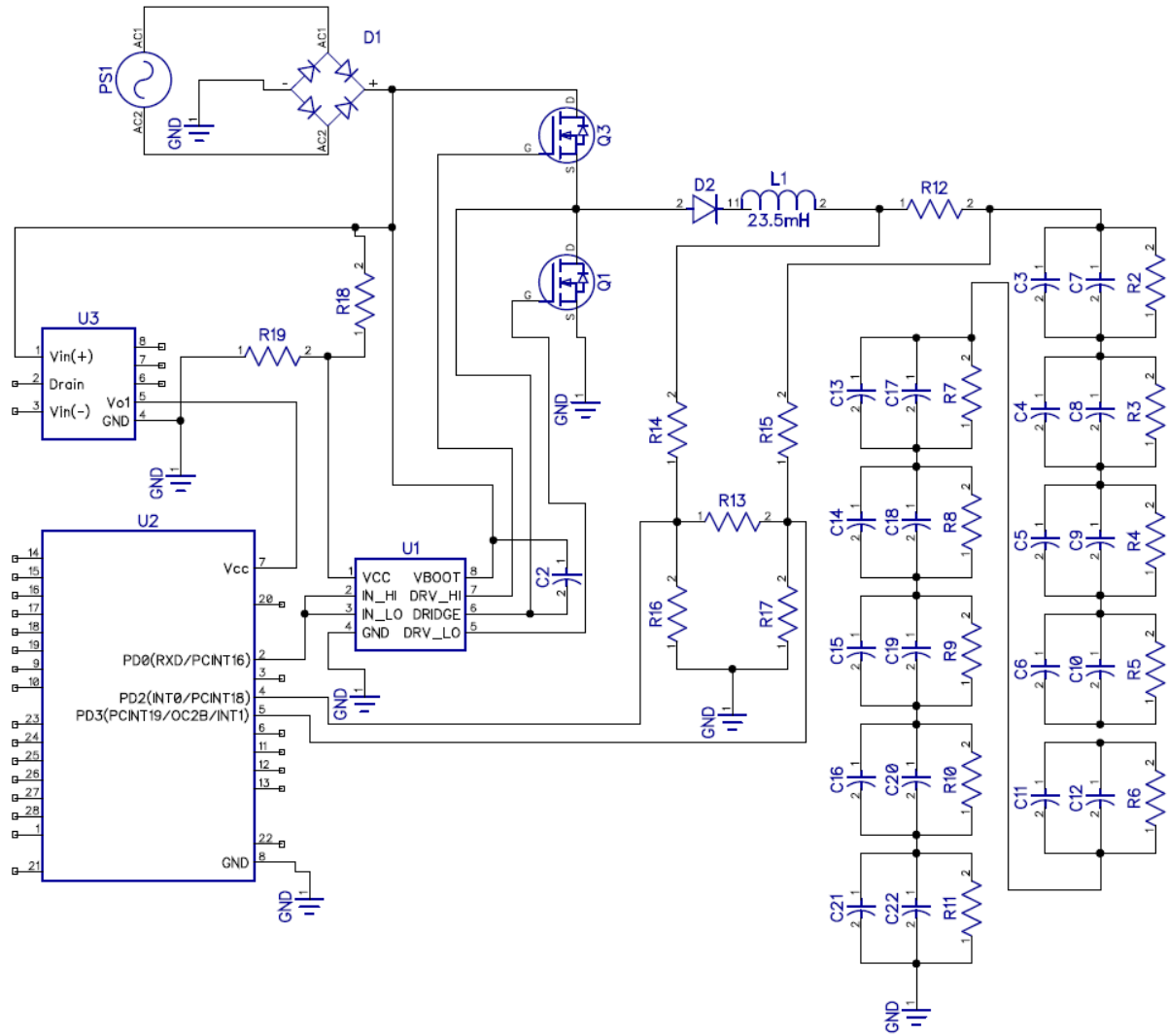


Figure 1. Typical Application Resonant Converter (LLC type)

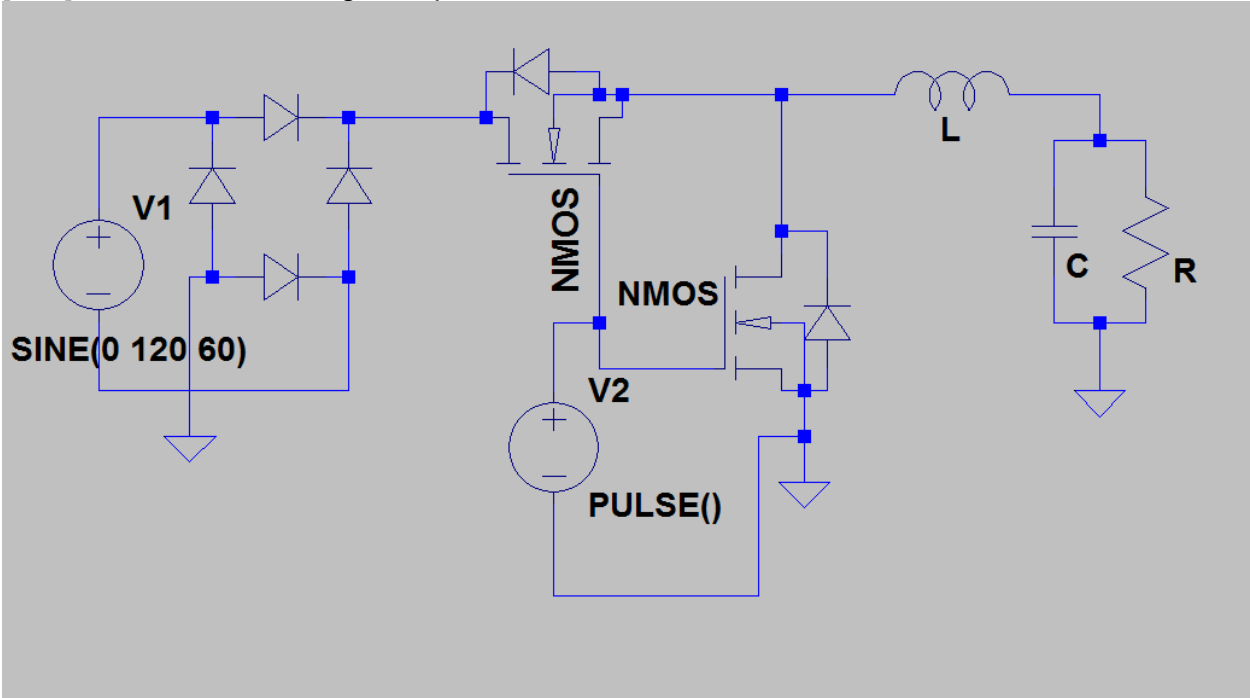
[16] Microcontroller and current sensing circuit



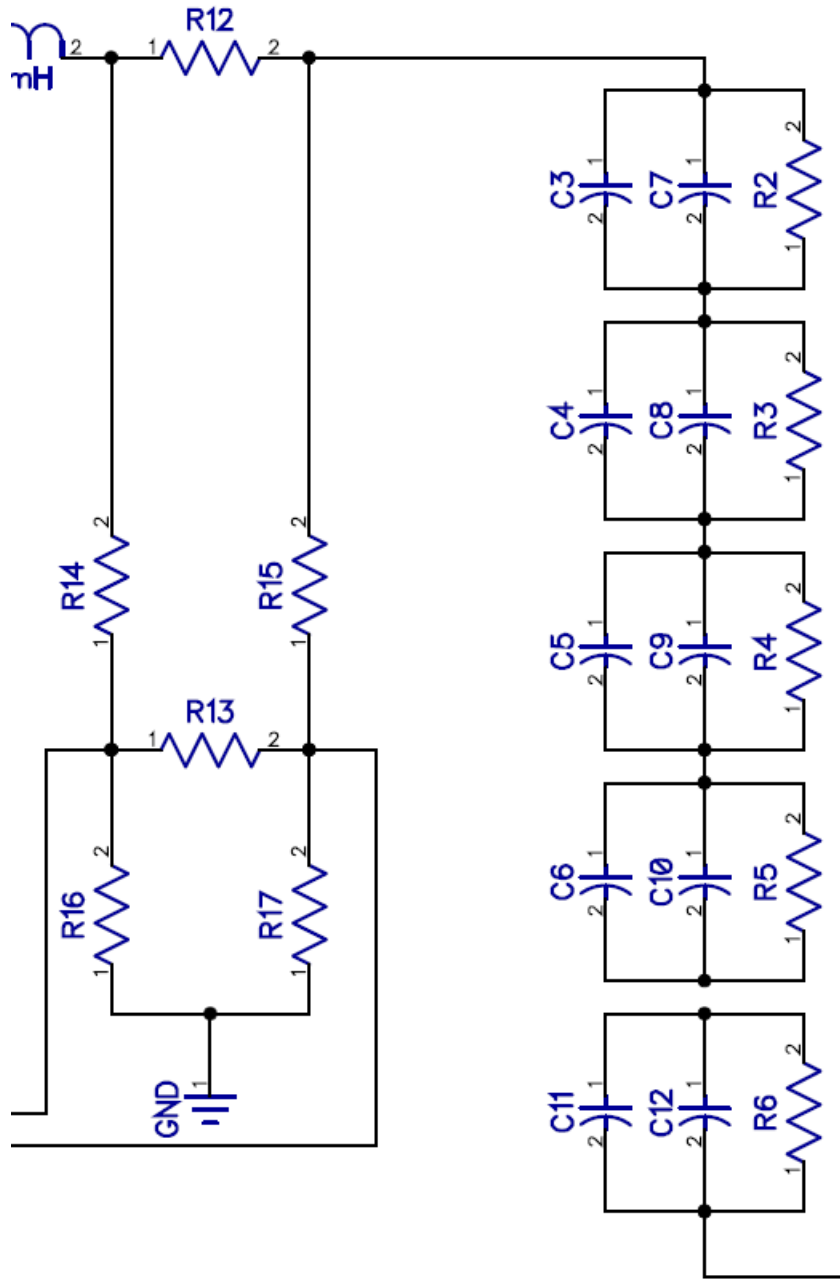
[17] Final circuit redesign



[18] Final circuit redesign simplified

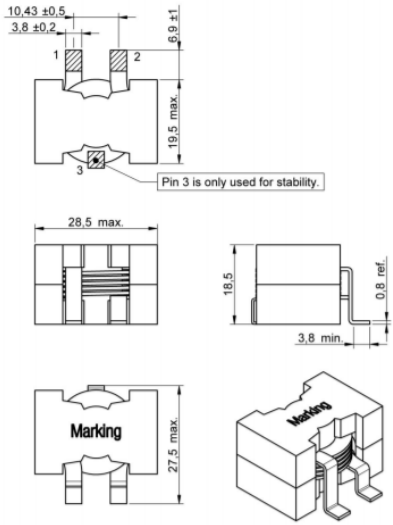


[19] Voltage divider for Microcontroller

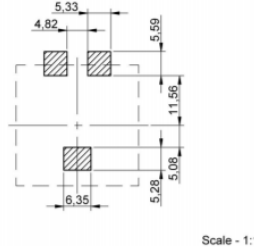


[20] Würth Inductor datasheet

A Dimensions: [mm]



B Recommended land pattern: [mm]



D Electrical Properties:

Properties	Test conditions		Value	Unit	ToL
Inductance	100 kHz/ 10 mA	L	4.7	µH	± 15%
Rated current	ΔT = 50 K	I _R	30.0	A	max.
Saturation current	I _{ΔL/L} < 30%	I _{sat}	78.0	A	typ.
DC Resistance	@ 20°C	R _{DC}	2.4	mΩ	±10%
Self resonant frequency		f _{res}	20	MHz	typ.

C Schematic:



E General information:

It is recommended that the temperature of the part does not exceed 125°C under worst case operating conditions.

- Ambient temperature: -40°C to +75°C (referring to I_R)
- Operating temperature: -40°C to +125°C
- Storage temperature (on tape & reel): -20°C to +40°C; 75% RH max.
- Test conditions of Electrical Properties: 20°C, 33% RH if not specified differently

Reference on drawing	Description
Marking	7443640470 (Article Number)
Date code	YYWW

REV	DATE	BY	CHECKED	DESCRIPTION
1.3	2015-09-08	KuS	BD	WE-HCF SMD High Current Inductor Würth Elektronik eSsa GmbH & Co. KG EMC & Inductive Solutions Max-Eyth-Str. 1 74638 Wriedenberg Germany Tel. +49 (0) 79 42 945 - 0 www.we-online.com eSsa@we-online.com
1.2	2015-03-03	SSI	BD	
1.1	2014-09-16	SSI	BD	
1.0	2014-05-08	SSI	BD	

DESCRIPTION	
WE-HCF SMD High Current Inductor	
Order - No.	7443640470
Size	2818



[21] Close up of main circuit

