Micro-Grid Wind Energy System

Final Report

MECHANICAL ENGINEERING DEPARTMENT, CAL POLY, SAN LUIS OBISPO

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Statement of Disclaimer

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Abstract

With the completion of a 3.5kW wind turbine located on Esculea Ranch, the power generated from the turbine was dissipated through electric resistance heaters. ABC Wind was given the task to design, build, and implement a system what will efficiently use the turbine's harnessed power. After interviewing with the Beef Operations Manager of Escuela Ranch, it was decided to use the turbine's power to supply supplementary water to anywhere on the ranch where and when needed by grazing cattle. The purpose of this project was to research, design, build and implement a system that would harness the generated power and use it to provide supplementary water across the ranch. To begin, research was done online to generate ideas and to find existing systems in the field. An interview with Dr. Lemieux was scheduled to better understand the wind turbines power generation. With this gathered information, ABC Wind proposed a micro-grid system to harness, store, and utilize the power when needed pump supplementary water. Furthermore, ABC Wind also proposed to tie into an existing water line to pump to 1000 gallon storage tanks located on a high elevation from where it can then be routed to virtually anywhere on the ranch. A 4.1kWh battery was donated to the project for storing energy and to use as a power source when the turbine would not produce sufficient energy for the system. A pump was chosen to overcome the calculated 325ft of head due to elevation and fluid pressures. Given the turbine's 0-500V wide range of voltage production and the high power, we researched, designed, and tested a buck converter to regulate the output with a constant voltage. This constant voltage of 28V is necessary to correctly charge the battery and to drive the pump for our system. From this, ABC Wind was able to design and propose a system to be implemented for the use of the turbine on Esculea Ranch.

Chapter 1: Introduction

The Cal Poly Wind Power Research Center (CPWPRC), directed by Dr. Patrick Lemieux, has recently completed construction of a 3.5 kW wind turbine located on the Escuela Ranch. Currently power generated by the turbine is dissipated in the form of heat through electric resistance heaters. Dr. Lemieux has requested a senior project team to develop an add-on system that better utilizes the energy produced and benefits the College of Agriculture's operations on the ranch.

After meeting with Aaron Lazanoff, Beef Operations Manager of Escuela Ranch, it was concluded that the best way to benefit the ranch was to develop a micro-grid system that would provide supplementary water to holding tanks at a high point on the ranch. Once the water was raise to these holding tanks, it could be directed to water troughs around the ranch to water the 150 head of cattle that graze the ranch.

The following specifications for the micro-grid system were developed early on in the project:

I. **Interface with existing control system**
   - Must be able to tie into the control box for the turbine generator.
   - Additions to the system must not affect current operating process.

II. **Condition generated power for use in applications**
   - Make power usable for safely charging battery system.
   - Make power usable for safely running a pump.

III. **Specify and install a pump to use supplementary water**
   - Provide up to 1,800 gallons of water a day.
   - Must be able to easily tie into existing water lines.
   - Be able to pump up to a 325 ft increase in height.
   - Be able to pump a distance up to 1.35 miles

IV. **Develop a system to efficiently use generated power.**
   - Be able to adjust between charging batteries, running pump, and energizing electric resistance heaters.

V. **Create a system that is safe to install and operate**
   - Install fail-safe to protect pump from cavitation if water supply runs low.
   - Install fail-safe to protect water line from over pressurization.
   - Install fail-safe to protect against battery overcharging.

VI. **Create a durable/ maintainable system**
   - Provide housing to protect against weathering.
   - Make major components easily accessible.

Chapter 2: Background

There are several existing systems that use wind energy to pump water. Most of these, however, differ from our situation in that we are not using a submerged pump and are not pumping completely vertical from a well. The costs of 1kW turbines alone from our competitors that are used for irrigation purposes are roughly $3,000. This does not include the tower. Additional costs for electrical components, pump, energy storage, installation, etc. raises the total cost of the system to upwards of $15,000. Also, this cost, given from Bergy Wind Power, does not include the piping materials that are needed for the pumping system [1]. There are subtle differences however, depending on the individual usage of the system. For example, a wind energy project in Egypt is not only being utilized for irrigation, but for drinking water and for consumer use of the electricity generated [2]. The cost per system is $2,500 per wind turbine to pump water and $4,000 per wind turbine to generate electricity. Another competitor, AltE Store, shows similar pricing as well as numerous other competitors [3].

The overall set up of using wind energy to pump water does not seem to vary much among the various competitors. The setup up shown in the package from Bergy Wind Power consists of a battery bank, an inverter, a transformer, a tilt-up tower, and a turbine with power center. Although it is unclear of how exactly the Egypt project had its system setup, a form of voltage regulator, energy storage, and monitoring system would be inevitable to maintain such a system.

Specific Background

The generator selected for this specific application is the Ginlong GL-PMG-3500. This generator will produce up to 500 volts DC and 7 amps depending on the speed of the generator as well as the load placed on the generator. The nacelle is made from fiber glass and was specifically designed to minimize the boundary layer separation and therefore minimize the aerodynamic drag. The rotor consists of three 6-foot long blades that are made from carbon-fiber and E-glass material; the blades are then attached to an aluminum hub by a set of bolts. The above mentioned components come together to form a wind turbine with the following characteristics shown in Table 1.

Table 1. Cal Poly Wind Turbine Specifications.

Basic Wind Turbine Specifications	
Wind Turbine Type	Horizontal-Axis Wind-Turbine (HAWT)
Wind Turbine Weight	460 *lbf*
Number of Blades	3
Length of Blades	6 *ft*
Rated Power	3 *kW*
Voltage Range	0-500 *VDC*
Current Range	0-7 *amps*
Rated Rotor Speed	230 *rpm*
Rated Wind Speed	22.4 *mph* (10 *m/s*)
Rotor Tip to Wind Speed Ratio, λ	4
Cut-off Wind Turbine Speed	300 *rpm* (Wind Speed of 30 *mph*)

Escuela ranch follows a natural grazing habit for the cattle; this means that the cattle are moved between fields every 20 to 30 days. Therefore the pumping requirements will be changing depending on where the cattle are located. The maximum distance the pump will be required to pump is to the E6 storage tanks (see Figure 1, Destination 1) located 1.35 miles with a total elevation gain of 325 feet.

Standard testing regimes will be necessary to ensure the overall compatibility of the proposed systems. We plan to test each individual component separately and simulate variations at the input and at the outputs. After several successful runs with each component, new tests will be conducted with two elements of the system and vary the input and outputs and ensure that these are compatible. This will be done until all the components in question are brought into the testing setup. At this time, the overall system compatibility will be tested.

After the approval of our proposed piping route, the Escuela Ranch administration suggested that they can physically install the pipe needed as well as install any tanks needed on either end of the system. Also, a small housing unit is necessary to protect several of the system's components from the elements. A number of the pumps that can potentially be used for this application require protection from dirt and any rain. The batteries also will be installed in this facility for the same reasons. Depending on the controllers decided for the final design, these devices may be housed in this unit as well.

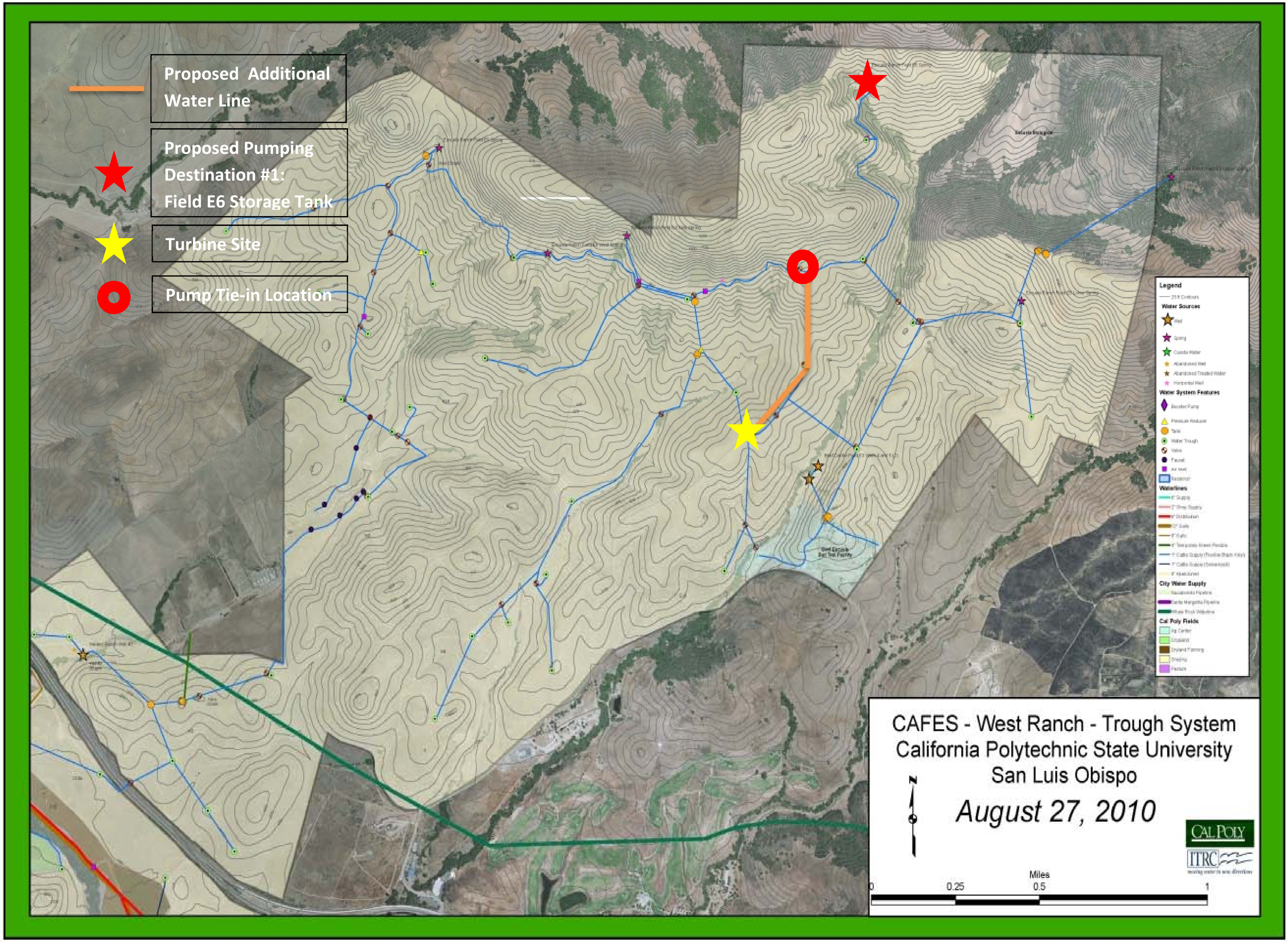


Figure 1. Map of the Escuela Ranch trough system with proposed supplement water line.

Chapter 3: Design Development

Basic Design Specifications

Overview:

The core objective of our project is to use the power being generated from a wind turbine to supply supplementary water to cattle troughs located throughout Escuala ranch. Pumping from the wind turbine site to an appropriate location consists of pumping up to a maximum of 1.35 miles away and 325 feet of elevation gain.

Customer Specifications:

Due to the high usage of 1” schedule 40 pipe throughout the ranch, the customer requested that we use this piping. Because we are supplying supplementary water the customer also requested that we try to run the pump as long as possible every day. Lastly, as an added bonus, the customer said that if we could pump into an axillary tank located even farther away from the initial location to help store extra water when it is not needed would be even better.

Our specifications:

Using the fact that on average cattle drink twelve gallons of water per day and there are 150 cattle on the Escuala ranch, the maximum amount of water we want to supply is 1800 gallons every day. Because the output from the turbine is a DC voltage we decided that it would be easiest to have the whole system be DC powered. For the system to be useful it needs tie into the existing pipe system as well as the wind turbine system, this means the pumping system must integrate into existing systems flawlessly. Due to the remote location of the pumping station, we decided that the whole system needs to be simple, rugged, easily maintained, and protected from the elements. Along with the remote location comes the fact that the whole system will rarely be checked, this means that the system needs to have fail safes that protect the battery from being over charged or over-draw and if the controller fails that the system reverts to the resistive heating of water. Lastly but most importantly the whole system needs to be safe; due to both high voltage and amperage safety is of utmost importance for the system.

Meeting Basic Design Specifications

Because the power supply (wind turbine) is intermittent but our power draw (pump) is constant, a battery will be needed to buffer the power difference. Since a battery operates a set DC voltage, matching the pump to the battery voltage is a must for the simplest and most rugged system design. Pumping through 1” pipe will not yield the highest system efficiency, however to help lower the pump power and to run for the longest periods of time it was decided that pumping at low flow rates would be the best option to meet previously set specifications. To tie into existing pipe systems a check valve will be used to ensure that no water will flow back into the pump while integrating the already existing resistive heater into the pumping system will ensure that we interface with the wind turbine properly.

Lastly to ensure the safety of all operators, the battery along and all high power electrical lines will be kept inside a service hut.

System Setups

Parallel:

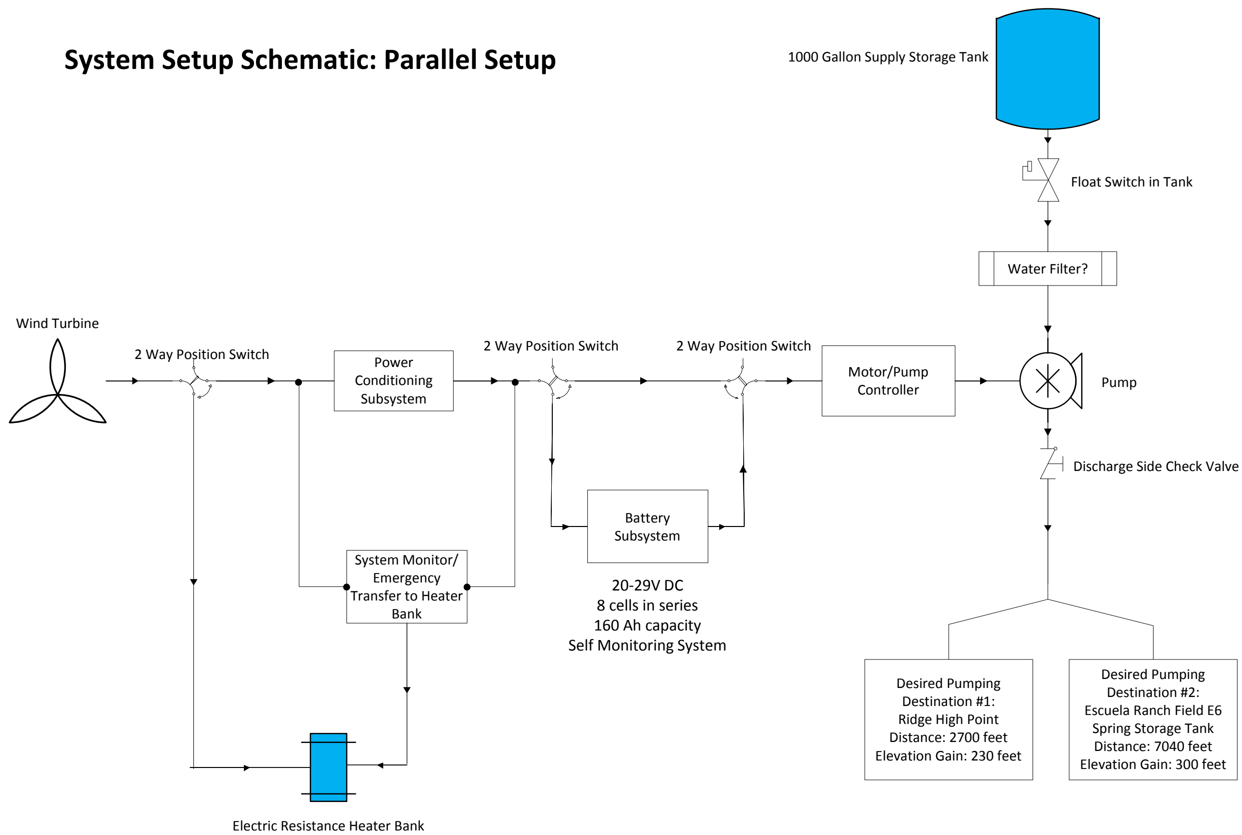


Figure 2. Schematic of the system in a parallel setup.

In the parallel setup of the system both the battery and pump are connected to the output of the power conditioning subsystem. This configuration provides greater control of how power from the turbine is utilized. Through a combination of switches, power can be directed to charge the battery, run the pump, or a combination of the two. While the parallel setup grants more flexibility concerning where power is used, more complexity is required to control and monitor the system in order to run it semi-autonomously.

Series:

System Setup Schematic: Series Setup

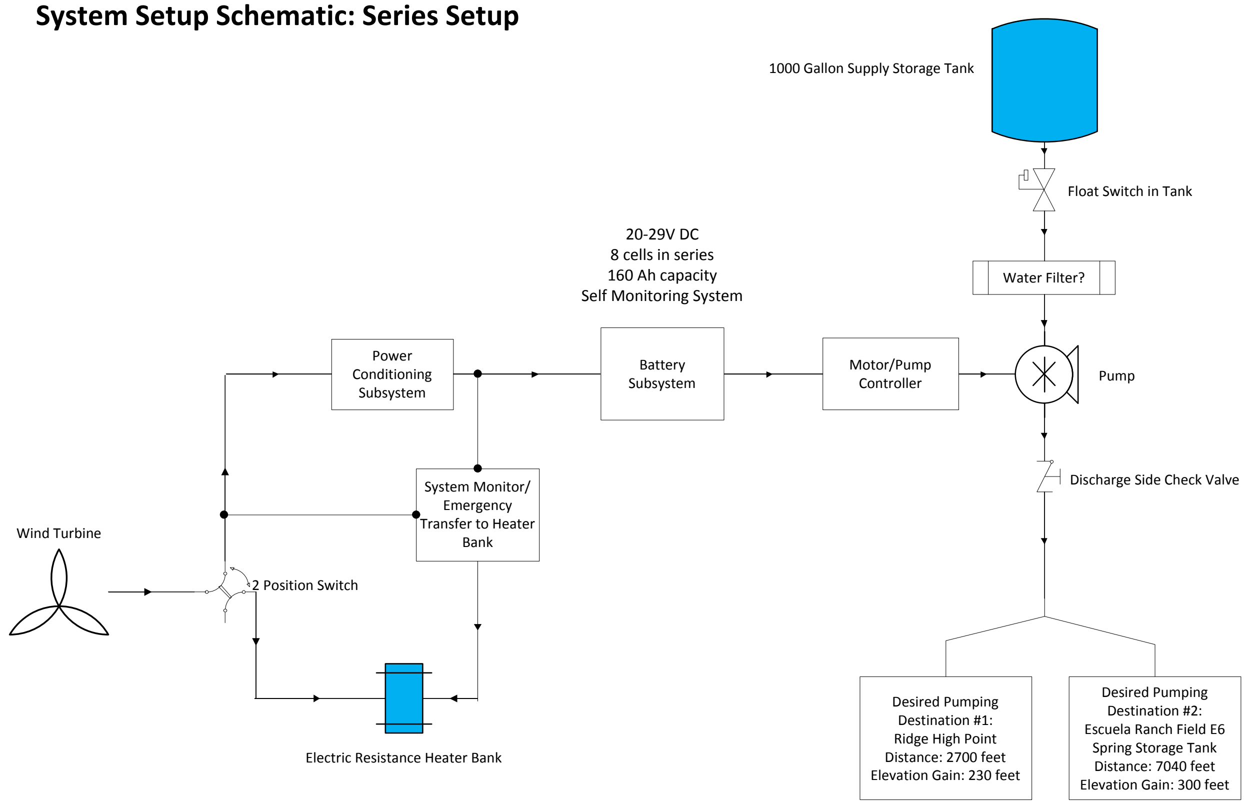


Figure 3. Schematic of the system in a series setup.

In the series setup of the system, the pump is connected directly to the battery. In this configuration, power passes through the power conditioning subsystem to the battery while the pump simultaneously pulls power from the battery. This system allows for the battery to charge while the pump is running, as long as the power draw by the pump is less than the power supplied to the battery. The series system configuration is more simplistic than the parallel configuration, but does not allow as much flexibility in directing the flow of power.

In both system configurations, fail safes will be put in place in case the turbine outputs a spike in power that cannot be handled by the system. In this situation, power will be directed to the electric resistance heater bank and the power will be dissipated in the form of heat. Power will also be transferred to the heater bank in the case of the battery being fully charged and the pump not being run.

System Components and Selection

Pump

In order to supply water to the storage tanks in field E6, the losses that the pump must overcome needs to be calculated. The power draw from the pump must also be taken into consideration since the turbine generates a limited amount of power and the battery has a set capacity. Equation (1) can be used to calculate the total losses, h_a, of the purposed system,

$$h_a = \frac{p_2}{\gamma} + (z_2 - z_1) + h_{major} + (K_L + 1)\frac{Q^2}{\left(\frac{1}{4}D^2\pi\right)2g} \tag{1}$$

where z is the elevation, p is the pressure, Q is the flow rate, D is the diameter of the pipe, K_L is the minor losses associated with the system, h_{major} is the friction head loss of the pipe, γ is the ratio of specific heats, and g is gravity. From Eq. (1), the total head loss of the system is 356 feet. Based on the losses of the system, the amount of power required, P, can be estimated using Eq. (2),

$$P = h_a g \rho \frac{Q}{\eta} \tag{2}$$

where ρ is density and η is an estimated efficiency of the pump. The code use to calculate the losses and the power need can be found in Appendix A.

In specifying a pump for the system, multiple criteria were addressed and placed into a PUGH decision matrix seen in Table 2. In order to meet the requirement of the project, the pump needs to provide a total dynamic head (TDH) of at least 360 feet in order to overcome the losses of the system. Only pumps capable of achieving this TDH were considered in the matrix. Along with the amount of head the pump could supply, the power required to run the pump was given great consideration. Since the amount of energy produced by the turbine is limited, pump efficiency was also examined. Since the amount of energy produced by the turbine is limited, the pump needed to have a power requirement of no more than 700 watts. Coupled with the power, the voltage the pump used was important because this value would influence the type and number of batteries needed to match the voltage.

Table 2. PUGH decision matrix used for selecting a pump for the system.

Criteria	Weight	Dankoff Solaram Surface Pump		Dankoff Solar Slow Pump		Sun Pump SCB 12-60P-52V		Sun Pump SPB 4.23C Piston Pump	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Cost	4	-1	-4	+1	+4	+1	+4	-1	-4
Capacity (gpm)	4	+1	+4	+1	+4	+1	+4	+1	+4
Capacity (head)	5	+1	+5	+1	+5	+1	+5	+1	+5
Input Requirements (watts)	4	+1	+4	+1	+4	-1	-4	0	0
Input Voltage (V)	4	+1	+4	+1	+4	-1	-4	-1	-4
Maintenance	2	0	0	0	0	0	0	+1	+2
Reliability	4	+1	+4	+1	+4	0	+4	0	0
Endurance to Elements	3	+1	+3	-1	-3	0	0	0	0
Efficiency	3	+1	+3	+1	+3	-1	-3	0	0
Total:		6	23	6	25	0	6	1	3

After completing the decision matrix, two pumps stood out. The Dankoff Solaram Surface Pump and the Dankoff Solar Slow Pump had the lowest required power, while still producing the required TDH. Along with the low power consumption, these two pumps can be configured to run on 24 volt DC power, making them easy to connect to a small battery bank.

Battery

The battery subsystem is used to store excess energy from the turbine and to run the pump when the turbine output is not sufficient enough to supply power to the pump. The criteria used to select the battery system are listed in the PUGH decision matrix seen in Table 3. The capacity of the battery system is an important consideration because the higher the capacity, the longer we can run the pump during low periods of turbine output. In this system, the battery was estimated to be cycled once a day, while this is most likely an overestimate, it was helpful in providing an absolute minimum life for a battery.

Table 3. PUGH decision matrix used for selecting a battery for the system.

		International Battery Model IB 24VDC 008 ESS 160 FHE SASL FTSP/Lithium Iron Phosphate		Trojan T-1275 12V Deep Cycle Battery		12V 120Ah Starting Battery	
Criteria	Weight	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Cost	3	-1	-3	+1	+3	+1	+3
Number of Charge Cycles	4	+1	+4	0	0	-1	-4
Capacity (Ah)	4	+1	+4	+1	+4	+1	+4
Monitoring	4	+1	+4	-1	-4	-1	-4
Voltage	2	+1	+2	+1	+2	+1	+2
Replacement Cost	2	-1	-2	+1	+2	+1	+2
Total:		2	9	3	7	2	3

From the preliminary decision matrix the International battery and the Trojan deep cycle battery are the top concepts. The International battery system has some added benefits over the deep cycle battery. It has a built in monitoring system that regulates how much charge is held the individual battery cells and can automatically shut off power when it is fully charged. The advantage for the deep cycle batteries is that they are much cheaper to purchase, but to equal the capacity of the International Battery multiple batteries would need to be purchased. The deep cycle batteries do not have a charge monitoring system and could possibly wear out quicker and not provide the same quality power to the pump. The bottom line is that for either battery system an external battery charging system is going to have to be implemented.

Power Conditioning Subsystem

Due to the variable power output from the turbine, a system needs to be implemented to condition the power and make it more usable. In order to accomplish this, the proposed solution is to use voltage regulators to standardize the output voltage from the turbine. Table 4 shows the decision matrix used for selecting the power conditioning subsystem. Efficiency played a large role in the selection of the conditioner due to the fact that there is not a large amount of power being produced by the turbine and the more power we can use to pump the better we will meet the set design requirements. Cost was the second most important factor due to the pump most likely taking a large section of our budget. Voltage range and maximum power are weighted heavily as well because the larger these ranges the more power can be collected and used for pumping.

Table 4. PUGH decision matrix for power conditioner for the system.

Criteria	Weight	Linear Regulator		Switching Regulator		Custom Regulator	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Cost	4	+1	4	0	0	-1	-4
Reliability	2	+1	2	+1	2	0	0
Efficiency	5	-1	-5	+1	5	+1	5
Voltage Range	3	+1	3	-1	-3	+1	3
Max Power	3	0	0	0	0	+1	3
Simplicity	2	+1	2	0	0	-1	-2
External Power Needed	3	+1	3	-1	-3	-1	-3
Total:		4	9	0	1	0	2

After completing the decision matrix, the linear regulator stood out as the cheapest, most reliable, and simplest solution to regulating power. The down side to using a linear regulator is that it is not nearly as efficient as a switching or custom regulator. While the linear regulator looks to be the best solution right now, more research will be needed to verify the outcome of the decision matrix.

Energy Production

Using collected daily wind speed data from June 2010 to June 2011 at the turbine location, and using a basic equation relating the power output to the size of the turbine and wind speed (see Appendix 2) figure 4 was produced relating wind speed and power generated over a twenty-four hour period.

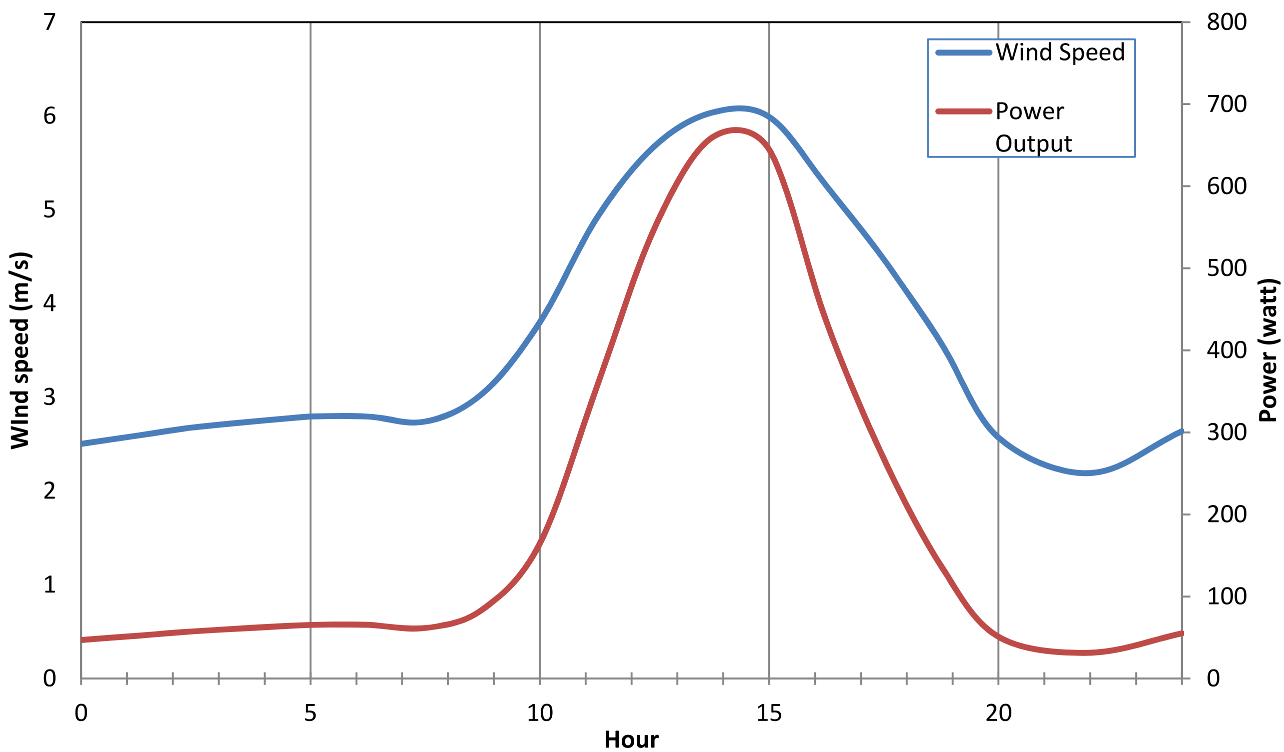


Figure 4. Yearly average wind speed and estimated corresponding power produced.

Summing the total amount of power produced daily (See appendix 2) gives a daily average of 3847 watts produced. Now that there is an approximate number for the amount of power being produced the two pumps can be compared to see how much of the total daily need (1800 gallons) can be fulfilled when being used to pump up to the E6 storage tank.

Table 5. This table compares the Solar Slow pump against the Solram Solar pump when pumping up to the E6 storage tanks.

	Head loss (ft)	Flow rate (GPM)	Power (watt)	*Ave. daily pumping time (hours)	Ave. daily Gallons	% of Daily Need
Solar Slow pump #1403	360	2	300	10.26	1231.04	68.39
Solram Solar Pump #18121	360	2.25	275	11.19	1510.82	83.93

*This takes into consideration an 80 percent efficiency.

As shown, both pumps could meet the demands of pumping up to the E6 storage container but due to the Solaram's higher efficiency it would be able to supply 15.5% more water while using the same

amount of energy. The Solaram pump also has the ability to pump against much higher head losses (up to 960 feet) than the Solar Slow Pump. The Solaram can also pump dirty water and can be run dry for short periods of time, the Solar Slow Pump can do neither, however the cost of both pumps differs drastically.

Cost Considerations

<u>Pump Cost</u>

Both pumps must be overhauled every 5 years (bushing, bearings, ect…) and must be replaced every 20 years. Based on these time constraints and how much water each pump can provide on a daily basis a basic cost analysis was preformed (see appendix for details).

Table 6. 20-year costs for the Dankoff Solar Slow Pump and the Dankoff Solaram Pump (including pump overhaul every 5 years).

Pump	Price [$]	Overall Kit Price ($)	Overall Cost for 15 years	Complete Pump Replacement (20 years)	20 year cost [$]
Solar Slow Pump #1403 24 VDC	1140	200	600	1140	1740
Solaram Surface Pump #18121 24 VDC	3670	200	600	3670	4270

Next, using the 20 years cost and how much water each pump can provide daily, the cost per gallon of water pumped can be figured out (see appendix)

Table 7. The two pumps were compared when being used to pump to the E6 storage tank

	Ave. Daily Gallons	Ave. Gallons per 20 years	Ave. cost/gallon (¢/gallon)
Solar Slow pump #1403	1231.04	8.99E+06	0.019
Solrам Solar Pump #18121	1510.82	1.10E+07	0.039

After comparing the two pumps it can be found that it is going to cost at least twice as much to run the Solaram Solar Pump. While using the Solaram Pump will yield a 12-19% increase in the amount of water pumped per day but at twice the cost of the Solar Slow Pump it is up to the customer to decide if they want the extra capacity.

Battery Cost

Assumptions for the battery costs are that the battery will be cycled once a day and that the cycle will not exceed %20 of the batteries capacity. While many other batteries could be used for the job, these specific batteries are all deep cycle and are built for high energy applications and being cycled daily.

Table 8**.** Comparison of costs for three different battery options

Battery Model	Cost ($)	Number needed	Total cost ($)	Life (Cycles)	Life years	20 year cost ($)
24 VDC International 4.1kWh	5000*	1	5000	3500	9.6	10429
Trojan 27TMH - 12V 115Ah Heavy Duty Deep Cycle Battery	185	4	740	2000	5.5	2701
Trojan J150 - 12V 150Ah Heavy Duty Deep Cycle Battery	230	4	920	2000	5.5	3358
	230	2	460	2000	5.5	1679

*Please note that since the International battery is being donated by Cal Poly's chapter of the Department of Energy's Center for Renewable Energy and Alternative Electric Transportation Technologies (CREATT) program, the initial cost can be eliminated. After the battery is used up it seems that the Trojan J150 would be the best option due to the low cost and high capacity. If it is found that the International battery's capacity was never fully reached, the whole system could be run with only two J150 batteries. If more capacity is needed then using the Trojan 27TMH battery would be recommended due to the lower cost and comparable capacity.

Preliminary Testing and Analysis

Voltage Regulation

Voltage regulation is extremely important to the system operation. As mentioned above the three options to accomplish this task were; a linear regulator, a switching regulator (of undecided topography), or a custom built regulator (again, topography undecided). The linear regulator was by far the most simple but also the most inefficient. The efficiency and the amount of power needed to be dissipated by a linear regulator is determined by the current, the input voltage, and the wanted output voltage. Given these variables the power needed to be dissipated is:

$$P_{Diss} = (V_{in} - V_{out}) * I \qquad (3)$$

The efficiency of a linear regulator is given as:

$$\eta = \frac{V_{out}}{V_{in}} \qquad (4)$$

To help illustrate the efficiency and the amount of power needed to be dissipated by a linear regulator, two graphs have been provided below. In figure 5 the efficiency drops off very quickly and as seen in figure 6, the power that is not used must be dissipated. Needless to say this voltage regulator is extremely inefficient and would not be a good design for this application.

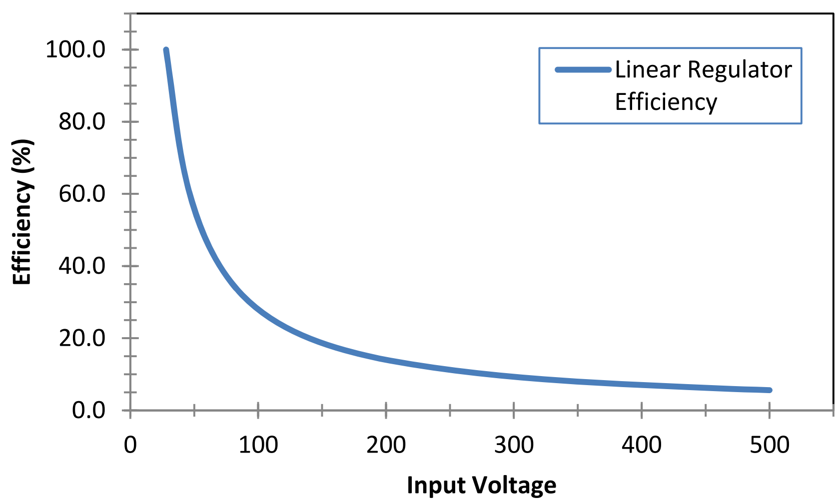


Figure 5. Efficiency of a linear regulator set to output 28 volts.

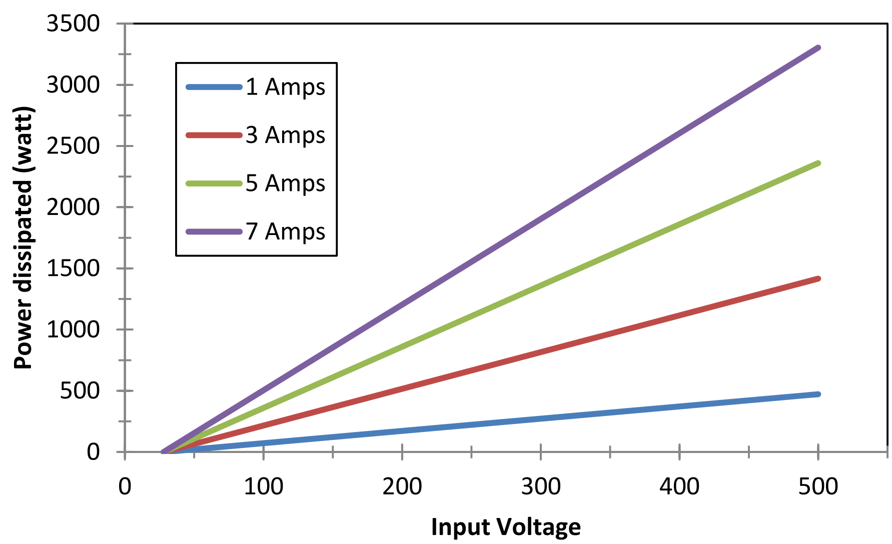


Figure 6. Power needed to be dissipated at different voltages and currents.

After looking into different companies who built power regulators only a few were found to actually fit our power needs. Unfortunately after talking to these companies it was discovered that all of these converts are actually custom built and much too expensive for our budget, this lead to the final option

of building a custom voltage regulator. Because there were no electrical engineers on the team we decided that the best regulator would be the regulator with the simplest topography. Looking into the different regulator topography's the buck converter became a favorite due to its simplicity, potential efficiency (70-95%), and ease of access to published papers and articles[1] containing full design equations (see appendix A). Figure 7 shows the topography of a buck converter, the way a buck converter works is a switch is opened and closed which charges and discharges a capacitor and inductor. The voltage across a load is monitored and is fed back to a controller that can control the switch, the voltage and current across the load can be kept relatively constant due to the capacitors and inductor ability to act as a "buffer" between the input voltage and current.

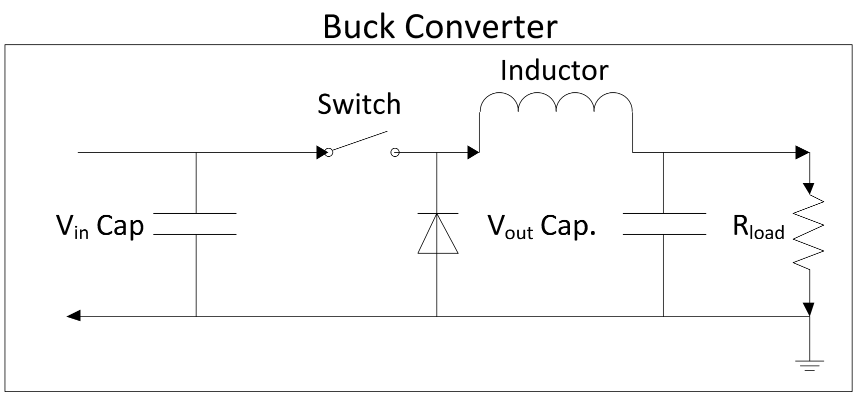


Figure 7. Basic Topography of a Buck converter.

To test the buck converter a small scale converter was first built. Using the ESS code in appendix A the following specs for the converter were applied as seen in table 9.

Table 9. Wanted specifications for small scale buck converter.

	Minimum	Maximum
Input (volts)	2	35
Output (volts)	2	2
Output Current (amps)	-	10

The controller was an arduino uno controller board, the voltage across the load was fed into the board and a simple control loop changed the PWM signal going to the switch. To help with switching the MOSFET a simple op-amp was used to compare the PWM signal to 3.3 volts. The result was that the op-amp would output an amplified PWM signal which was then used to drive the gate of the MOSFET.

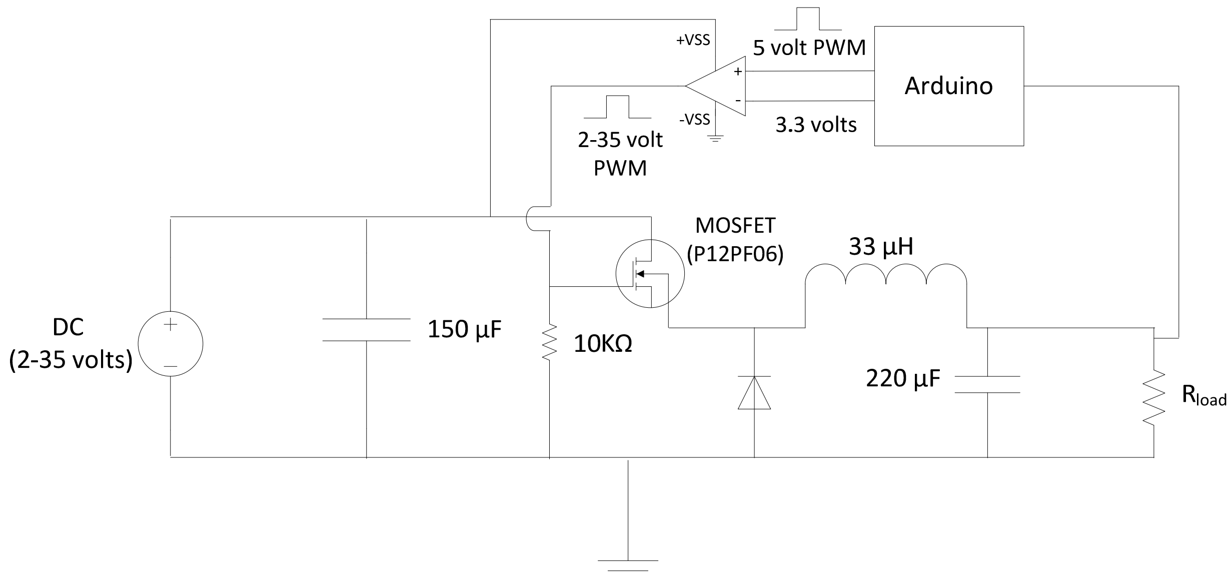


Figure 8. Small-scale buck converter diagram.

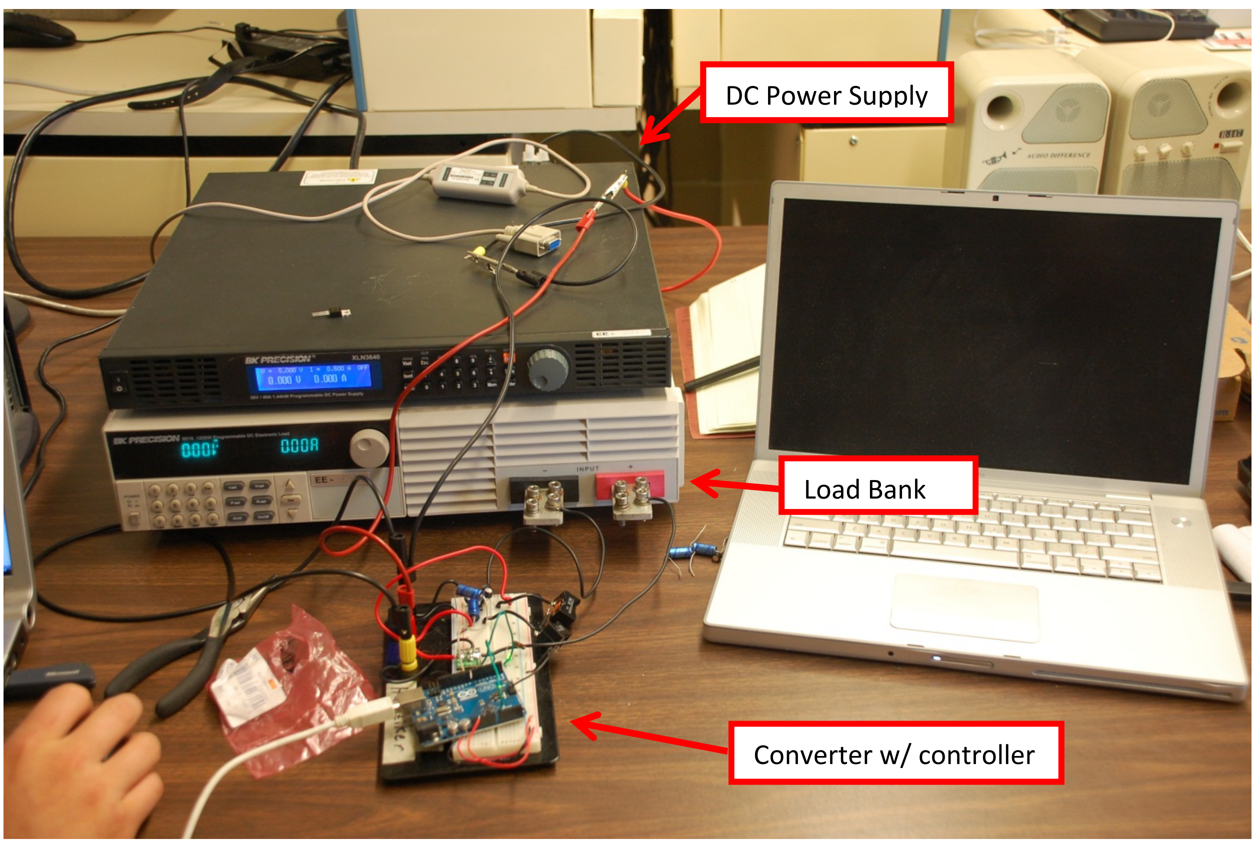


Figure 9. Small-scale buck converter test setup.

After building the small scale converter it was found that the MOSFET being used would not properly turn on until 15 volts, also, due to the wiring used the maximum possible output current was limited to 1 amp. Even though we had these setbacks the small scale converter was still able provide some very useful information. Some sample data gather can be seen in Table 10. The test would consist of a given load resistance, and input voltage which would be ramped up, the input current, output current, and output voltage were then all measured.

Table 10. Example Test data for the small scale buck converter.

10 Ω Load Resistance				
Input Voltage	Input Current	Output Voltage	Output Current	Efficiency (%)
15	0.054	2	0.2	49.38
17	0.047	1.99	0.2	49.81
19	0.046	2.02	0.2	46.22
21	0.043	2.01	0.2	44.52
23	0.04	2	0.2	43.48
25	0.039	2.01	0.2	41.23
27	0.036	2.03	0.2	41.77
29	0.036	2	0.2	38.31
31	0.035	2.05	0.2	37.79
33	0.033	2.05	0.2	37.65
35	0.032	2.03	0.2	36.25

The efficiency for the converter is given by equation 5:

$$\eta = \frac{(V_{out} I_{out})}{(V_{in} I_{in})} x\ 100 \tag{5}$$

Surprisingly the converter efficiency is not nearly as high as proposed by some of the design calculations. But when the efficiency of the converter is graphed against different loads (as seen in Figure 7) the efficiency climbs with a lower load resistance, and inversely higher output current.

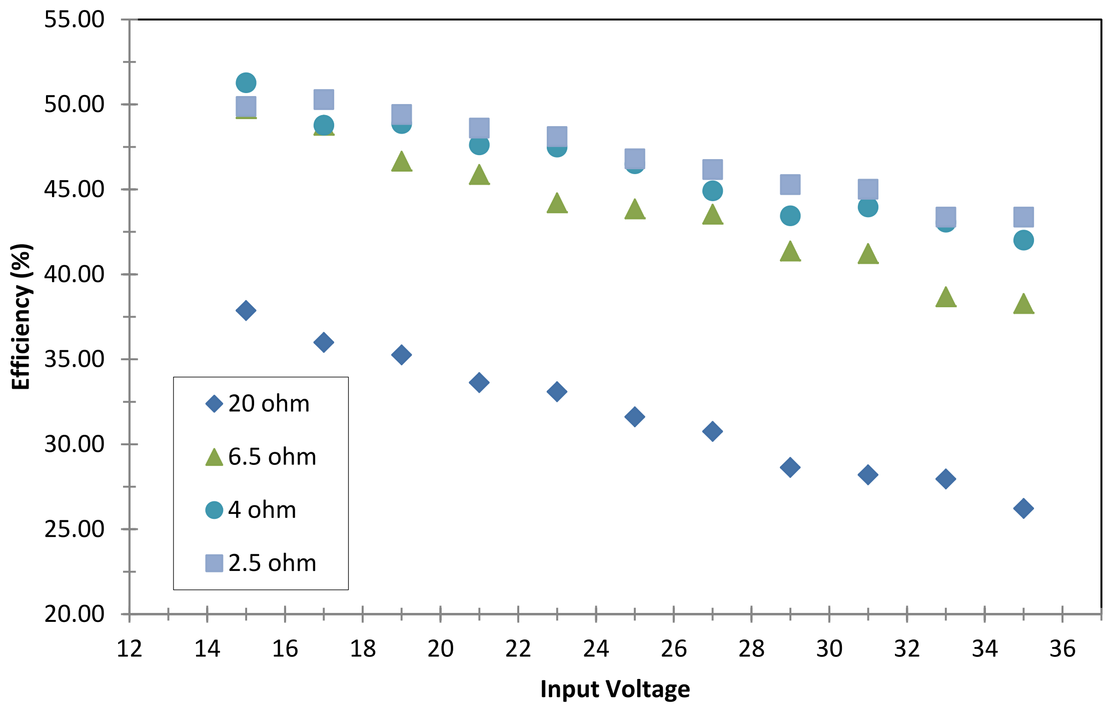


Figure 10. Efficiency of the small scale converter against input voltages and different load resistances.

When the average efficiencies of the tests are graphed against the output current as seen in Figure 8, there appears to be correlation between the two that is power based.

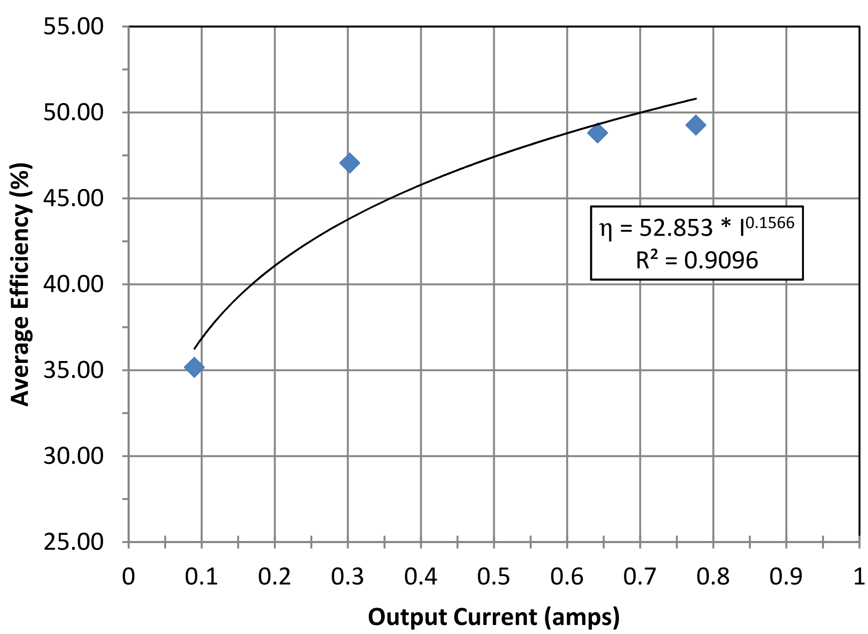


Figure 11. Average converter efficiency versus the output current.

Using the correlation in Figure 8 produces the results seen in Table 11 which are much closer to the calculated efficiencies of the converter.

Table 11. Output current and the predicted efficiency.

Output Current (amps)	Predicted Efficiency (%)
1	52.85
2	58.91
3	62.78
4	65.67
5	68.00
6	69.97
7	71.68
8	73.20
9	74.56
10	75.80

Chapter 4: Description of the Final Design

System Layout

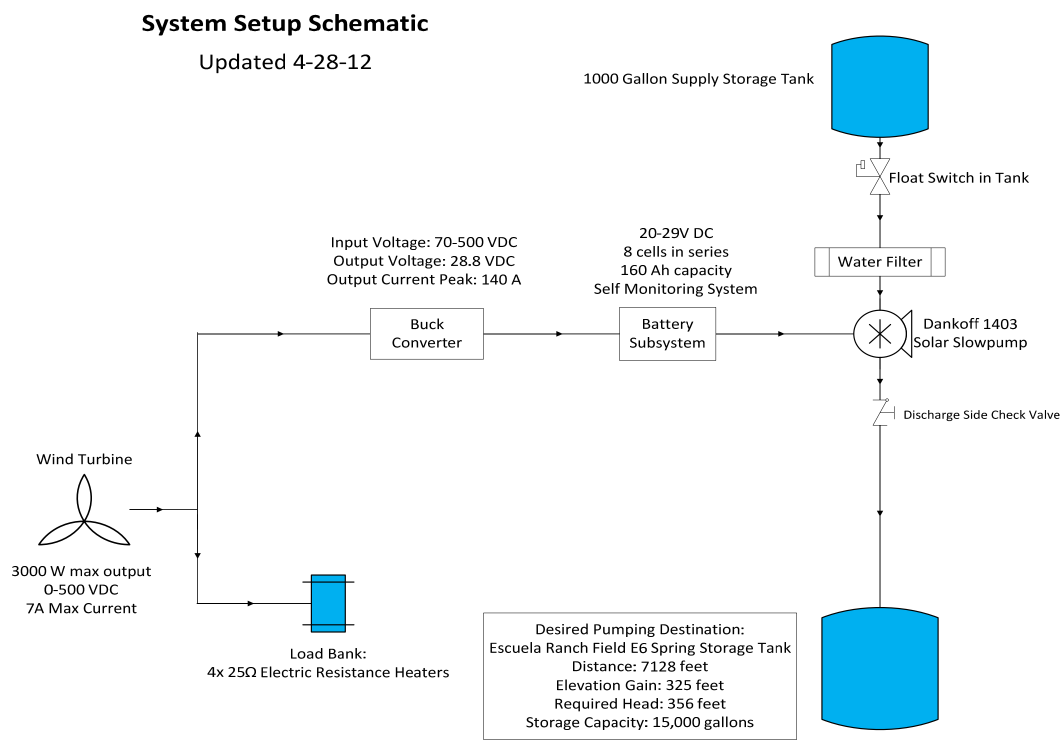


Figure 12: Schematic of final system design

The final design of our system is shown in Figure 5. Some components have already been selected out of the several options listed above where as other components are still being researched. Specifics of these selected and pending components will be discussed in further detail in the sections below.

System Description

Our system begins with a custom built buck converter to help regulate the wild DC voltage out of the wind turbine. The regulated voltage will be outputted at a nominal 28 volts and feed into a Coleman Air battery charge controller. The battery charger will ensure proper charging with the necessary three stages of battery charging. Any excess energy will be bypassed to a resistive load.

The following components have been tentatively selected, but still need to be approved by Dr. Lemieux. Price quotes have been obtained for the charge controller, while a price quote for the buck converter is still being developed.

<u>Buck Converter</u>

The full size buck converter was constructed much like the small scale converter. This converter used the same circuitry to amplify the PWM signal that was used to drive the gate of the IGBT. To measure the voltage across the load a simple voltage divider was constructed to output 0-5 volts when the load voltage ranged from 0-30 volts. As seen in Figure 13, the large scale converter is almost identical to the small scale converter, except for the fact that the op-amp chip uses an external power source to amplify the PWM signal.   Using buck converter design equations (listed in Appendix 2) the values for the capacitors, inductor, and switches are listed below.

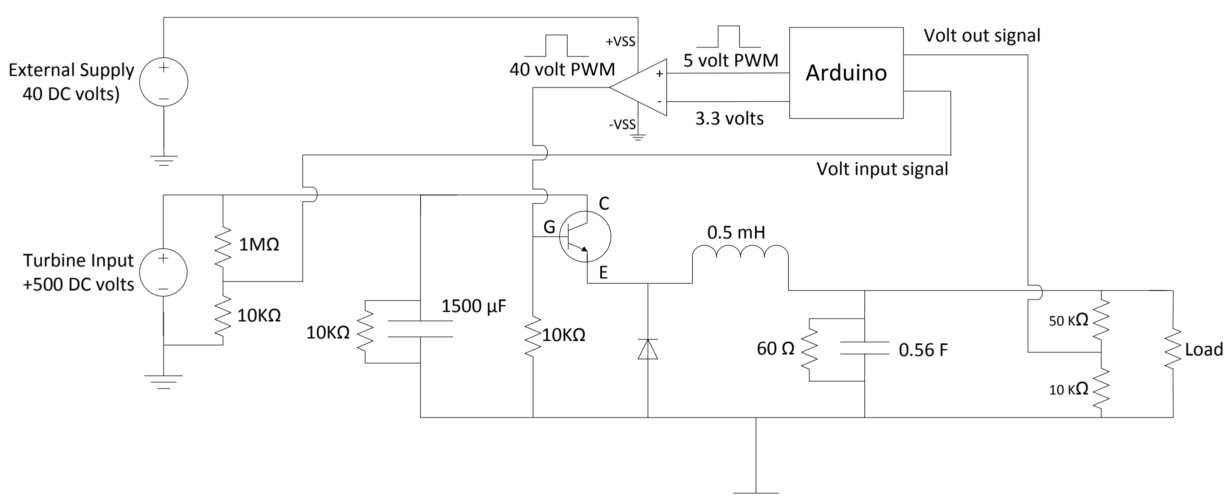


Figure 13. Full-scale buck converter diagram.

Table 12. Buck Converter specifications.

Buck Converter	
Rated Power	3.5 kW
Operating Voltage Range	30-500 VDC
V_{in} Capacitor	1.36 mF
Switch Type	IGBT
Inductor	70.5 µH
V_{out} Capacitor	1.12 F

<u>Battery Pack</u>

The battery pack that will be used for this application will be the 24 VDC International 4.1kWh discussed earlier in this report. The large capacity enables running the system for an extended amount of time at the customer's discretion. The fact that this battery is being donated is an important deciding factor in terms of minimizing cost of our system. Also, the on-board battery management system will provide helpful data acquisition for future energy generation testing over time. The on-board battery management system will also be helpful in regulating even discharge of the battery cells.

<u>Solar Slow Pump #1403</u>

Based on an update in our calculations with more precise data than the original over-estimates used, the Solar Slow Pump has been selected for this application. The Solar Slow Pump has the capacity to overcome the newly calculated head value of 360 feet to our final destination. The relatively lower price range of this pump was also a significant factor in our selection due to our small budget. However, a housing unit will be necessary for this component as it will be need protection from dirt and the elements.

<u>Water Source</u>

As discussed with the customer, water will be pumped to the turbine location from an existing installed pump. This water will already be filtered and readily available to pump to the end location.

<u>Filter</u>

To ensure that no dirt goes through our pump, a filter will be installed just before the pump inlet as another precaution. This will be a simple and cheap fail safe to avoid damage to the relatively more expensive component.

<u>Piping</u>

The piping being supplied for our system by Escuela Ranch is 1" PE schedule 40 pipe with a pressure rating of 160 psi. Since the system head pressure will be near the rated pressure of the pipe, some metal

piping will be installed at the beginning of the line just after the pump. Specifics on the material to be used are to be determined.

Tank

The final destination will be three 12-feet tall 5,000 gallon tanks. The 12 feet extra elevation is included in our system head calculations. The large capacity enables the shut-off factor for our system to be the wind available and not the capacity to store. This allows maximum usage of our overall system and therefore a better efficiency and usage of the overall energy generated by the wind turbine.

Maintenance and Repair Considerations

When in the field, this system will be installed in a NEMA 4/4X enclosure, so it will have a cover allowing for easy access to the converter, pump, and battery system. The battery should not need any regular maintenance or repair. If any issues occur with the pump, the illustrated pump manual can be found in Appendix D. Replacement brushes can also be purchased if needed. The filter for the pump should be periodically checked to see if it is becoming clogged and restricting flow. If the buck converter experiences any problems, it can be easily accessed and removed if need be. An electrical engineer may be needed to examine and trouble shoot if persisting problems occur.

Chapter 5: Product Realization

Most components of this system are ordered parts and do not require additional manufacturing. Construction of the buck converter is one exception. The different components of the buck converter needed to be mounted and installed in a clean and accessible manner. For mounting of the converter, all of the parts were secured to an acrylic board. This board is currently installed in an electrical rack that is not rated for use outside, but can be installed into an appropriately rated enclosure at a later date to be deployed in the field. The primary manufacturing process employed in the mounting of the components was use of a wireless drill to drill the holes needed for the mounting screws. The wireless drill was also used to drill the port holes in the copper terminals used for connecting wires. A drill press was used to drill the counterbore holes into the heat sinks to allow for the screw heads to rest on the base plate of the heat sink.

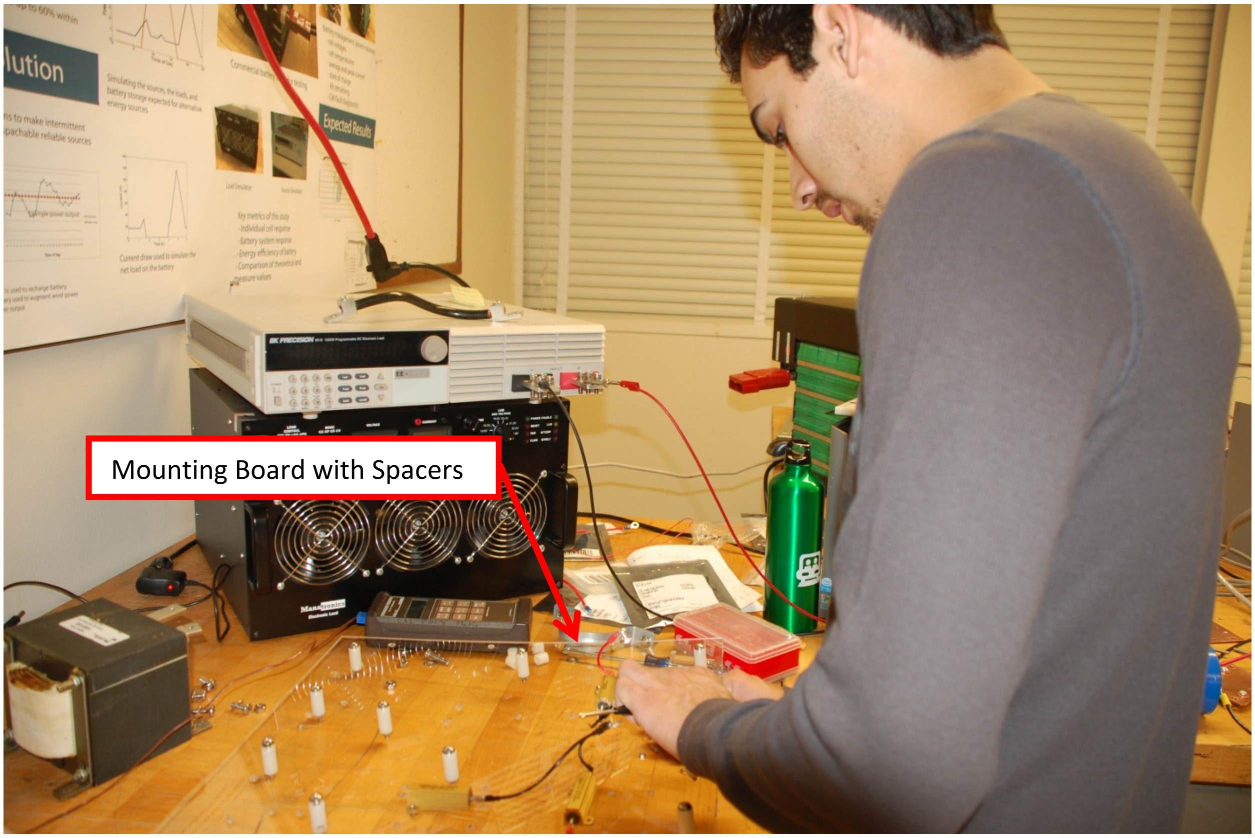


Figure 14: Installation of support pegs to mounting plate.

Along with mounting the components to the board, the circuit needed to be wired together. This required soldering wires. Soldering was done by hand and heat shrink was used placed over terminal connections in order to help secure the terminals to the wire as well as to help prevent accidental shorting of components.

For future manufacturing of the buck converter design, it is recommended to use a more durable material for the mounting board, but one that can still provide a level of isolation between components.

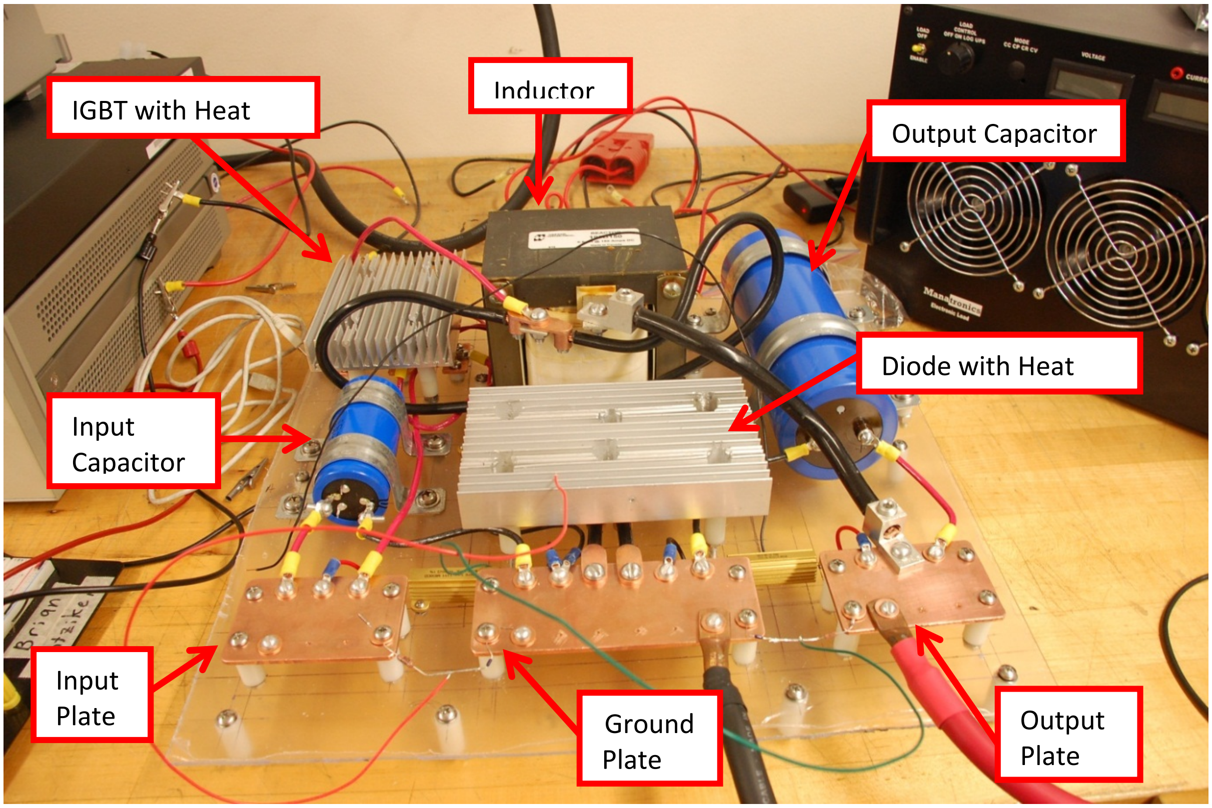


Figure 15: Top view of mounted and wired buck converter.

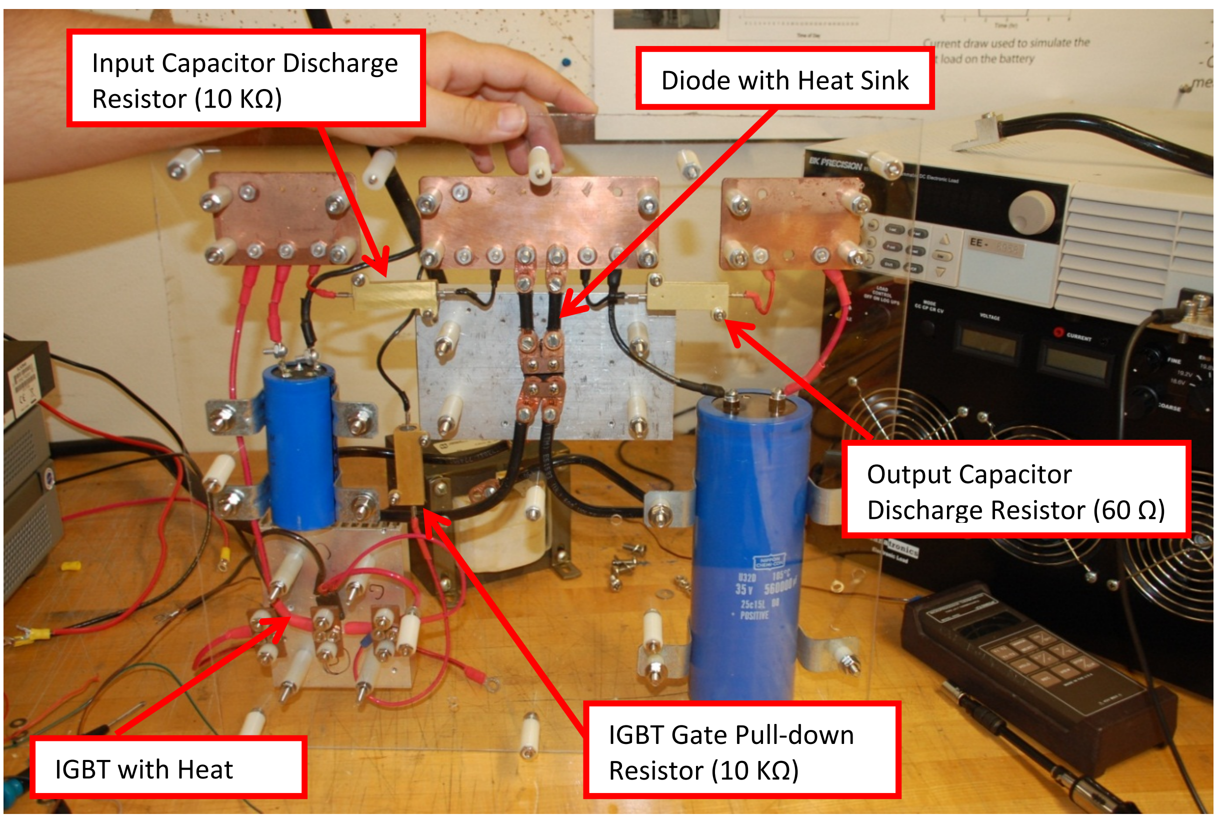


Figure 16: Bottom view of buck converter during mounting.

Chapter 6: Design Verification

Buck Converter Testing

When testing the power conditioner two main concerns will be:

- Efficiency
- Appropriate output voltage

To test and verify that the power conditioner is working correctly, the conditioner will be hooked up to a DC power source that can range from 0-500 volts with noise added onto the signal. While the input voltage is less than 28 volts, the conditioner will be expected to smooth out the signal and output an appropriate voltage. When the input voltage exceeds 28 volts, the output shall remain at a constant 28 volts while the current varies. The input and output power will also be measured to find the efficiency of the conditioner throughout different voltage ranges.

Much like the small scale converter the large scale converter was given a varying load resistance along with a range of input voltages, the input current, output voltage, and output current were then recorded as shown in Table 12. Because we had some trouble getting the input voltage past the op-amp driver voltage, the output voltage was set to 5 volts so that at least some data could be taken.

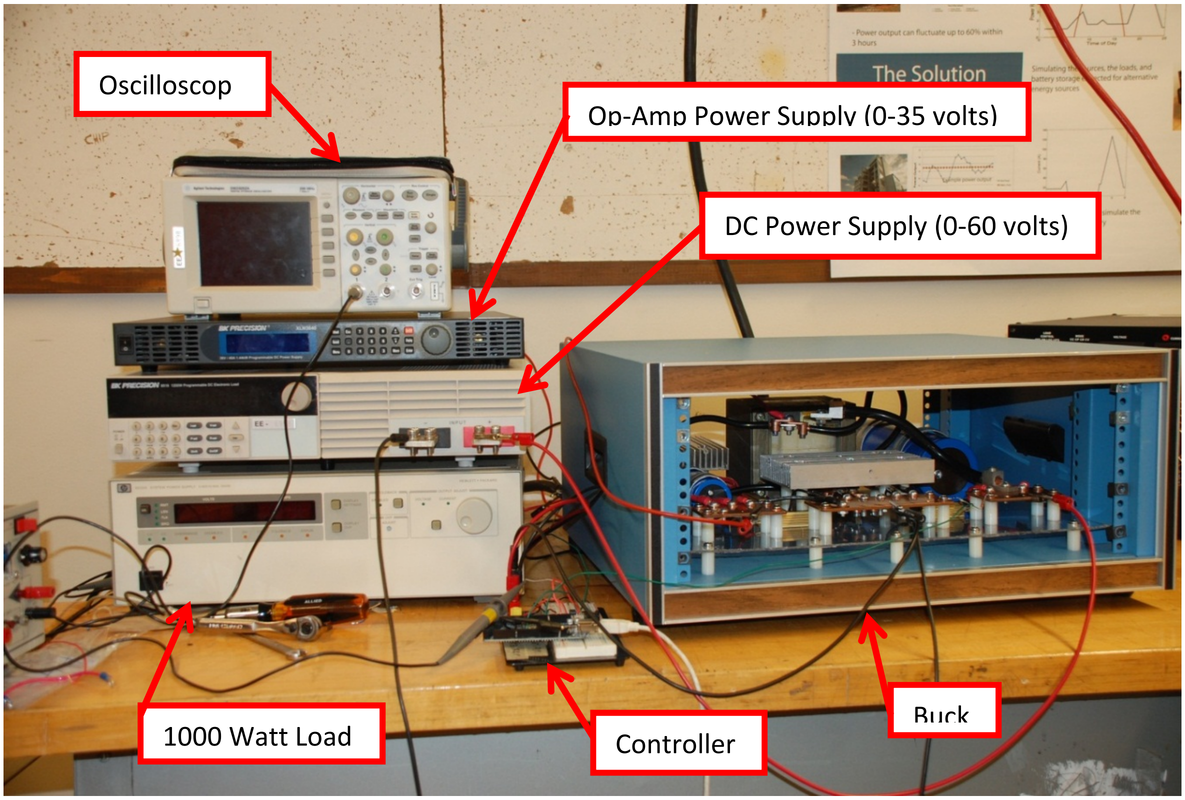


Figure 17: Full-scale buck converter test setup

Table 13. Test data for the buck converter.

5 Ω load Resistance				
Input Voltage	Input Current	Output Voltage	Output Current	
6.2	0.98	4.9	0.98	0.790
10	0.65	5	1	0.769
15	0.46	5.03	1	0.729
20	0.39	5.06	1.01	0.655
25	0.35	5.06	1	0.578
30	0.43	5.03	1	0.390

Again the buck converter did not perform as efficiently as expected, but this was suspect to both the driver circuitry not working correctly (hence the last data point very low efficiency), and because much like the small scale converter, there was simply not enough current being pulled through the load. After a few test the average efficacy for each load resistance was graphed against the current. The data showed a power relationship and using excel, a correlation was made.

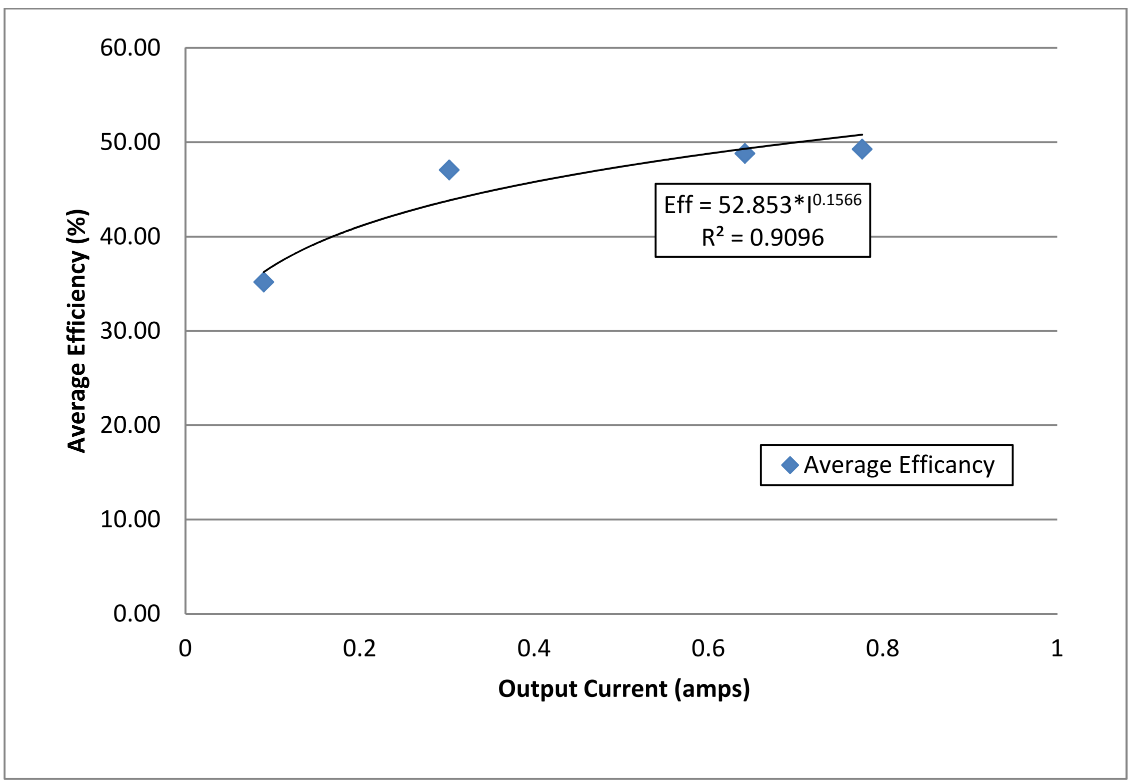


Figure 18. The average efficiency against the output current.

Using the correlation in Figure 11 produces the results seen in Table 14 which are much closer to the calculated efficiencies of the converter.

Table 14. Output current and Predicted Efficiency.

Output Current (amps)	Efficiency (%)
10	78.193
20	81.905
30	84.157
40	85.792
50	87.082
60	88.151
70	89.065
80	89.864
90	90.575
100	91.216
110	91.799

Pump Testing

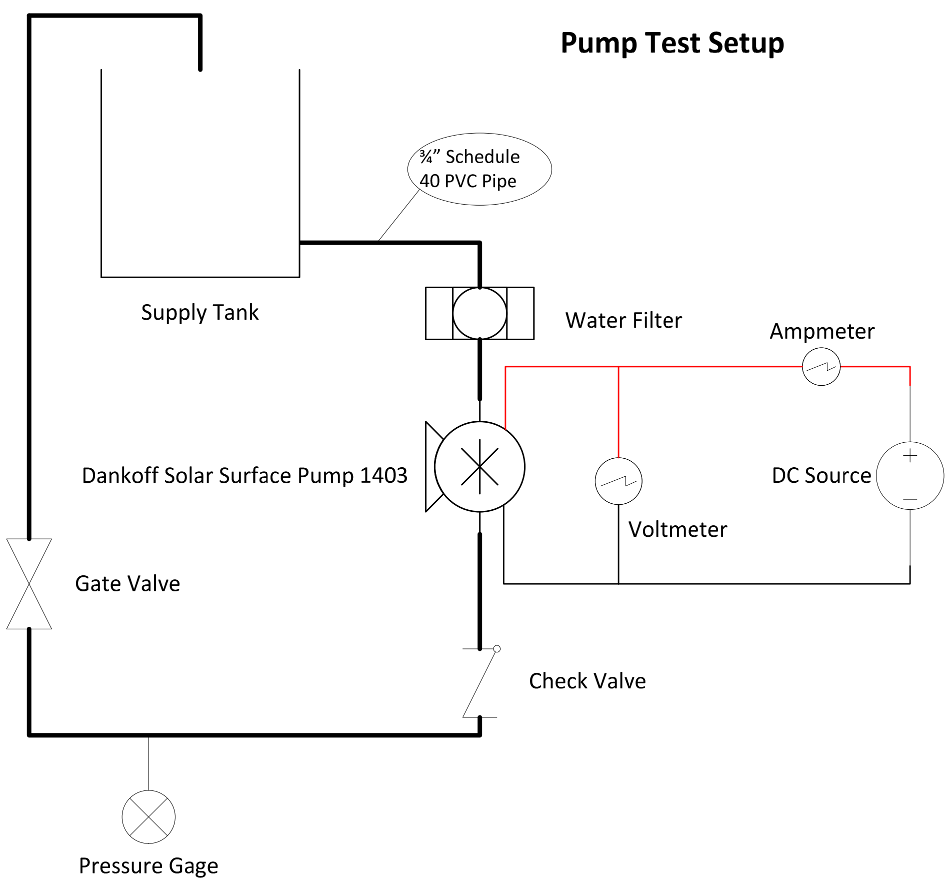


Figure 19: Pump testing system setup.

When testing the pump, the main concerns will be:

- Efficiency
- Flow rate
- Simulating appropriate head losses

A key relation to use when testing the pump is

$$1\ psi = 2.31\ feet\ of\ \ TDH$$

which relates the head of the pump to pressure in the line.

The system used to test the pump is shown in Fig. 19. The filter will be placed between the supply tank and the pump. On the discharge side of the pump, a check valve will prevent water from flowing back into the pump. Continuing down the line will be a T-joint in the line that leads to a pressure gage. Further down the line will be a brass gate valve. The downstream side of the gate valve leads back into the supply tank, so the tank should not run dry. Connected to the wiring of the pump will be an ammeter and a voltmeter to measure current and voltage draw while the pump is running.

The pump will be hooked up to DC power source set at the pump's operating voltage, 24-28 VDC. Starting with the gate valve fully open, begin running the pump. Measurements of pressure, voltage, and current should be taken at each step. Step the gate valve closed so the pressure read from the pressure gage increases in increments of 10 psig. Take an additional measurement at the pressure based on the total head loss of the system.

NOTE: The check valve and gate valve are rated to 200 psi. This pressure should not be exceeded.

NOTE: Cavitation can result in damage to the pump. Make sure the supply tank does not run dry. If the tank does run dry, turn off the pump immediately.

An additional test that will be useful to run would be to pump from one tank into another. With the second tank empty begin running the pump with the gate valve fully-open. Time the amount of time it takes to fill an amount of the second tank. This data can be used to calculate the flow rate of the pump.

Battery

When testing the battery, the main concerns will be:

- Charge rate
- Discharge rate
- Max/Min voltage for safe operation
- Battery management system

The Battery will be hooked up to a power source and fully charged; the time taken to charge the battery will be recorded. Next a load bank will then be used to pull charge from the battery. The load bank will consist of a 24 volt load with a set amount of current, multiple tests will be needed to fully characterize the battery. To test the battery management system two tests will be conducted; one will test the maximum voltage the battery will operate at before it shuts off, the second will test the minimum voltage the battery will operate at before it shuts off. To test the maximum voltage of operation a power source will be connected to the battery and will charge the battery. Upon reaching full charge (29 volts) the power source will be checked to see if it has been grounded out due to the battery shutting off. A similar test will be used to test the minimum voltage the battery will operate at but instead of using a power source a load bank will be used to drain the battery and verify that the battery will turn off when a minimum voltage (20 volts) is reached.

Chapter 7: Conclusions and Recommendations

Buck Converter:

While the converter is built and has had some light testing, further testing and modification of the converter is needed, this includes:

- An electrical engineer is needed to check the switching circuitry to make sure it is built correctly
- If the switching circuitry is not built correctly a redesign of the circuitry is needed
- Thermo couples should be applied to the heat sinks to measure heat generation and serve as an ability to shut down if needed
- A second diode will be needed between the converter and the battery to prevent the battery from "charging" the converter
- Two switches in series should be installed as a precaution against one of the switches failing and shorting out.
- The converter needs to be further tested and characterized, this should include hooking it up to the wind turbine generator when it is on a dynamometer
- A better way to measure the output voltage is needed, the voltage divider works, but it seems to be off by a volt or two every other day

Pump:

Testing for the pump should be complete prior to implementation into system. Take notice of all the notes outlined in the procedure for testing the pump in the section above. Although the pump outlined above will sever its designed purpose, here are several options for modifications and improvements:

- The addition of a remote pump shut-off system so that the pump may be shut down at the discretion of the user.
- A display system to indicate the flow rate, pressure, and power consumption.
- A data acquisition system to record and monitor the flow rate, pressure, and power consumption over time for maintenance issues.

ABC Wind proposed and delivered a system capable of meeting the needs outlined by the Escuela Ranch and Dr. Lemieux. Given the complexity with the required power electronics needed to complete the voltage regulator, the project is not currently in a state to be fully operational in the field. However, ABC Wind has outlined above the remaining necessary steps required to do so and has proven the functionality of the system.

References

1. "1 kW pump system." *Bergey Wind Power*. N.p., n. d. Web. 02 Feb. 2012. <http://www.bergey.com/pages/1_kw_pump_system>.
2. Schelle, Donald and Jorge Castorena. “Buck Converter Design Demystified.” Power Electronics Technology, June 2006. <http://my.ece.ucsb.edu/Bobsclass/194/References/NonIsolated/Buck/Buck%20Converter%20Design%20Demystified%20606PET25.pdf>
3. "Small-Scale Wind Turbines for Water Pumping and Electricity Generation, Egypt." Arab States: Egypt-2, 2003. Web. 07 Feb 2012. <http://sgp.undp.org/download/SGP_Egypt2.pdf>.
4. "Whisper 200 Wind Turbine for Water Pumping." *Alt E Store*. N.p., n. d. Web. 07 Feb. 2012. <http://www.altestore.com/store/Wind-Turbines/Southwest-Windpower-Turbines-Parts/Whisper-200-Wind-Turbines/Whisper-200-Wind-Turbine-for-Water-Pumping/p6865/>.

Appendix A:

Head Loss Calculation EES Code

Buck Converter Design EES Code

Estimate Energy Production Calculation

Head Loss Calculations

File:C:\Users\meuser\AppData\Local\Temp\Head_Loss_Calculation.EES 2/28/2012 10:40:03 AM Page 1
EES Ver. 8.889: #552: For use by Mech. Engin. Students and Faculty at Cal Poly

Flowrate

$$Q = \frac{3}{448.83} \cdot 1 \quad [ft^3/s]$$

efficiency of pump

$$e = 0.5 \quad [-]$$

Pressure in pipe we tie into

$$P_2 = 50 \cdot 144 \cdot 1 \quad [lbf/ft^2]$$

Elevation change

$$z_2 = 222 \quad [ft]$$

$$z_1 = 0 \quad [ft]$$

Losses

$$K_L = 10.1 \quad [-]$$

$$h_{major} = 1.263 \cdot 27 \cdot 1 \quad [ft]$$

Pipe inner diameter

$$D = \frac{1.049}{12} \cdot 1 \quad [ft]$$

Gravity

$$g = 32.2 \quad [ft/s^2]$$

Water Specs

$$\gamma = 62.4 \quad [lbf/ft^3]$$

$$\rho = 1.94 \quad [slug/ft^3]$$

Total Losses

$$h_a = \frac{P_2}{\gamma} + z_2 - z_1 + h_{major} + [K_L + 1] \cdot \frac{Q^2}{[0.25 \cdot D^2 \cdot \pi]^2 \cdot 2 \cdot g} \quad ft$$

Power needed

$$Conv_{Watts} = \frac{1000}{550 \cdot 1.34} \cdot 1 \quad [W/(lbf*ft/s)]$$

$$P = h_a \cdot g \cdot \rho \cdot \frac{Q}{e} \quad lbf\ ft/s]$$

$$P_{Watts} = P \cdot Conv_{Watts}$$

w

SOLUTION

Unit Settings: Eng F psia mass deg

$Conv_{Watts}$ = 1.357 [W/(lbf*ft/s)]
D = 0.08742 [ft]
e = 0.5 [-]
g = 32.2 [ft/s^2]
γ = 62.4 [lbf/ft^3]
h_a = 371.7 [ft]
h_{major} = 34.1 [ft]
K_L = 10.1 [-]
P = 310.4 [lbf*ft/s]
P_2 = 7200 [lbf/ft^2]
P_{Watts} = 421.2 [W]
Q = 0.006684 [ft^3/s]
ρ = 1.94 [slug/ft^3]
z_1 = 0 [ft]
z_2 = 222 [ft]

No unit problems were detected.

Buck Converter Design

File:C:\Users\meuser\AppData\Local\Temp\Buck converter calcs Rev1.EES 5/17/2012 9:34:24 AM Page 1
EES Ver. 8.889: #552: For use by Mech. Engin. Students and Faculty at Cal Poly

Inductor Calcs

$$L = [V_{IN,MAX} - V_{OUT}] \cdot \frac{V_{OUT}}{V_{IN,MAX}} \cdot \frac{1}{f_{SW}} \cdot \frac{1}{LIR \cdot I_{OUT,MAX}}$$

$$V_{IN,MAX} = 500$$

$$V_{OUT} = 28$$

$$f_{SW} = 5000$$

$$LIR = 0.3$$

$$I_{OUT,MAX} = \frac{P_{rating}}{V_{OUT}}$$

$$P_{rating} = 3500$$

$$I_{PEAK} = I_{OUT,MAX} + \frac{\Delta I_{INDUCTOR}}{2}$$

$$\Delta I_{INDUCTOR} = LIR \cdot I_{OUT,MAX}$$

Output Capacitor Calcs

$$\Delta V = \sqrt{V_{OUT}^{2} \cdot L \cdot \frac{\left[I_{OUT,MAX} + \frac{\Delta I_{INDUCTOR}}{2}\right]^2}{C_o}} - V_{OUT}$$

$\Delta V = 2$ *max output voltage overshoot. Can be whatever we choose.*

$$V_{OUT,CAPACITOR} = \frac{1}{2 \cdot C_o} \cdot \left[\frac{V_{IN,MAX} - V_{OUT}}{L}\right] \cdot \left[\frac{V_{OUT}}{V_{IN,MAX} \cdot f_{SW}}\right]^2$$

$$V_{OUT,RIPPLE} = \frac{1}{2 \cdot C_o} \cdot \left[\frac{V_{IN,MAX} - V_{OUT}}{L}\right] \cdot \left[\frac{V_{OUT}}{V_{IN,MAX} \cdot f_{SW}}\right]^2 + \Delta I_{INDUCTOR} \cdot ESR_{C,o}$$

Typical output voltage ripple is less than 2%; according to article.

$$V_{OUT,RIPPLE} = 0.02 \cdot V_{OUT}$$

Input Capacitor Calcs

$$I_{C,I,RMS} = I_{OUT,MAX} \cdot \frac{\sqrt{V_{OUT} \cdot [V_{IN} - V_{OUT}]}}{V_{IN}}$$

For worst case scenario, V_{in} is twice the output voltage. Since the V_{in} will not operate at that low of a voltage, we will

use the start up voltage.

$V_{IN} = 70$ *startup voltage*

$V_{IN,MIN} = V_{IN}$

The input capacitance required for a stepdown converter depends on the impedence of the input power source. Need the impedence per ampere value and multiply that by input ripple current for imput capacitor to find value of input capacitor. Guess 22e-6

$C_I = I_{C,I,RMS} \cdot 0.000022$ *Found this approx in reading in article*

$ESR_{C,I} = 0.02 \cdot \frac{V_{IN,MAX}}{I_{C,I,RMS}}$ *NOTE: I kinda based this equation on the way $ESR_{C,o}$ was calculated*

....

Diode Selection

$$P_{DIODE} = \left[1 - \frac{V_{OUT}}{V_{IN,MAX}}\right] \cdot I_{OUT,MAX} \cdot V_D$$

Typical values for V_D is .7 V or .3 V. Ensure selected diode will be able to dissipate that much power. Ensure reverse repetitive max voltage is greater than max input voltage and the forward current specification must exceed or meet the max output current.

$V_D = 0.7$

....

Mosfet Selection

$T_{J,MAX} = 115$ *Based on numbers given in article. Can/probably should change for our design in the future.*

$T_{A,MAX} = 60$ *Based on numbers given in article. Can/probably should change for our design in the future.*

$T_{J,RISE} = T_{J,MAX} - T_{A,MAX}$

$$P_{D,TOT} = \frac{T_{J,RISE}}{\Theta_{JA}}$$

$\Theta_{JA} = 62$

Thermal resistance. Based on numbers given in article. Can/probably should change for our design in the future.

$T_{J,HOT} = T_{J,MAX}$ *$T_{J,HOT}$ was not really specified in the article. I assumed this.*

$$P_{D,RDS} = \frac{V_{OUT}}{V_{IN,MIN}} \cdot I_{OUT,MAX}{}^2 \cdot R_{DS,ON,HOT}$$

$$R_{DS,ON,HOT} = [1 + 0.005 \cdot (T_{J,HOT} - 25)] \cdot R_{DS,ON,25C}$$

$$R_{DS,ON,25C} = \frac{V_{IN,MIN}}{V_{OUT}} \cdot \frac{1}{I_{OUT,MAX}{}^2 \cdot [1 + 0.005 \cdot (T_{J,HOT} - 25)]} \cdot P_{D,TOT} \cdot 0.6$$

$$P_{D,SW} = C_{RSS} \cdot V_{IN,MAX}{}^2 \cdot f_{SW} \cdot \frac{I_{OUT,MAX}}{I_{GATE}}$$

Value below from gate driver/controller data sheet

$C_{RSS} = 3.0 \times 10^{-10}$ *Based on numbers given in article. Can/probably should change for our design in the future.*

Value below from MOSFET data sheet

$I_{GATE} = 1$ *Based on numbers given in article. Can/probably should change for our design in the future.*

....
....

Efficiency Calcs

$$P_{C,I,RMS} = I_{C,I,RMS}{}^2 \cdot ESR_{C,I}$$

$$P_{DCR,RMS} = (I_{OUT,MAX} + \Delta I_{INDUCTOR} \cdot \sqrt{2})^2 \cdot DCR_L$$

$DCR_L = 0.02$ *DC Resistance (guess)*

$$P_{C,o,RMS} = (\Delta I_{INDUCTOR} \cdot \sqrt{3})^2 \cdot ESR_{C,o}$$

$$P_{CU} = I_{OUT,MAX}{}^2 \cdot R_{CU}$$

$R_{CU} = 0.0047$ *Resistance of a copper pcb (estimation)*

$$\eta = \left[\frac{V_{OUT} \cdot I_{PEAK}}{V_{OUT} \cdot I_{PEAK} + P_{C,I,RMS} + P_{C,o,RMS} + P_{DCR,RMS} + P_{D,RDS} + P_{D,SW} + P_{DIODE} + P_{CU}} \right] \cdot 100$$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

$C_I = 0.001347$ [F]	$C_o = 2.538$ [F]
$C_{RSS} = 3.000E-10$	$DCR_L = 0.02$
$\Delta I_{INDUCTOR} = 37.5$ [H]	$\Delta V = 2$ [V]
$ESR_{C,I} = 0.1633$	$ESR_{C,o} = 0.01493$
$\eta = 72.68$	$f_{SW} = 5000$ [Hz]
$I_{C,I,RMS} = 61.24$ [A]	$I_{GATE} = 1$ [A]
$I_{OUT,MAX} = 125$ [A]	$I_{PEAK} = 143.8$ [A]
L = 0.000141 [H]	LIR = 0.3
$P_{CU} = 73.44$	$P_{C,I,RMS} = 612.4$
$P_{C,o,RMS} = 62.99$	$P_{DCR,RMS} = 633.9$
$P_{DIODE} = 82.6$ [W]	$P_{D,RDS} = 0.5323$
$P_{D,SW} = 46.87$	$P_{D,TOT} = 0.8871$

P_{rating} = 3500 [W]
$R_{DS,ON,25C}$ = 0.00005873
Θ_{JA} = 62
$T_{J,HOT}$ = 115
$T_{J,RISE}$ = 55
V_{IN} = 70 [V]
$V_{IN,MIN}$ = 70 [V]
$V_{OUT,CAPACITOR}$ = 0.00008276 [V]

R_{CU} = 0.0047
$R_{DS,ON,HOT}$ = 0.00008516
$T_{A,MAX}$ = 60
$T_{J,MAX}$ = 115
V_D = 0.7 [V]
$V_{IN,MAX}$ = 500 [V]
V_{OUT} = 28 [V]
$V_{OUT,RIPPLE}$ = 0.56 [V]

16 potential unit problems were detected.

Energy Production Calculations:

Turbine power output:

Using the basic wind turbine equation:

$P = \frac{1}{2} * C_P * \rho * A * V^3$

Where:

P is power *(watts)*

C_P is efficiency

ρ is density of air $\left(\frac{kg}{m^3}\right)$

A is area (m^2), $A = \pi * r^2$, where r is the radius of the wind turbine

V is wind speed $\left(\frac{m}{s}\right)$

Knowing that the turbine produces 3000 watts when the wind speed is 10 m/s, the efficiency can be solved for:

$C_P = \left(\frac{P*2}{\rho*\pi*r^2*V^3}\right)$

$C_P = \left(\frac{3000*2}{1.204*\pi*(1.828)^2*10^3}\right)$

$\boldsymbol{C_P = 0.47}$

Using this efficacy the collected wind speed can be plugged into the above equation and the power generated can be found. After finding the power output they can all be summed together to find the total power produced daily.

$Power_{tot} = 3847\ watts/day$

Pumps:

Using the given head loss, flow rate, power needed, and an assumed efficiency (%80) for each pump the run time can be found using:

$T_{run} = \frac{(Power_{tot} * \%eff)}{Power_{need}}$

This will give total run time per day for a specific head loss and flow rate. To find the total number of gallons moved per day use:

$Total = Q\left(\frac{gal}{min}\right) * T_{run}(hour) * 60(\frac{min}{hour})$

After the total amount of water moved per day has been found simply use this final equation to find the percentage proved daily

$Provide(\%) = \frac{Total}{1800} * 100$

Pump cost

After finding the 20 year cost per pump a simple equation can be used to fine the cost per gallon of water pumped

$$Price\left(\frac{cent}{gal}\right) = \frac{20\ year\ cost\ (dollar)}{Total(gal)*20(years)} * 100\left(\frac{cent}{dollar}\right)$$

Appendix B:

Cost Breakdown

Drawing Packet

Cost Break Down:

Small Scale Converter				
Item	**Vendor**	**Price (each)**	**Quantity**	**Total**
Input Capacitor	Newark	0.224	5	10.92
Output Capacitor	Newark	0.08	5	10.20
Indcutor	Newark	7.69	2	25.18
MOSFET	Sparkfun	0.95	3	7.58
Aurdino	Sparkfun	29.95	1	34.68
Voltage/Current Sensor	Sparkfun	19.95	1	24.68
			Sub Total	**113.24**

Buck Converter				
Item	**Vendor**	**Price (each)**	**Quantity**	**Total**
Inductor	DigiKey	355.58	1	355.58
Diode	DigiKey	31.5	1	75.31
IGBT	Newark	9.05	6	54.30
Input Capacitor	Digikey	53.46	1	85.47
Output Capacitor	Online Components	87.45	1	87.45
Op-Amp	Newark	0.91	10	9.10
Resistor (10 Kohm)	Newark	6.23	2	12.46
Resistor (60 ohm)	Newark	3.96	1	21.64
Mounting Hardware	Home Depot/Ace Hardware	245.17	1	245.17
			Sub Total	**946.48**

Pump				
Item	**Vendor**	**Price (each)**	**Quantity**	**Total**
Pump	Solar Conduit	922.79	1	922.79
Dry Run Switch	Northern Arizona Wind & Sun	69.79	1	69.79
Filter	altEstore	59.4	1	59.40
			Sub Total	**982.19**

Total	**2041.90**

Appendix C:

List of Vendor Contact Info

Appendix C

List of Vendors

General

Home Depot
1551 Froom Ranch Rd.
San Luis Obispo, CA 93405
Phone: (805) 596-0857
http://www.homedepot.com

Miner's Ace Hardware
2034 Santa Barbara Ave.
San Luis Obispo, CA 93401
Phone: (805) 543-2191
http://minershardware.com

McCarthy Steel
313 South Street
San Luis Obispo, CA 93401
Phone: (805) 543-1760

Pump

Solar Conduit
1840 Grandstand Dr.
San Antonio, TX 78231
Toll-Free: (888) 388-8808
https://solarconduit.com/shop

Dry Run Switch

Northern Arizona Wind & Sun Inc.
4091 E Huntington Drive
Flagstaff, AZ 86004
Toll-Free: (800) 383-0195
http://www.solar-electric.com

Filter

altE Store
43 Broad Street, Suite A408
Hudson, MA 01749
Toll-Free: (877) 878-4060
http://www.altestore.com/store/

IGBT

Newark Element 14
P.O. Box 94151
Palatine, IL 60094
Toll-Free: (800) 463-9275
http://www.newark.com/jsp/home/homepage.jsp

Output Capacitor

onlinecomponents.com
11125 S. Eastern Ave. Ste 120
Henderson, NV 89052
Phone: (702) 462-7300
http://www.onlinecomponents.com/#

Inductor, Diode, Input Capacitor

Digi-Key
webmaster@digikey.com
701 Brooks Avenue South
Thief River Falls, MN 56701
Toll-Free: (800) 344-4539
http://www.digikey.com/

Appendix D:

Vendor Supplied Component Specifications

and Data Sheet

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	APPROVED FOR RELEASE	11/25/12	C.H.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ACRYLIC BOARD	18X17X1/8" ACRLYIC	1
2	STANDOFF #10X1"	NYLON #10X1" LONG	20
3	STANDOFF #10X1/2"	NYLON #10X1/2" LONG	8
4	STANDOFF 1/4X1/2" L	NYLON 1/4X1/2" LONG	4
5	BATTERY OUTPUT TERMINAL	COPPER 3-1/2 X 2-1/4 X 1/8"	1
6	IGBT TERMINAL	COPPER 1-1/2 X 3/4 X 1/8"	3
7	TURBINE INPUT TERMINAL	COPPER 3-1/2 X 2-1/4 X 1/8"	1
8	CENTER TERMINAL	COPPER 5-3/4 X 2-1/4 X 1/8"	1
9	STANDOFF #10X1/4"L	NYLON #10X1/4" LONG	6
10	INPUT CAPACITOR BRACKET	U-BRACKET, STEEL, R1 X1" TALL	2
11	OUTPUT CAPACITOR BRACKET	U-BRACKET, STEEL, R1-1/2 X 1-1/4" TALL	2
12	OUTPUT CAPACITOR	CAP ALUM 1500UF 500V 20% SNAP	1
13	INPUT CAPACITOR	CAP, ALUM ELEC 10UF, 500V, 20%	1
14	RESISTOR	ALUM FILMED, 850F10KE, 10K OHM 50W	3
15	INDUCTOR	.5mH, 150A, 26LBS, D.C. REACTORS	1
16	IGBT AND HEAT SINK ASSY	HEAT SINK, IGBT IRG4PF50W	1
17	DIODE AND HEAT SINK ASSY	HEAT SINK; DIODE STTH200L06TV	1
18	WASHER 1/4"	SS, OD 3/4", ID 3/8"	12
19	MACHINE SCREW 1/4X1/2"L	SS, PHILIPS, 1/4 X 1/2" LONG	12
20	MACHINE SCREW #4X3/8"L	SS, PHILIPS, #4 X 3/8" LONG	6
21	MACHINE SCREW #10X1/2" LONG	SS, PHILIPS, #10X1/2" LONG	6
22	WASHER #10	COPPER, OD 1/2", ID1/5"	12
23	MACHINE SCREW #10X2"L	SS, PHILIPS, #10X2" LONG	8
24	#10 WASHER	SS, OD1/2", ID7/32"	34
25	MACHINE SCREW #10X1-1/2"L	SS, PHILIPS, #10X1-1/2" LONG	12
26	NUT #10	SS, #10-24, HEX	26
27	WASHER #4	SS, #4, OD 5/16, ID 1/8	6
28	NUT #4	SS, #4, HEX	6

NOTES:
1. ALL SCREWS GOING THROUGH THE ACRYLIC BOARD ARE FASTENED WITH A WASHER AND HEX NUT WITH THE RESPECTIVE SIZE.
2. TWO STANDOFFS ARE USED FOR EACH SCREW HOLE TO MOUNT BOTH HEATSINKS IN THIS ASSEMBLY AS SHOWN IN DETAIL A.
3. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: ASME Y14.5M-1994
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL:

TITLE:

BUCK CONVERTER

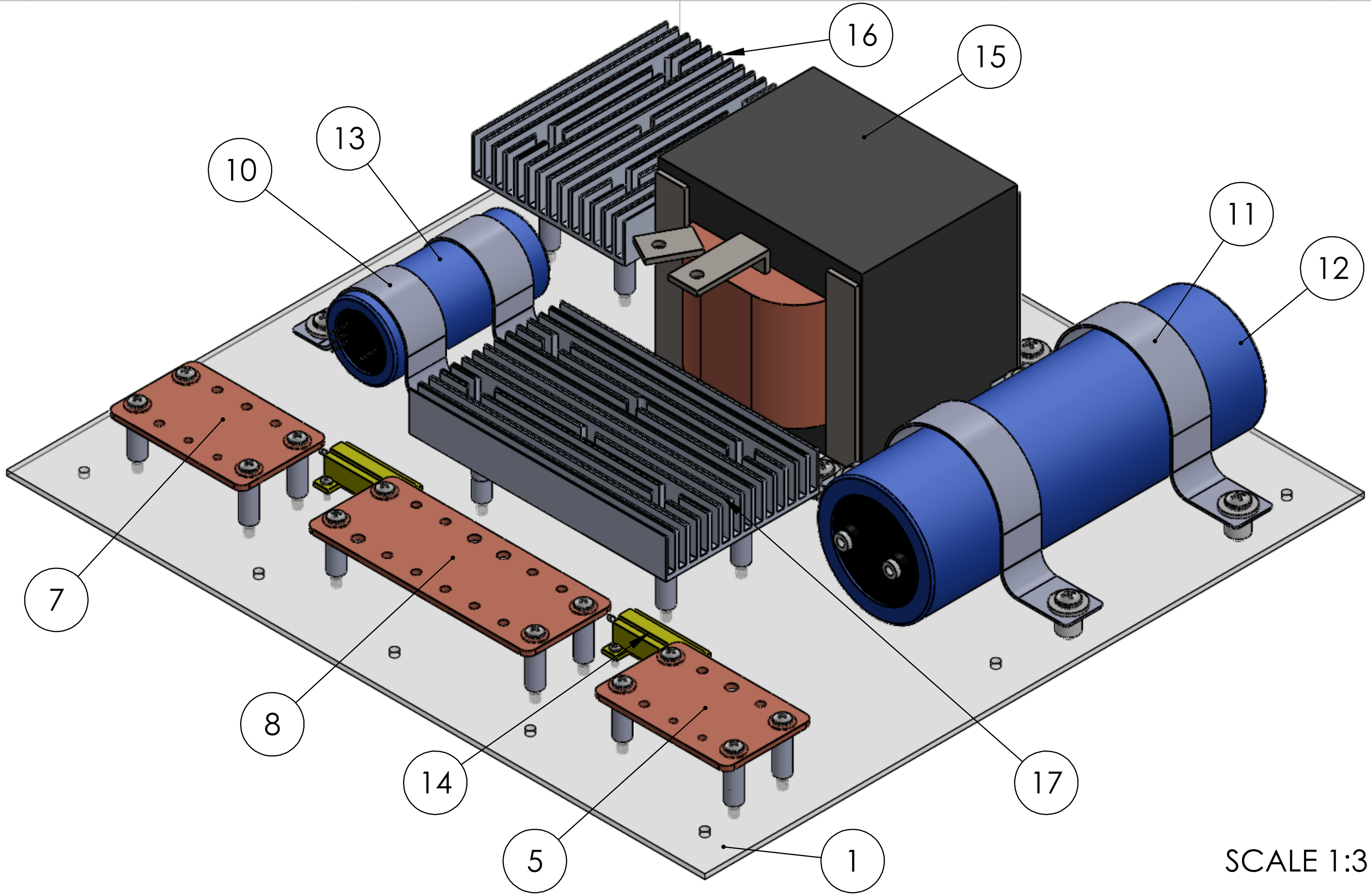
DWG NO. ABC2001-3500W-28V

A4

WEIGHT: APPROX 32LBS (14.5KG)

SCALE: 1:10

SHEET 1 OF 3



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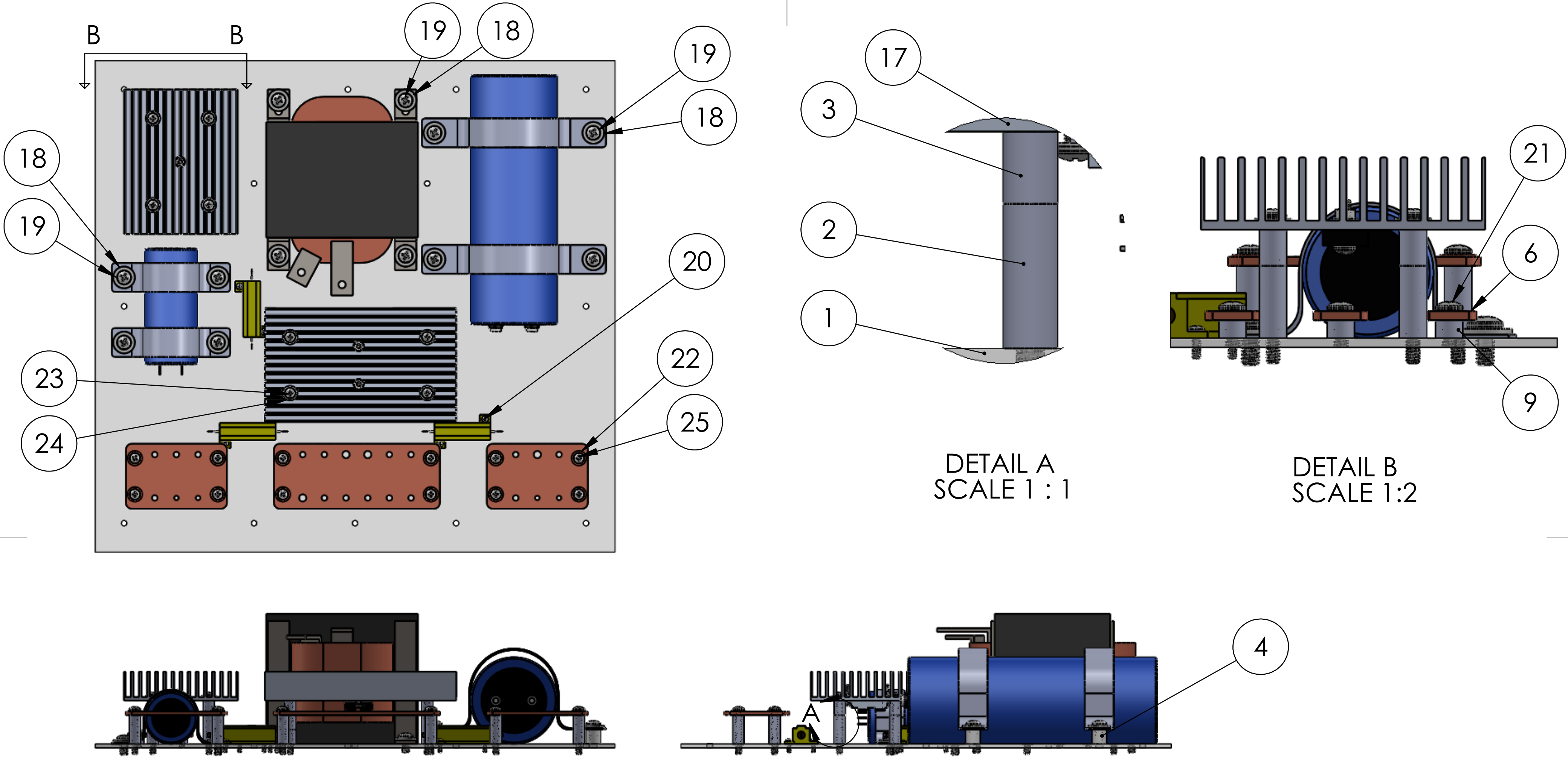
	NAME	SIGNATURE	DATE		TITLE:	
DRAWN	CESAR HURTADO	C.H.	9/30/12		BUCK CONVERTER	
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12			
APPV'D	AARON STEINKRAUS	A.S.	9/30/12			
MFG						
Q.A			MATERIAL:		DWG NO. ABC2001-3500W-28V	A4
			WEIGHT: APPROX 32LBS (14.5KG)		SCALE: 1:10	SHEET 2 OF 3



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ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL:

WEIGHT: APPROX 32LBS (14.5KG)

TITLE:

BUCK CONVERTER

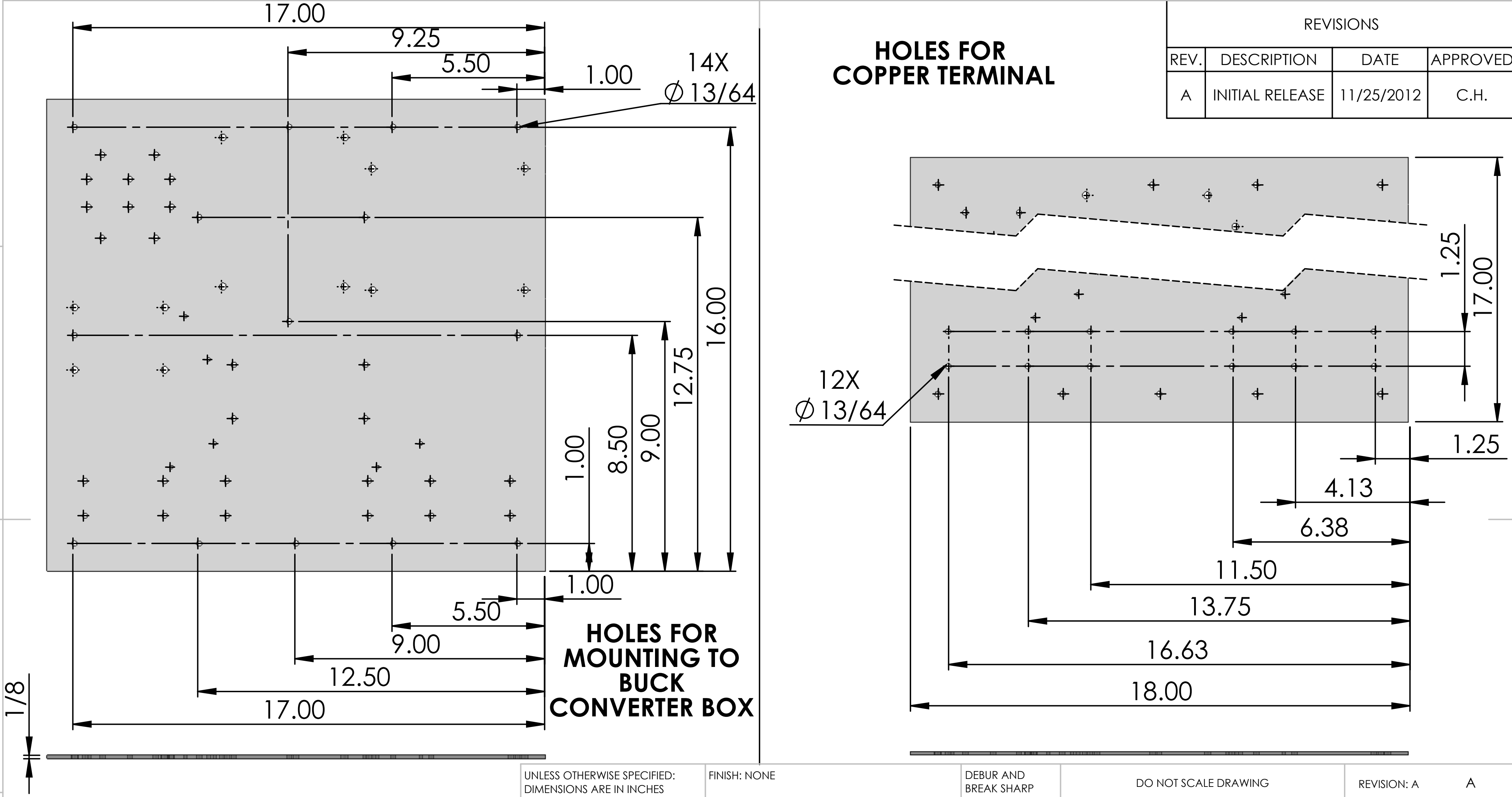
DWG NO. ABC2001-3500W-28V

A4

SCALE: 1:3

SHEET 3 OF 3

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	INITIAL RELEASE	11/25/2012	C.H.



NOTES:
1. DIMENSIONS ARE SPLIT TO AVOID CONFUSION WITH OVERLAPPING DIMENSIONS.
2. FRONT VIEW ARE SHOWN FOR REFERENCE. TOP VIEW OF BOARD CONSISTS SIGNIFICANT DIMENSIONS.
3. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: ASME Y14.5M-1994
LINEAR:
ANGULAR:

FINISH: NONE

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL: ACRYLIC

WEIGHT: APPROX 1.5LBS (.68KG)

TITLE:

ACRYLIC BOARD

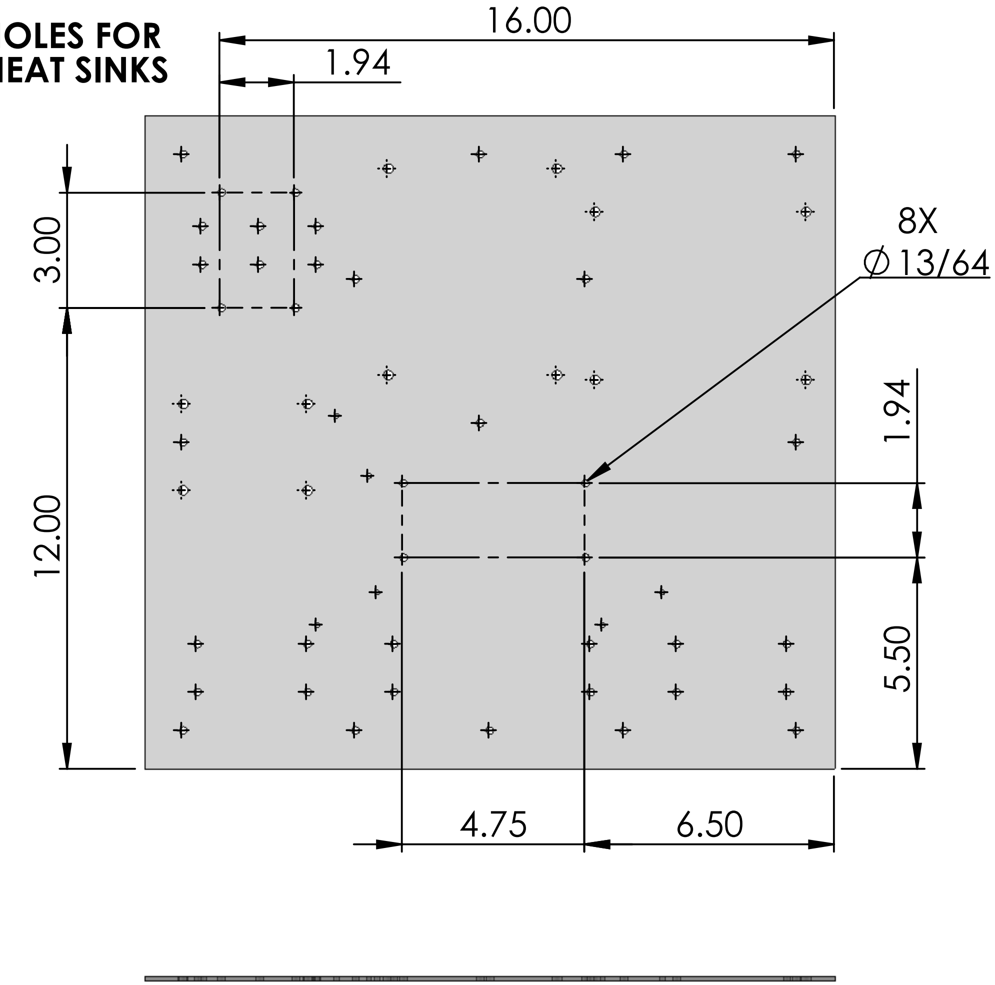
DWG NO. AB18X17X125

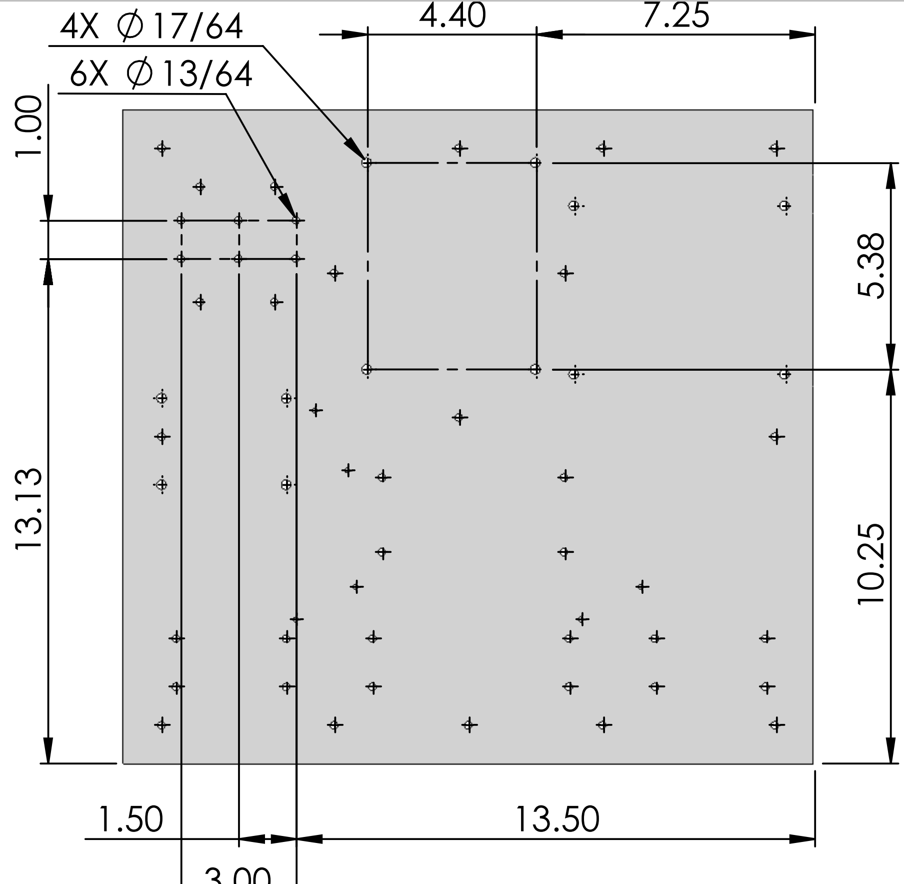
A4

SCALE: 1:5

SHEET 1 OF 3

HOLES FOR HEAT SINKS





HOLES FOR IGBT TERMINALS AND FOR INDUCTOR

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SURFACE FINISH:
TOLERANCES: ASME Y14.5M-1994
LINEAR:
ANGULAR:

FINISH: NONE

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL: ACRYLIC

WEIGHT: APPROX 1.5LBS (.68KG)

TITLE:

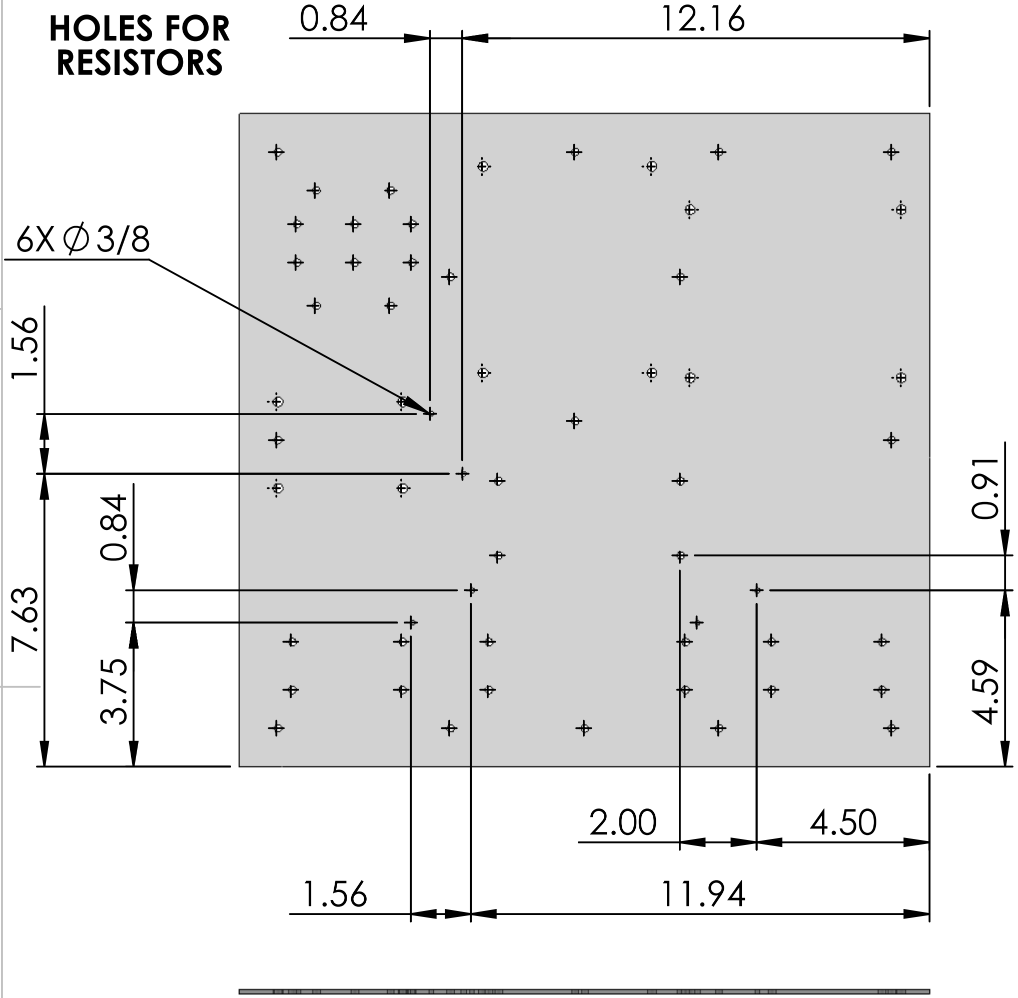
ACRYLIC BOARD

DWG NO. AB18X17X125

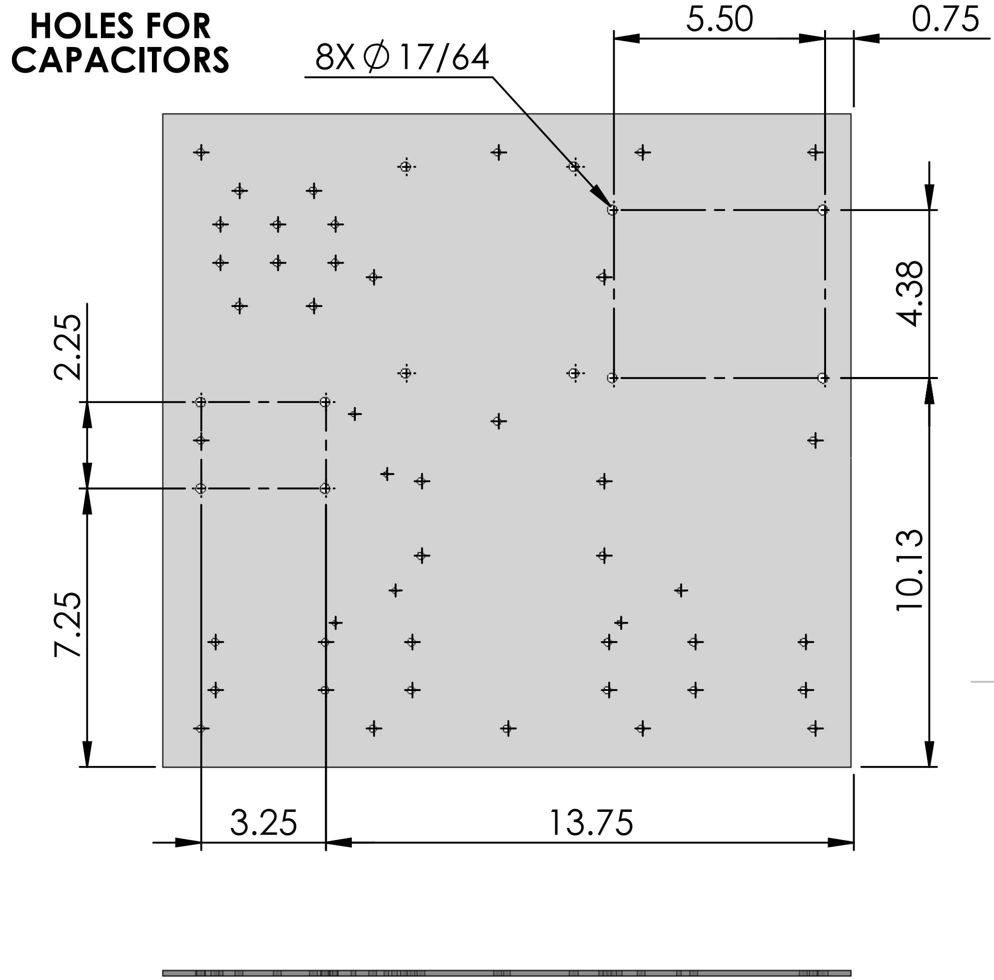
A4

SCALE: 1:5

HOLES FOR RESISTORS



HOLES FOR CAPACITORS



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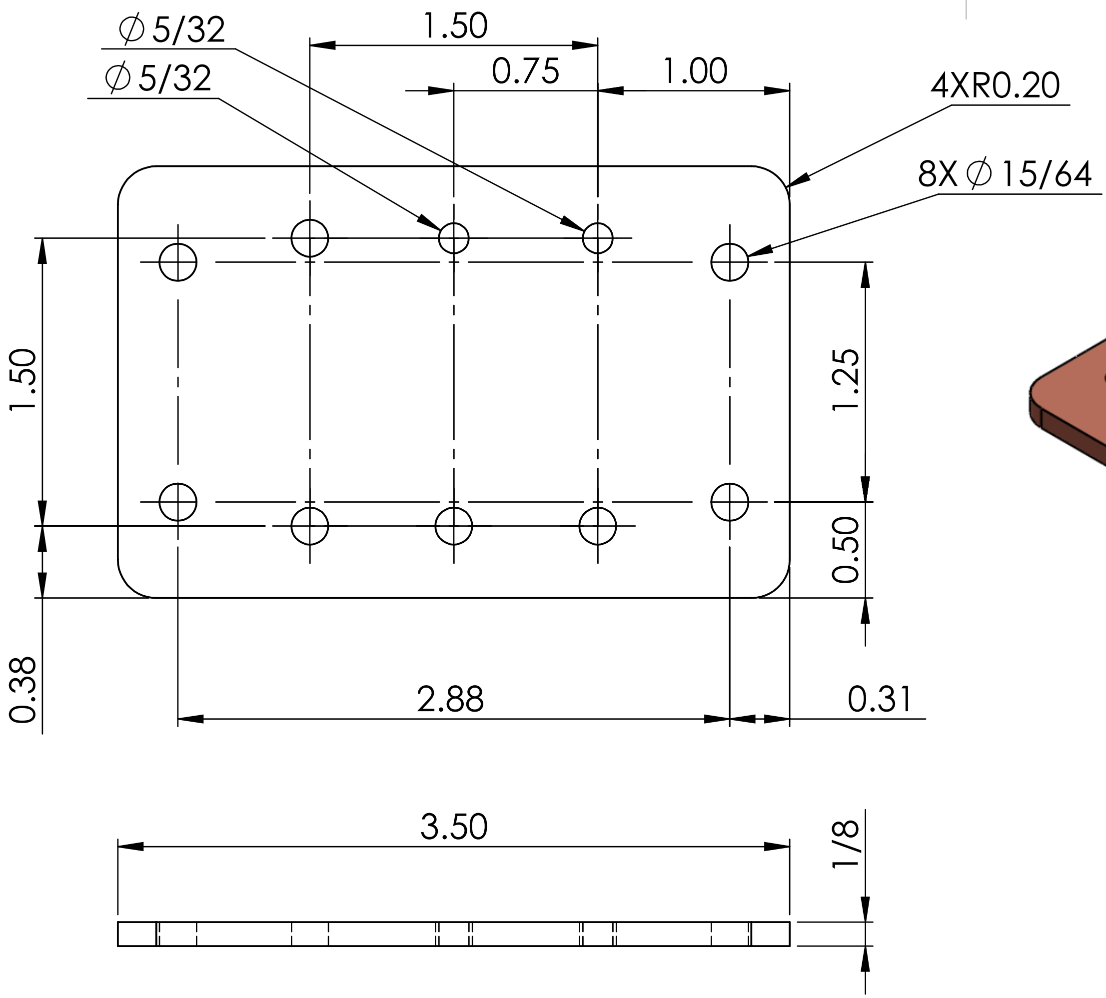
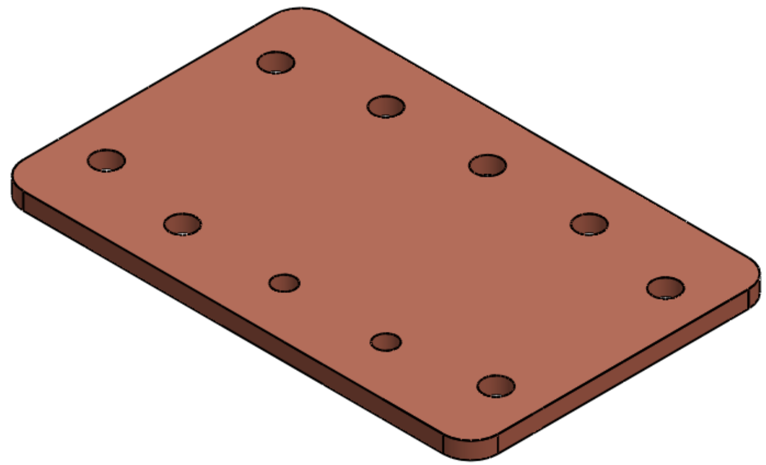
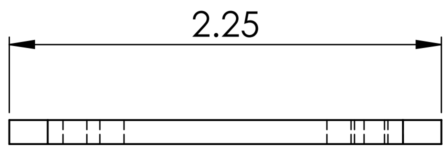
	NAME	SIGNATURE	DATE	TITLE:	
DRAWN	CESAR HURTADO	C.H.	9/30/12	ACRYLIC BOARD	
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12		
APPV'D	AARON STEINKRAUS	A.S.	9/30/12		
MFG					
Q.A			MATERIAL: ACRYLIC	DWG NO. AB18X17X125	A4
			WEIGHT: APPROX 1.5LBS (.68 KG)	SCALE: 1:5	SHEET 3 OF 3

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	APPROVED FOR RELEASE	11/25/2012	C.H.







NOTES:
1. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

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	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL: COPPER

WEIGHT: APPROX .31LBS (.14KG)

TITLE:

INPUT TERMINAL

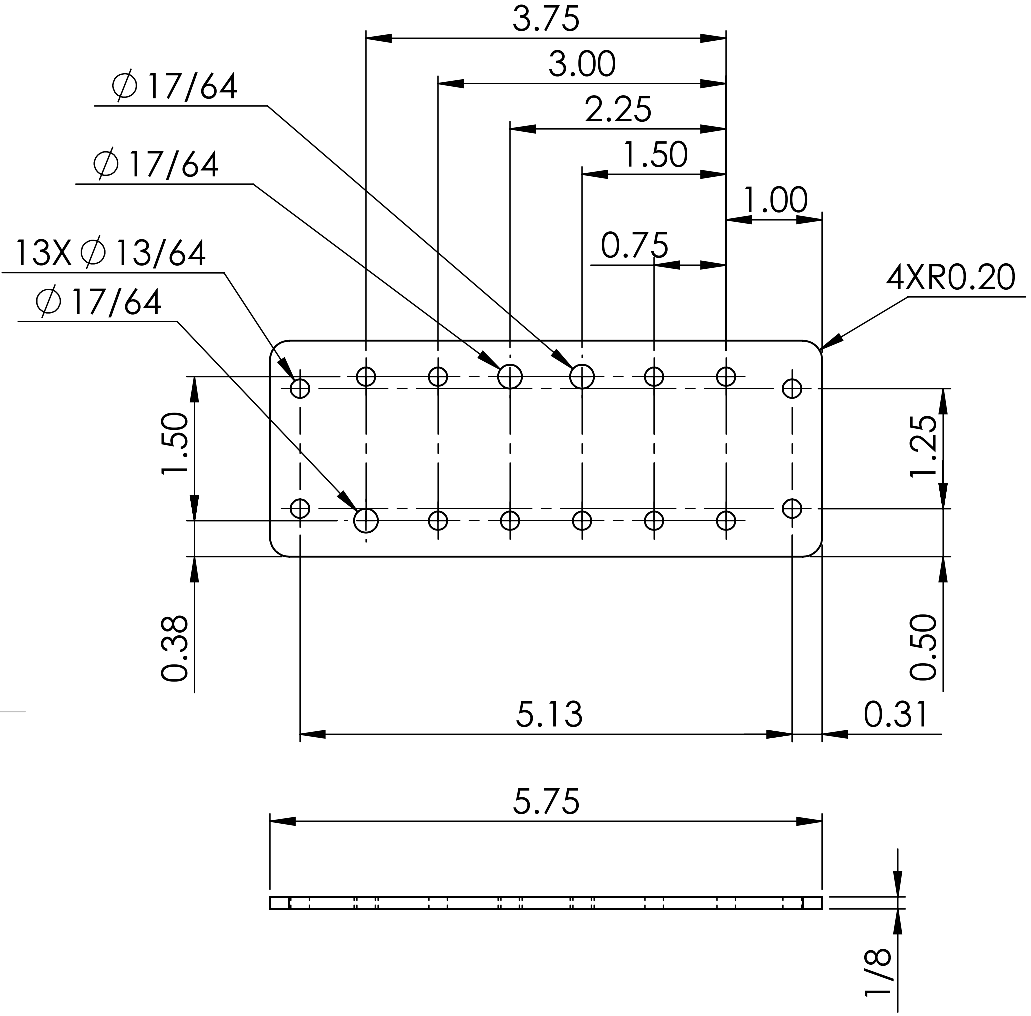
DWG NO. ABC1003-CU1

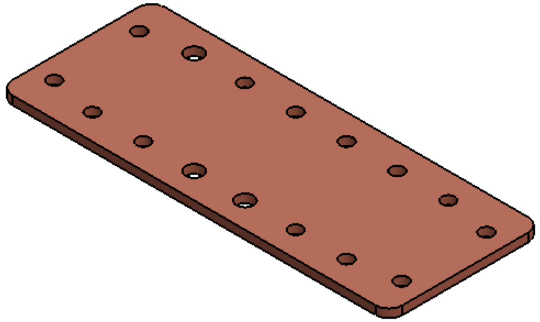
A4

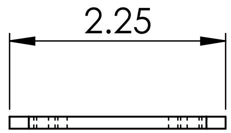
SCALE: 1:1

SHEET 1 OF 1

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	APPROVED FOR RELEASE	11/25/2012	C.H.







NOTES:
1. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

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	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL: COPPER

WEIGHT: APPROX .51LBS (.23KG)

TITLE:

CENTER TERMINAL

DWG NO. ABC1003-CU2

A4

SCALE: 1:2

SHEET 1 OF 1

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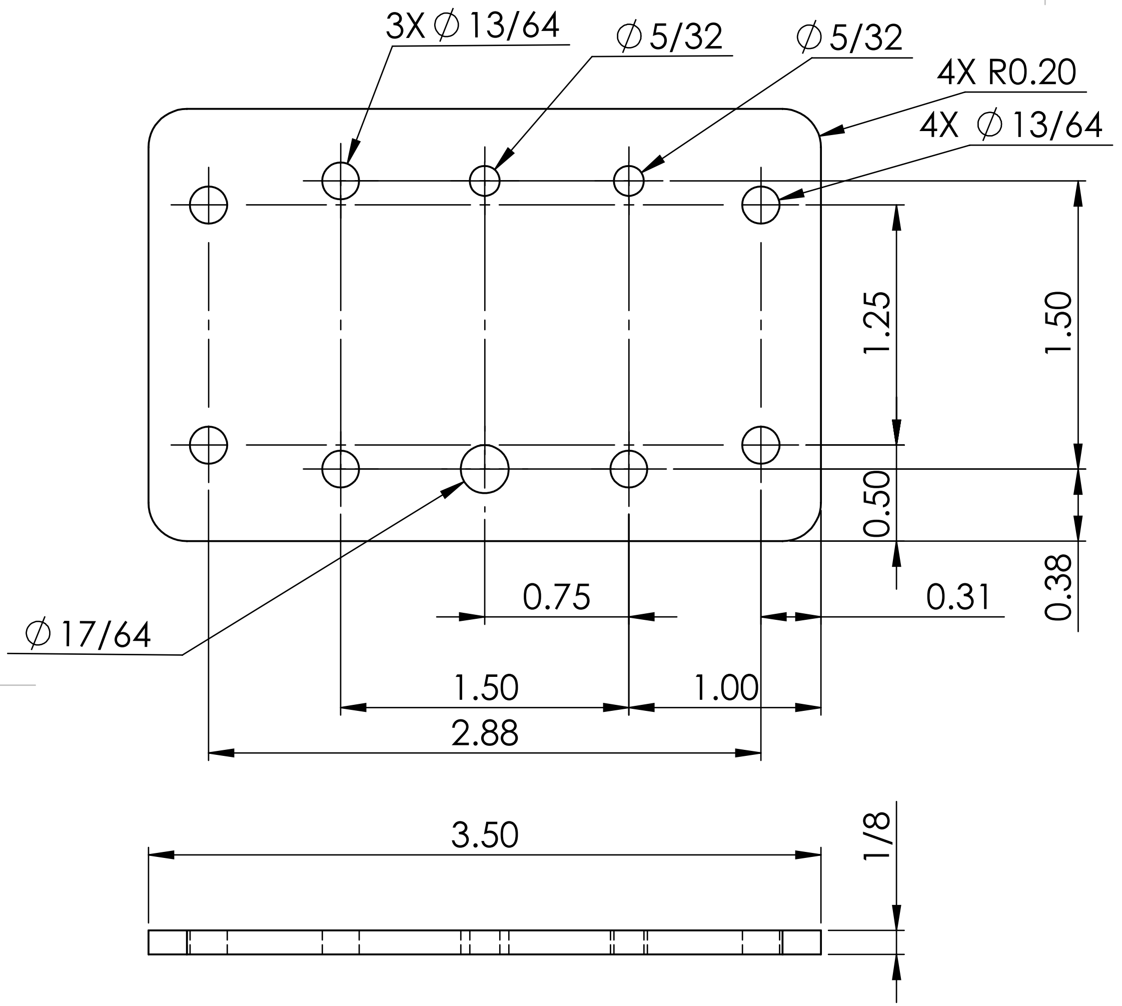
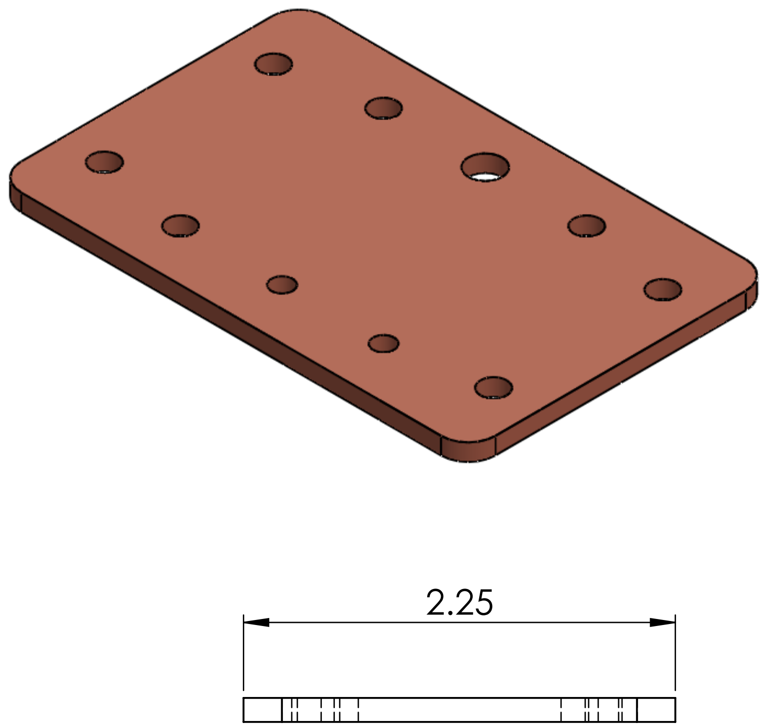


REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	APPROVED FOR RELEASE	11/25/12	C.H.



NOTES:
1. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

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SURFACE FINISH:
TOLERANCES: ASME Y14.5M-1994
LINEAR:
ANGULAR:

FINISH: POLISHED

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL: COPPER

WEIGHT: APPROX .315LBS (.14KG)

TITLE:

OUTPUT TERMINAL

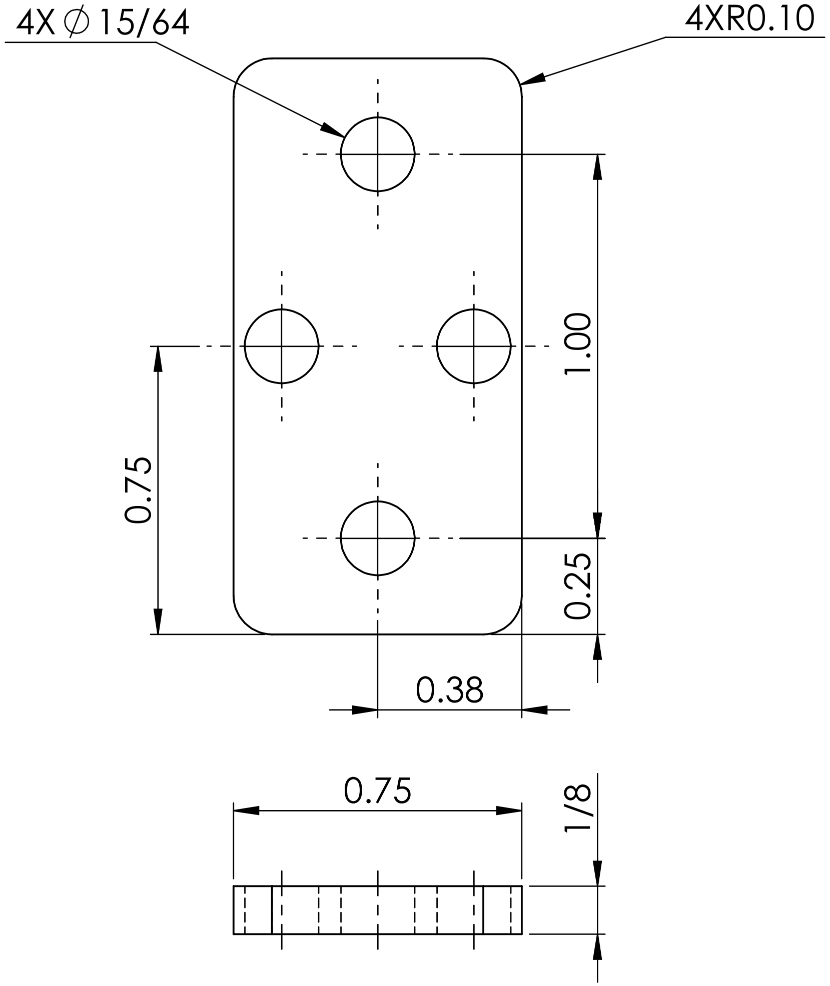
DWG NO. ABC1003-CU3

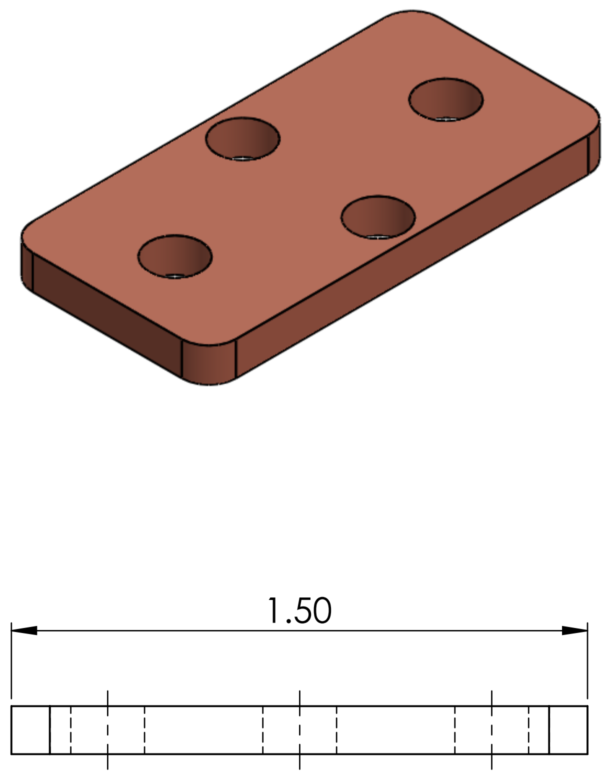
A4

SCALE: 1:1

SHEET 1 OF 1

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	APPROVED FOR RELEASE	11/25/12	C.H.





NOTES:
1. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: ASME Y14.5M-1994
LINEAR:
ANGULAR:

FINISH: POLISHED

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

TITLE:

IGBT TERMINAL

MATERIAL: COPPER

DWG NO. ABC1003-CU4

A4

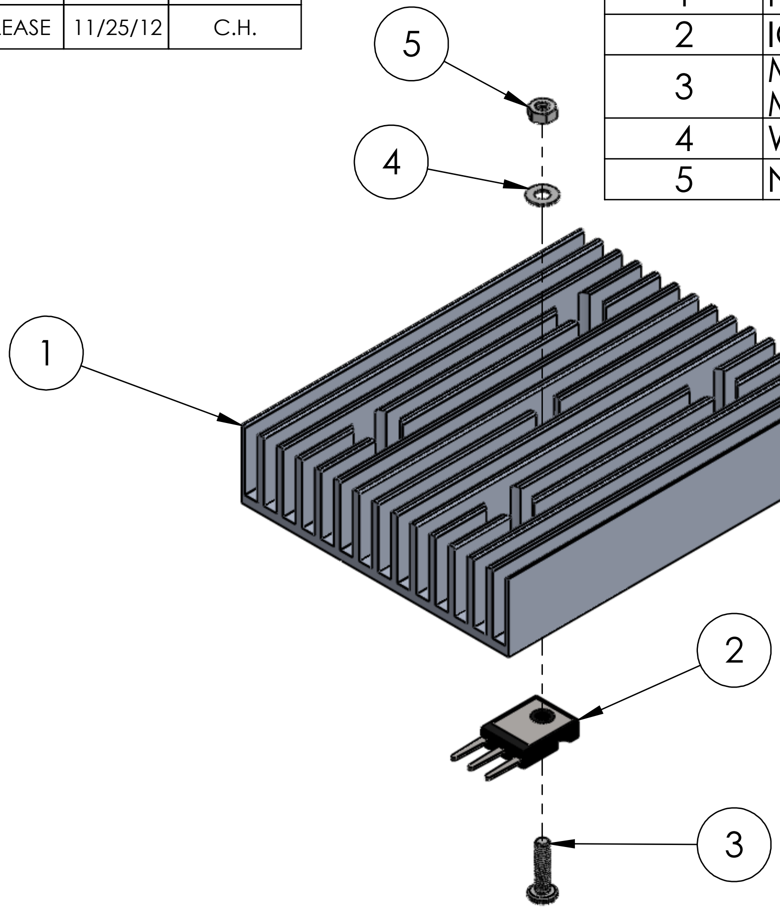
WEIGHT: APPROX .04LBS (.02KG)

SCALE: 2:1

SHEET 1 OF 1

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	APPROVED FOR RELEASE	11/25/12	C.H.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	HEAT SINK FOR IGBT	ALUM, 5X4X1"	1
2	IGBT IRG4PF50W	IR IRG4PF50W, 900VCES, 51IC	1
3	MACHINE SCREW M4X16MM L	SS, PHILIPS, M4X16MM LONG	1
4	WASHER M4	SS, M4	1
5	NUT M4	SS, HEX, M4	1



NOTES:
1. HOLES FOR M4 SCREW IS DRILLED WITH 11/64 DIAMETER.
2. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: ASME Y14.5M-1994
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL:

WEIGHT: APPROX 1.0LBS (.45KG)

TITLE:

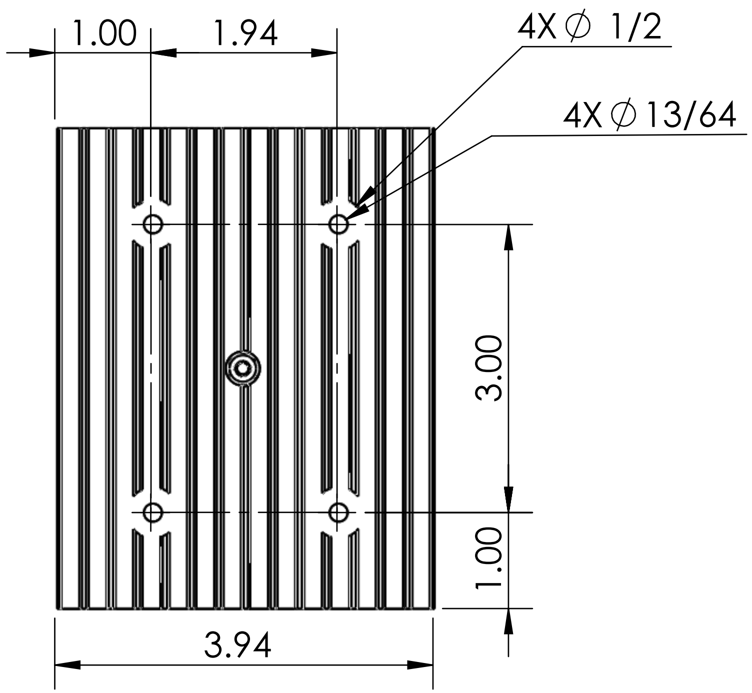
IGBT AND HEAT SINK ASSY

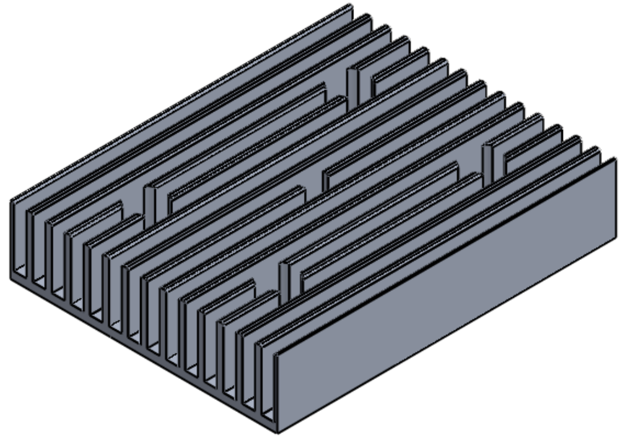
DWG NO. ABC1006-IGBT

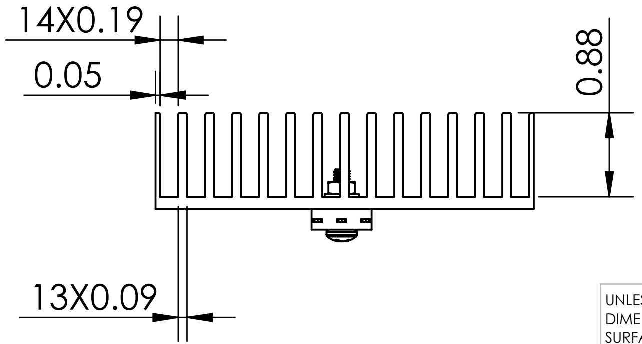
A4

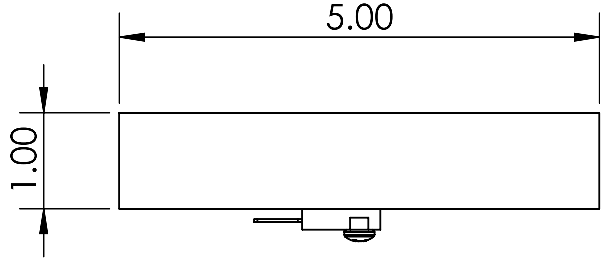
SCALE: 1:2

SHEET 1 OF 2



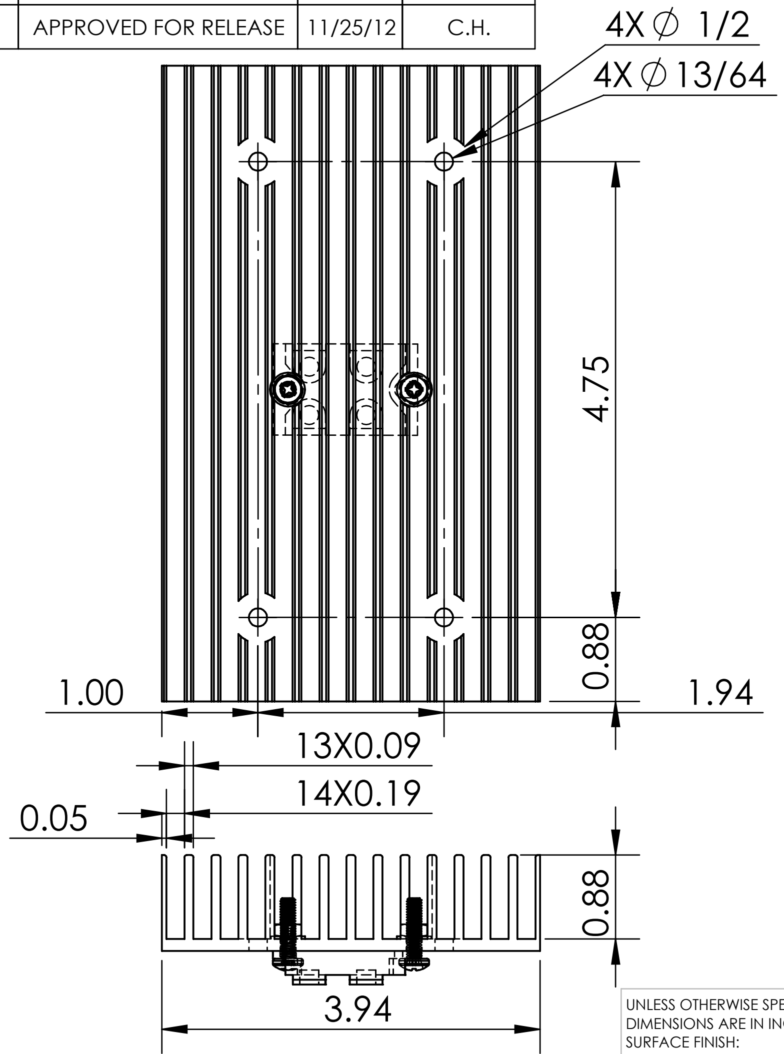


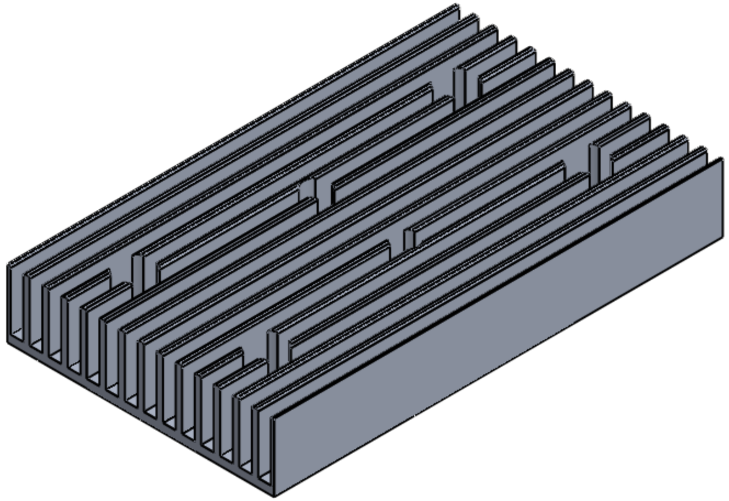


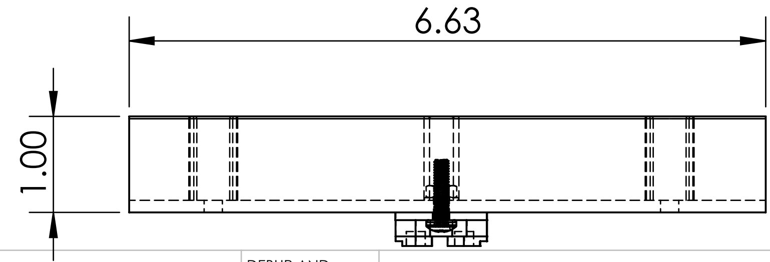


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: TOLERANCES: ASME Y14.5M-1994 LINEAR: ANGULAR:			FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING — REVISION: A
	NAME	SIGNATURE	DATE			TITLE:
DRAWN	CESAR HURTADO	C.H.	9/30/12			IGBT AND HEAT SINK ASSY
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12			
APPV'D	AARON STEINKRAUS	A.S.	9/30/12			
MFG						
Q.A				MATERIAL:		DWG NO. ABC1006-IGBT — A4
				WEIGHT: APPROX 1.0LBS (.45KG)		SCALE: 1:2 — SHEET 2 OF 2

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
A	APPROVED FOR RELEASE	11/25/12	C.H.







NOTES:
1. HOLES FOR M4 SCREWS ARE DRILLED WITH 11/64 DIAMETER.
2. DIMENSIONS AND TOLERANCES ARE IN ACCORDANCE WITH ASME Y14.5M-1994

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: TOLERANCES: ASME Y14.5M-1994 LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION: A

	NAME	SIGNATURE	DATE
DRAWN	CESAR HURTADO	C.H.	9/30/12
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12
APPV'D	AARON STEINKRAUS	A.S.	9/30/12
MFG			
Q.A			

MATERIAL:

WEIGHT: APPROX 1.0LBS (.45KG)

TITLE:

DIODE AND HEAT SINK ASSY

DWG NO.

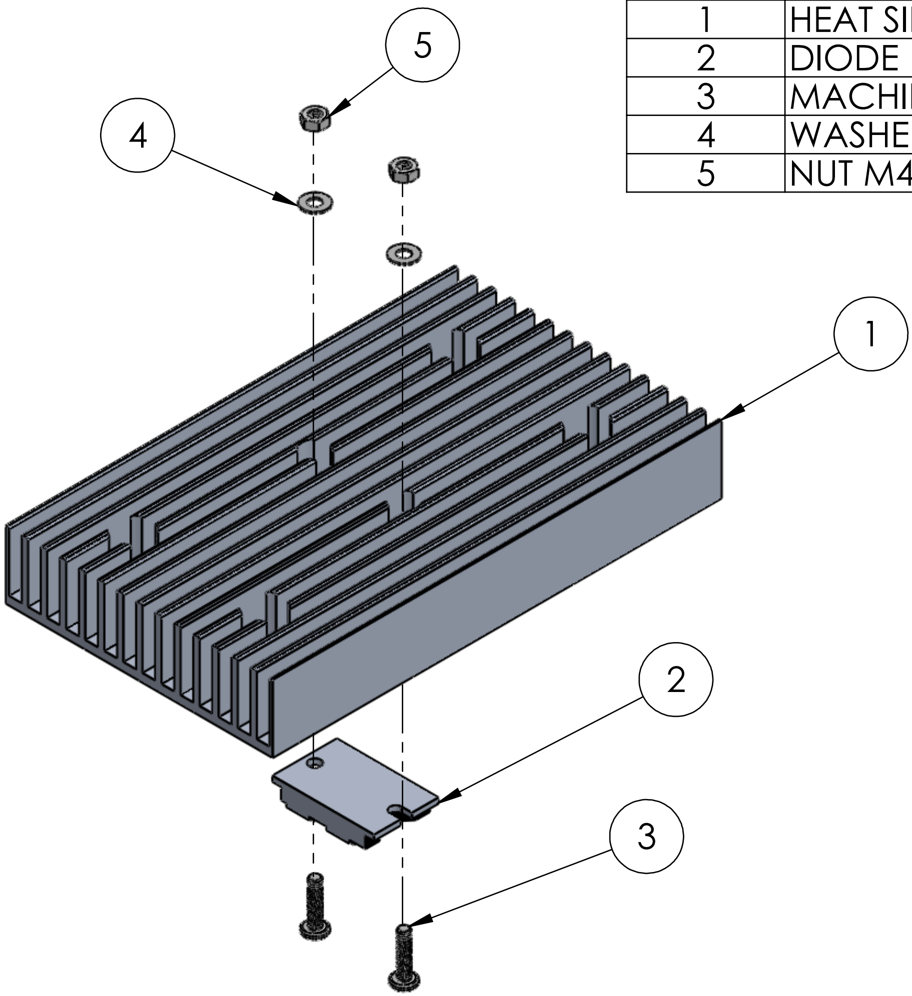
ABC1005-DIODE

A4

SCALE: 1:2

SHEET 1 OF 2

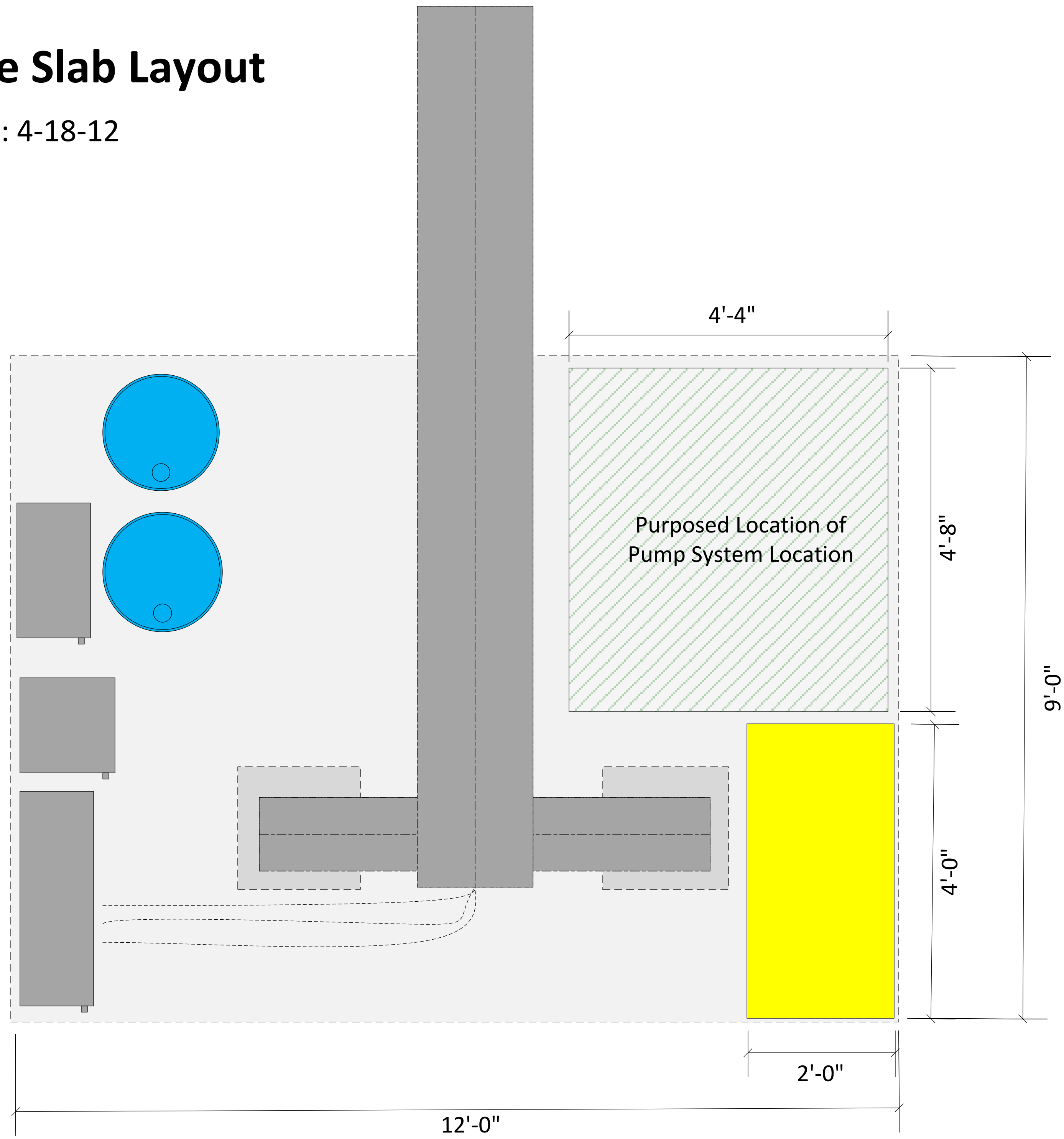
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	HEAT SINK FOR DIODE	ALUM, 6-5/8X4X1"	1
2	DIODE	FAST RECOVERY, STTH200L06TV	1
3	MACHINE SCREW M4X16MM L	SS, PHILIPS, M4X16MM LONG	2
4	WASHER M4	SS, M4	2
5	NUT M4	SS, HEX, M4	2



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: TOLERANCES: ASME Y14.5M-1994 LINEAR: ANGULAR:	FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION: A
	NAME	SIGNATURE	DATE		TITLE:	
DRAWN	CESAR HURTADO	C.H.	9/30/12		DIODE AND HEAT SINK ASSY	
CHK'D	BRIAN HUNTZIKER	B.H.	9/30/12			
APPV'D	AARON STEINKRAUS	A.S.	9/30/12			
MFG						
Q.A				MATERIAL:	DWG NO. ABC1005-DIODE	A4
				WEIGHT: APPROX 1.0LBS (.45KG)	SCALE: 1:2	SHEET 2 OF 2

Wind Turbine Slab Layout

Created: 4-18-12



Appendix C:

List of Vendor Contact Info

Appendix C

List of Vendors

General

Home Depot
1551 Froom Ranch Rd.
San Luis Obispo, CA 93405
Phone: (805) 596-0857
http://www.homedepot.com

Miner's Ace Hardware
2034 Santa Barbara Ave.
San Luis Obispo, CA 93401
Phone: (805) 543-2191
http://minershardware.com

McCarthy Steel
313 South Street
San Luis Obispo, CA 93401
Phone: (805) 543-1760

Pump

Solar Conduit
1840 Grandstand Dr.
San Antonio, TX 78231
Toll-Free: (888) 388-8808
https://solarconduit.com/shop

Dry Run Switch

Northern Arizona Wind & Sun Inc.
4091 E Huntington Drive
Flagstaff, AZ 86004
Toll-Free: (800) 383-0195
http://www.solar-electric.com

Filter

altE Store
43 Broad Street, Suite A408
Hudson, MA 01749
Toll-Free: (877) 878-4060
http://www.altestore.com/store/

IGBT

Newark Element 14
P.O. Box 94151
Palatine, IL 60094
Toll-Free: (800) 463-9275
http://www.newark.com/jsp/home/homepage.jsp

Output Capacitor

onlinecomponents.com
11125 S. Eastern Ave. Ste 120
Henderson, NV 89052
Phone: (702) 462-7300
http://www.onlinecomponents.com/#

Inductor, Diode, Input Capacitor

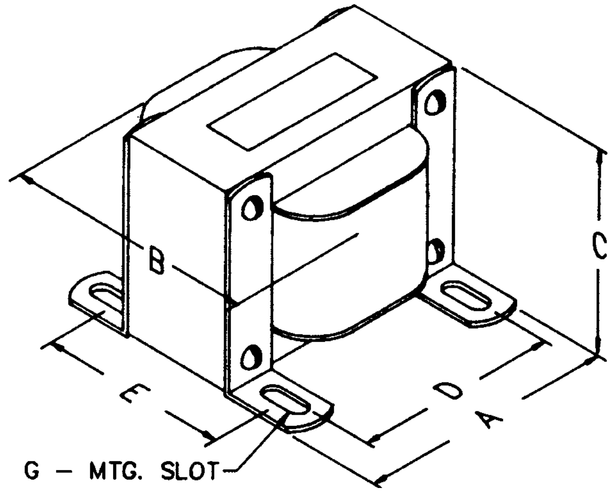
Digi-Key
webmaster@digikey.com
701 Brooks Avenue South
Thief River Falls, MN 56701
Toll-Free: (800) 344-4539
http://www.digikey.com/

Appendix D:

Vendor Supplied Component Specifications

and Data Sheets

D.C. Reactors (195 Series)



HEAVY CURRENT REACTORS

- Open core & coil, 4-slot bracket mounting chokes.
- Tolerance of 15% on both inductance & resistance.
- Inductances measured at rated D.C. current.
- Connections are made to a screw terminal or heavy copper tabs with holes
- Perfect for high current power supply filtering.

Part No.	Inductance (Millihenries)	D.C. Current (Amps)	Resistance (Ohms)	Insula-tion Class	Dimensions (Inches)						Wt. Lbs.
					A	B	C	D	E	Mtg. - Slot (G)	
195B150	0.5	150	.0018	B	5.25	5.50	4.47	4.38	4.13	.28 x .56	26
195C20	1.0	20	.013	A	3.00	3.06	2.50	2.50	2.25	.20 x .38	3
195C30	1.0	30	.009	A	3.75	3.85	3.13	3.13	2.50	.20 x .38	6
195C50	1.0	50	.005	A	4.50	5.25	3.75	3.75	3.50	.20 x .38	14.5
195C75	1.0	75	.004	A	5.25	6.00	4.47	4.38	4.63	.28 x .56	23
195C100	1.0	100	.0036	B	5.25	6.50	4.47	4.38	5.13	.28 x .56	26
195E20	2.5	20	.022	A	3.75	4.20	3.13	3.13	2.75	.20 x .38	6.5
195E30	2.5	30	.013	A	4.50	5.25	3.75	3.75	3.50	.20 x .38	12.5
195E50	2.5	50	.008	A	5.25	6.00	4.47	4.38	4.63	.28 x .56	23.5
195E75	2.5	75	.008	B	6.00	6.63	5.16	5.00	4.88	.28 x .56	32.5
195E100	2.5	100	.006	B	9.00	9.75	7.50	7.00	6.00	.44 x .75	88
195G10	5	10	.040	A	3.75	3.60	3.13	3.13	2.25	.20 x .38	5.5
195G20	5	20	.025	A	4.50	4.75	3.75	3.75	3.00	.20 x .38	10.5
195G30	5	30	.023	A	5.25	5.00	4.47	4.38	3.63	.28 x .56	16
195G50	5	50	.021	B	7.50	6.50	6.25	6.00	4.50	.38 x .63	38
195G75	5	75	.01	B	9.00	9.50	7.76	7.00	7.00	.44 x .75	87
195J10	10	10	.07	A	3.75	4.35	3.13	3.13	3.00	.20 x .38	8
195J20	10	20	.045	A	5.25	5.00	4.47	4.38	3.63	.28 x .56	17.5
195J30	10	30	.037	A	6.00	7.50	5.00	5.00	5.88	.31 x .50	36
195J50	10	50	.023	B	9.00	9.75	7.50	7.00	6.25	.44 x .75	79
195M10	20	10	.013	A	4.50	4.75	3.75	3.75	3.00	.20 x .38	10.2
195M20	20	20	.075	A	6.00	7.50	5.00	5.00	5.88	.31 x .50	34
195M30	20	30	.045	B	6.00	7.63	5.16	5.00	5.88	.28 x .56	41
195P5	30	5	.23	A	3.75	4.20	3.13	3.13	2.75	.20 x .38	6.5
195P10	30	10	.17	A	4.50	5.25	3.75	3.75	3.50	.20 x .38	16
195P20	30	20	.13	B	5.25	6.91	4.47	4.38	5.54	.28 x .56	28
195R10	50	10	.165	A	5.25	5.50	4.47	4.38	4.13	.28 x .56	26
195R20	50	20	.13	B	9.00	8.25	7.50	7.00	5.75	.44 x .75	72
195T5	100	5	.64	A	4.50	5.25	3.75	3.75	3.50	.20 x .38	14
195T10	100	10	.42	B	7.50	6.00	6.25	6.00	4.25	.38 x .63	35

CANADA
Guelph, Ontario (519) 822-2960
St. Laurent, Quebec (514) 343-9010
USA
Cheektowaga, NY (716) 630-7030

www.hammondmfg.com

EUROPE
Basingstoke, UK 01256 812812
AUSTRALIA
Queenstown, Australia 61-8-8240-2244

Aluminum Capacitors
Power Long Life 4-Terminal Snap-In

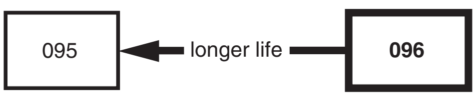


Fig. 1

QUICK REFERENCE DATA	
DESCRIPTION	**VALUE**
Nominal case size (D x L in mm)	35 x 50 to 45 x 100
Rated capacitance range C_R	390 µF to 2700 µF
Tolerance on C_R	± 20 %
Rated voltage range, U_R	350 V to 500 V
Category temperature range	- 40 °C to + 85 °C
Endurance test at 85 °C	2000 h
Useful life at 85 °C	5000 h
Useful life at 40 °C, 1.4 x I_R applied	200 000 h
Shelf life at 0 V, 85 °C	1000 h
Based on sectional specification	IEC 60384-4/EN130300
Climatic category IEC 60068	40/085/56

FEATURES

- Polarized aluminum electrolytic capacitors, non-solid electrolyte
- Large types, minimized dimensions, cylindrical aluminum case, insulated with a blue sleeve
- Pressure relief on the side of the aluminum case
- Very long useful life: 5000 h at 85 °C
- Temperature range up to 85 °C
- Keyed polarity
- Low ESR, high ripple current capability
- Compliant to RoHS Directive 2002/95/EC

Pb-free

RoHS COMPLIANT

APPLICATIONS

- Telecommunication and industrial systems
- Smoothing and filtering applications
- Switched mode power supplies
- Renewable energy power converters
- Energy storage in pulse systems
- For excellent mounting stability

MARKING

The capacitors are marked (where possible) with the following information:

- Rated capacitance (in µF)
- Tolerance code on rated capacitance, code letter in accordance with IEC 60062 (M for ± 20 %)
- Rated voltage (in V)
- Date code (YYMM)
- Name of manufacturer
- Code for factory of origin
- "-" sign to identify the negative terminal, visible from the top and side of the capacitor
- Code number
- Climatic category in accordance with IEC 60068

SELECTION CHART FOR C_R, U_R, AND RELEVANT NOMINAL CASE SIZES (Ø D x L in mm)

C_R (µF)	U_R (V)					
	350	**385**	**400**	**420**	**450**	**500**
390	-	-	-	-	-	35 x 60
470	-	-	-	-	-	35 x 70
560	-	-	-	-	35 x 60	35 x 70 40 x 60
680	-	35 x 50 40 x 50	35 x 60 40 x 50	35 x 60 40 x 50	35 x 70 40 x 50	35 x 80 40 x 70
820	35 x 50 40 x 40	35 x 60 40 x 50	35 x 60 40 x 50	35 x 70 40 x 60	35 x 80 40 x 60	35 x 100 40 x 80
1000	35 x 60 40 x 50	35 x 70 40 x 60	35 x 70 40 x 60 45 x 50	35 x 80 40 x 60	35 x 100 40 x 70 45 x 60	40 x 100 45 x 70
1200	35 x 70 40 x 60	35 x 80 40 x 70	35 x 80 40 x 70 45 x 60	40 x 70	40 x 80 45 x 70	45 x 100
1500	35 x 80 40 x 70 45 x 60	40 x 80 45 x 60	35 x 100 40 x 80 45 x 70	40 x 100 45 x 70	40 x 100 45 x 80	45 x 100
1800	40 x 80 45 x 60	40 x 100 45 x 70	40 x 100 45 x 80	40 x 100 45 x 80	45 x 100	-
2200	40 x 100 45 x 70	40 x 100	45 x 100	45 x 100	-	-
2700	45 x 100	45 x 100	45 x 100	-	-	-

DIMENSIONS in millimeters **AND AVAILABLE FORMS**

PRINTED WIRING

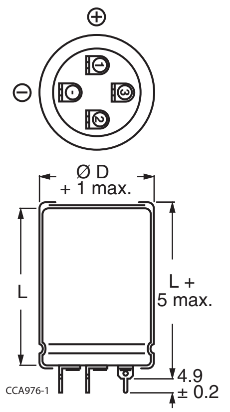


Fig. 2 - Printed wiring pin version
(Case Ø D = 35 mm)

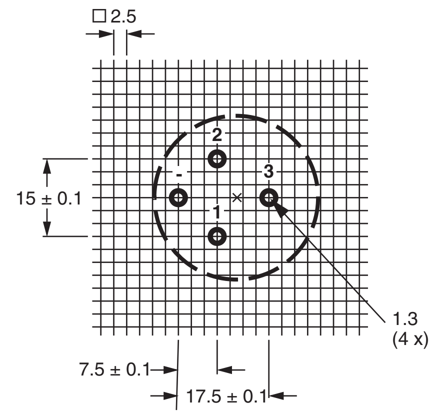


Fig. 3 - Mounting hole diagram viewed from component side
(Case Ø D = 35 mm)

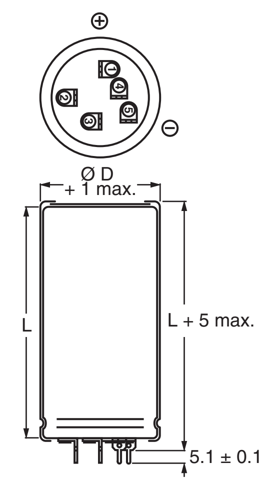


Fig. 4 - Printed wiring pin version
(Case Ø D = 40 mm)

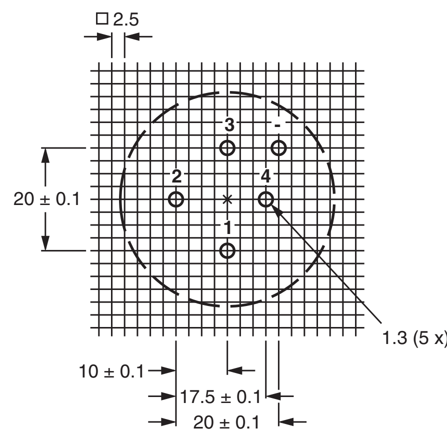


Fig. 5 - Mounting hole diagram viewed from component side
(Case Ø D = 40 mm)

FOUR TERMINAL SNAP-IN

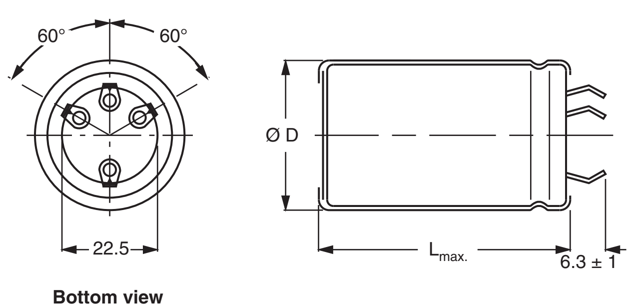
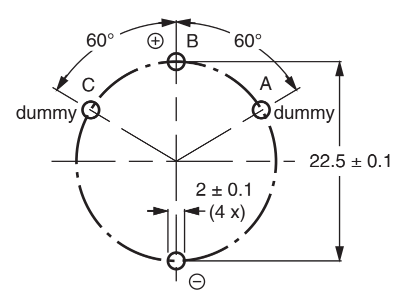


Fig. 6 - 4-Terminal snap-in



Dummy terminals (A and C) must be free from the electrical circuit

Fig. 7 - Mounting hole diagram

Pin numbers 2, 3 and 4 (if present) should be free from the electrical circuit or connected to the minus terminal.

Table 1

DIMENSIONS in millimeters, **MASS AND PACKAGING QUANTITIES**						
NOMINAL CASE SIZE Ø D x L	**Ø $D_{MAX.}$**	**4T-SI $L_{max.}$**	**PW L + 5**	**MASS (g)**	**PACKAGING QUANTITIES (units per box)**	**CARDBOARD BOX DIMENSIONS L x W x H**
35 x 50	36	52	55	72	50	390 x 198 x 60
35 x 60	36	62	65	91	50	390 x 198 x 70
35 x 70	36	72	75	103	50	377 x 375 x 97
35 x 80	36	82	85	115	50	377 x 375 x 107
35 x 100	36	102	105	151	50	377 x 375 x 127
40 x 40	41	42	45	70	50	440 x 223 x 60
40 x 50	41	52	55	94	50	440 x 223 x 70
40 x 60	41	62	65	118	25	230 x 230 x 80
40 x 70	41	72	75	134	25	230 x 230 x 90
40 x 80	41	82	85	150	25	230 x 230 x 100
40 x 100	41	102	105	176	25	230 x 230 x 120
45 x 40	46	42	-	88	36	TBD
45 x 50	46	52	-	119	36	377 x 375 x 77
45 x 60	46	62	-	150	36	377 x 375 x 87
45 x 70	46	72	-	170	36	377 x 375 x 97
45 x 80	46	82	-	190	36	377 x 375 x 107
45 x 100	46	102	-	250	36	377 x 375 x 127

ELECTRICAL DATA	
SYMBOL	**DESCRIPTION**
C_R	Rated capacitance at 100 Hz
I_R	Rated RMS ripple current at 100 Hz and 85 °C
I_{L5}	Max. leakage current after 5 min at U_R
ESR	Max. equivalent series resistance at 100 Hz
Z	Max. impedance at 10 kHz

Note

- Unless otherwise specified, all electrical values in Table 2 apply at T_{amb} = 20 °C, P = 86 kPa to 106 kPa, RH = 45 % to 75 %

ORDERING EXAMPLE

Electrolytic capacitor 096 series

820 µF/385 V;

Printed wiring:

Ordering code: MAL2 096 18821 E3
Former 12NC: 2222 096 18821

4-terminal snap-in:

Ordering code: MAL2 096 68821 E3
Former 12NC: 2222 096 68821

Table 2

ELECTRICAL DATA AND ORDERING INFORMATION								
U_R (V)	**C_R 100 Hz (µF)**	**NOMINAL CASE SIZE Ø D x L (mm)**	**I_R 100 Hz 85 °C (A)**	**I_{L5} 5 min (µA)**	**ESR 100 Hz (mΩ)**	**$Z_{max.}$ 10 kHz (mΩ)**	**CATALOG NUMBER MAL2096.......**	
							4T-SI	**PW**
350	820	35 x 50	4.0	578	126	82	15821E3	65821E3
	820	40 x 40	3.8	578	134	90	25821E3	75821E3
	1000	35 x 60	4.7	704	104	67	15102E3	65102E3
	1000	40 x 50	4.8	704	108	72	25102E3	75102E3
	1200	35 x 70	5.3	844	87	57	15122E3	65122E3
	1200	40 x 60	5.4	844	90	59	25122E3	75122E3
	1500	35 x 80	6.0	1054	71	47	15152E3	65152E3
	1500	40 x 70	6.2	1054	73	49	25152E3	75152E3
	1500	45 x 60	6.3	1054	76	52	35152E3	-
	1800	40 x 80	6.9	1264	62	41	25182E3	75182E3
	1800	45 x 60	6.6	1264	68	48	35182E3	-
	2200	40 x 100	8.2	1544	51	34	25222E3	75222E3
	2200	45 x 70	7.4	1544	57	41	35222E3	-
	2700	45 x 100	9.2	1894	44	30	35272E3	-

ELECTRICAL DATA AND ORDERING INFORMATION								
U_R (V)	C_R 100 Hz (µF)	NOMINAL CASE SIZE Ø D x L (mm)	I_R 100 Hz 85 °C (A)	I_{L5} 5 min (µA)	ESR 100 Hz (mΩ)	$Z_{max.}$ 10 kHz (mΩ)	CATALOG NUMBER MAL2096.......	
							4T-SI	PW
385	680	35 x 50	3.7	528	140	88	18681E3	68681E3
	680	40 x 50	4.2	528	140	87	28681E3	78681E3
	820	35 x 60	4.4	635	116	73	18821E3	68821E3
	820	40 x 50	4.5	635	120	76	28821E3	78821E3
	1000	35 x 70	5.0	774	96	60	18102E3	68102E3
	1000	40 x 60	5.1	774	99	63	28102E3	78102E3
	1200	35 x 80	5.5	928	81	51	18122E3	68122E3
	1200	40 x 70	5.7	928	83	53	28122E3	78122E3
	1500	40 x 80	6.5	1159	68	43	28152E3	78152E3
	1500	45 x 60	6.2	1159	74	50	38152E3	-
	1800	40 x 100	7.7	1390	56	36	28182E3	78182E3
	1800	45 x 70	7.0	1390	62	43	38182E3	-
	2200	40 x 100	8.2	1698	49	32	28222E3	78222E3
	2700	45 x 100	9.1	2083	43	29	38272E3	-
400	680	35 x 60	4.1	548	134	82	16681E3	66681E3
	680	40 x 50	4.2	548	138	85	26681E3	76681E3
	820	35 x 60	4.4	660	114	71	16821E3	66821E3
	820	40 x 50	4.5	660	119	75	26821E3	76821E3
	1000	35 x 70	5.0	804	94	59	16102E3	66102E3
	1000	40 x 60	5.1	804	97	62	26102E3	76102E3
	1000	45 x 50	5.1	804	103	67	36102E3	-
	1200	35 x 80	5.5	964	80	50	16122E3	66122E3
	1200	40 x 70	5.7	964	82	52	26122E3	76122E3
	1200	45 x 60	5.9	964	85	55	36122E3	-
	1500	35 x 100	7.1	1204	64	40	16152E3	66152E3
	1500	40 x 80	6.5	1204	67	43	26152E3	76152E3
	1500	45 x 70	6.6	1204	69	46	36152E3	-
	1800	40 x 100	7.7	1444	56	35	26182E3	76182E3
	1800	45 x 80	7.3	1444	59	39	36182E3	-
	2200	45 x 100	8.6	1764	48	32	36222E3	-
	2700	45 x 100	9.1	2164	42	29	36272E3	-
420	680	35 x 60	4.1	575	137	85	14681E3	64681E3
	680	40 x 50	4.2	575	141	89	24681E3	74681E3
	820	35 x 70	4.6	693	114	71	14821E3	64821E3
	820	40 x 60	4.7	693	117	74	24821E3	74821E3
	1000	35 x 80	5.1	844	95	59	14102E3	64102E3
	1000	40 x 60	5.1	844	100	64	24102E3	74102E3
	1200	40 x 70	5.7	1012	84	54	24122E3	74122E3
	1500	40 x 100	7.2	1264	66	42	24152E3	74152E3
	1500	45 x 70	6.6	1264	71	48	34152E3	-
	1800	40 x 100	7.6	1516	57	37	24182E3	74182E3
	1800	45 x 80	7.2	1516	60	40	34182E3	-
	2200	45 x 100	8.5	1852	49	33	34222E3	-

ELECTRICAL DATA AND ORDERING INFORMATION

U_R (V)	C_R 100 Hz (µF)	NOMINAL CASE SIZE Ø D x L (mm)	I_R 100 Hz 85 °C (A)	I_{L5} 5 min (µA)	ESR 100 Hz (mΩ)	$Z_{max.}$ 10 kHz (mΩ)	CATALOG NUMBER MAL2096.......	
							4T-SI	PW
450	560	35 x 60	3.8	508	155	94	17561E3	67561E3
	680	35 x 70	4.2	616	129	78	17681E3	67681E3
	680	40 x 50	4.2	616	136	85	27681E3	77681E3
	820	35 x 80	4.8	742	108	66	17821E3	67821E3
	820	40 x 60	4.7	742	112	70	27821E3	77821E3
	1000	35 x 100	6.0	904	89	54	17102E3	67102E3
	1000	40 x 70	5.3	904	93	58	27102E3	77102E3
	1000	45 x 60	5.5	904	97	62	37102E3	-
	1200	40 x 80	6.0	1084	78	49	27122E3	77122E3
	1200	45 x 70	6.1	1084	81	52	37122E3	-
	1500	40 x 100	7.2	1354	63	39	27152E3	77152E3
	1500	45 x 80	6.8	1354	67	43	37152E3	-
	1800	45 x 100	8.0	1624	55	35	37182E3	-
500	390	35 x 60	2.9	394	475	421	19391E3	69391E3
	470	35 x 70	3.3	474	395	350	19471E3	69471E3
	560	35 x 70	3.6	564	333	296	19561E3	69561E3
	560	40 x 60	3.7	564	336	299	29561E3	79561E3
	680	35 x 80	4.1	684	275	245	19681E3	69681E3
	680	40 x 70	4.2	684	277	247	29681E3	79681E3
	820	35 x 100	5.1	824	229	203	19821E3	69821E3
	820	40 x 80	4.7	824	231	206	29821E3	79821E3
	1000	40 x 100	5.6	1004	189	169	29102E3	79102E3
	1000	45 x 70	5.3	1004	195	176	39102E3	-
	1200	45 x 100	6.4	1204	160	144	39122E3	-
	1500	45 x 100	7.0	1504	131	118	39152E3	-

ADDITIONAL ELECTRICAL DATA

PARAMETER	CONDITIONS	VALUE
Voltage		
Surge voltage	≥ 350 V versions	$U_s = 1.1 \times U_R$
Reverse voltage		$U_{rev} \leq 1$
Current		
Leakage current	After 1 min at U_R	$I_{L1} \leq 0.006\ C_R \times U_R + 4$ µA
	After 5 min at U_R	$I_{L5} \leq 0.002\ C_R \times U_R + 4$ µA
Inductance		
Equivalent series inductance (ESL)	All case sizes	Ca. 20 nH

RIPPLE CURRENT AND USEFUL LIFE

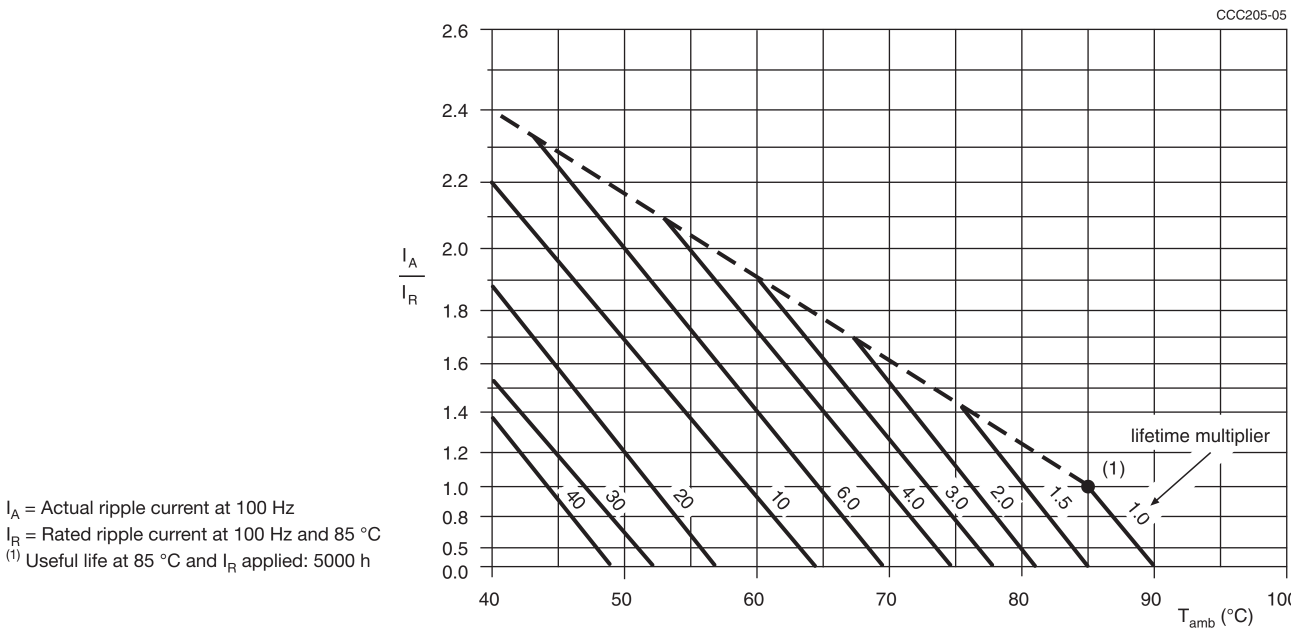


Fig. 8 - Multiplier of useful life as a function of ambient temperature and ripple current load

Table 3

MULTIPLIER OF RIPPLE CURRENT (I_R) AS A FUNCTION OF FREQUENCY	
FREQUENCY (Hz)	**I_R MULTIPLIER**
50	0.9
100	1.0
200	1.2
400	1.3
1000	1.4
10 000	1.5

Table 4

TEST PROCEDURES AND REQUIREMENTS			
TEST		**PROCEDURE (quick reference)**	**REQUIREMENTS**
NAME OF TEST	**REFERENCE**		
Endurance	IEC 60384-4/ EN130300 subclause 4.13	T_{amb} = 85 °C; U_R applied 2000 h	ΔC/C: ± 10 % ESR ≤ 1.3 x spec. limit Z ≤ 2 x spec. limit I_{L5} ≤ spec. limit
Useful life	CECC 30301 subclause 4.13	T_{amb} = 85 °C; U_R and I_R applied; 5000 h	ΔC/C: ± 30 % ESR ≤ 3 x spec. limit Z ≤ 3 x spec. limit I_{L5} ≤ spec. limit no short or open circuit, no visible damage total failure percentage: ≤ 3 %
Shelf life	IEC 60384-4/ EN130300 subclause 4.17	T_{amb} = 85 °C; no voltage applied; 1000 h After test: U_R to be applied for 30 min 24 h to 48 h before measurement	ΔC/C: ± 10 % ESR ≤ 1.2 x spec. limit I_{L5} ≤ 2 x spec. limit

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U32D Series

UNITED CHEMI-CON

■ Large Can
■ Screw Terminals
■ High Ripple
■ 6.3 to 400VDC Voltage Range
■ Dimensions in Inches
■ RoHS Compliant
■ +105°C Maximum Temperature

The U32D series allows for extremely high ripple currents for applications such as inverter designs and motor controllers. This series of capacitors offers very large capacitance of up to 2.2F and a maximum temperature rating of +105°C which allows a high operating temperature without sacrificing life. These capacitors are available with a variety of high current English or Metric thread terminals. Mounting options available are a three-footed clamp or bottom stud. (A special order two-footed clamp is also available for selected diameters.) All case size dimensions are based on inches. Custom designs are available upon request.

Summary of Specifications

- **Screw terminals: high and low post, English and Metric thread.**
- **Capacitance range: 180µF to 2.2F.**
- **Voltage range: 6.3 to 400VDC.**
- **Category temperature range: −40°C to +105°C.**
- **Leakage current: 0.02CV(µA) or 5mA, whichever is smaller, after 5 minutes at +25°C.**
- **Standard capacitance tolerance: ±20%**
- **Nominal case size (D×L): D = 35mm (1.375”) to 89mm (3.500”); L = 41mm (1.625”) to 220mm (8.625”).**
- **Rated lifetime: 2,000 hours at +105°C with rated ripple current applied.**

U32D Specifications - Screw Terminals

Item	Characteristics
Category Temperature Range	−40 to +105°C
Rated Voltage Range	6.3 to 400VDC
Capacitance Range	180µF to 2.2F at +25°C, 120Hz
Capacitance Tolerance	±20% (M) at +25°C, 120Hz
Leakage Current	I = 0.02CV (µA) or 5mA, whichever is smaller, after 5 minutes at +25°C. Where I = Max. leakage current (µA), C = Nominal capacitance (µF) and V = Rated voltage (V)
Rated Ripple Current Multipliers	See tables below
Endurance (Load Life)	The following specifications shall be satisfied when the capacitors are restored to +25°C after subjecting them to DC voltage for 2,000 hours at +105°C with the rated ripple current applied. The sum of the DC voltage and peak AC voltage must not exceed the full rated voltage of the capacitors. Capacitance change: ≤ 20% from initial measurement ESR change : ≤ 200% of initial specified limit Leakage current : ≤ initial specified limit
Shelf Test	The following specifications shall be satisfied when the capacitors are restored to +25°C after exposing them for 500 hours at +105°C without voltage applied. The rated voltage shall be applied to the capacitors for a minimum of 30 minutes, at least 24 hours and not more than 48 hours before the measurements. Capacitance change: ≤ 20% from initial measurement ESR change : ≤ 200% of initial specified limit Leakage current : ≤ initial specified limit

Rated Ripple Current Multipliers

Ambient Temperature (°C)

≤ +45°C	+65°C	+85°C	+105°C
1.41	1.29	1.00	0.57

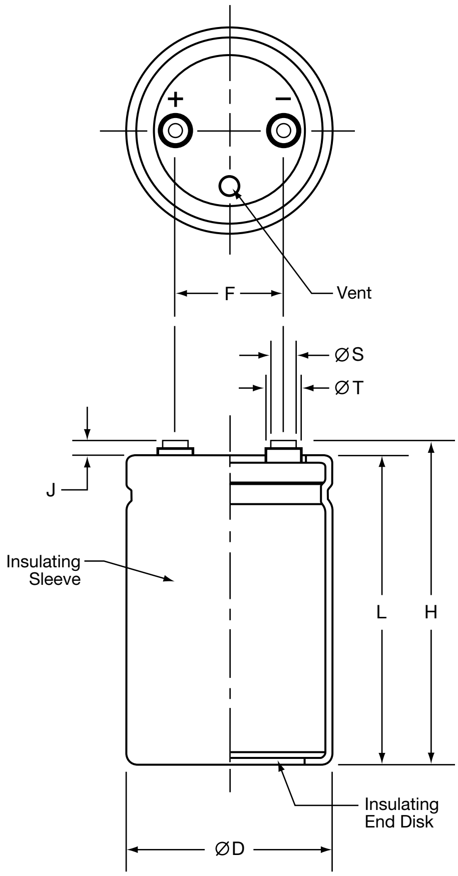
Frequency (Hz)

DC Rated Voltage	Case Diameter	50Hz	120Hz	300Hz	1kHz	10kHz	50kHz
6.3-50V	Ø35-Ø76	0.95	1.00	1.03	1.05	1.09	1.12
63-80V	Ø35	0.90	1.00	1.06	1.10	1.18	1.22
	Ø51-Ø76	0.95	1.00	1.03	1.05	1.09	1.12
100V	Ø35	0.82	1.00	1.12	1.22	1.30	1.33
	Ø51	0.90	1.00	1.06	1.10	1.18	1.22
	Ø63-Ø76	0.95	1.00	1.03	1.05	1.09	1.12
160-250V	Ø35	0.80	1.00	1.19	1.34	1.46	1.52
	Ø51-Ø63	0.81	1.00	1.14	1.26	1.36	1.41
	Ø76	0.82	1.00	1.12	1.22	1.30	1.33
315-400V	Ø35-Ø89	0.80	1.00	1.19	1.34	1.46	1.52

Diagram of Dimensions - Screw Terminals

Large Can/Screw Terminals

Unit: inches (mm)



Case Dimensions

Case Size Code	øD +0.080 (2.0)	L ±0.040 (1.0)	F ±0.010 (0.25)
A41 A54 A67 A79 A92 AA5 AB7 AD0 AE3	1.375 (35.0)	1.625 (41) 2.125 (54) 2.625 (67) 3.125 (79) 3.625 (92) 4.125 (105) 4.625 (117) 5.125 (130) 5.625 (143)	0.500 (12.7)
C48 C54 C67 C79 C92 CA5 CB7 CD0 CE3	2.000 (50.8)	1.875 (48) 2.125 (54) 2.625 (67) 3.125 (79) 3.625 (92) 4.125 (105) 4.625 (117) 5.125 (130) 5.625 (143)	0.875 (22.2)
D79 DA5 DB7 DD0 DE3	2.500 (63.5)	3.125 (79) 4.125 (105) 4.625 (117) 5.125 (130) 5.625 (143)	1.125 (28.6)
E92 EA5 EB7 ED0 EE3 EN0	3.000 (76.2)	3.625 (92) 4.125 (105) 4.625 (117) 5.125 (130) 5.625 (143) 8.625 (220)	1.250 (31.8)
FA5 FB7 FE3	3.500 (89.0)	4.125 (105) 4.625 (117) 5.625 (143)	1.250 (31.8)

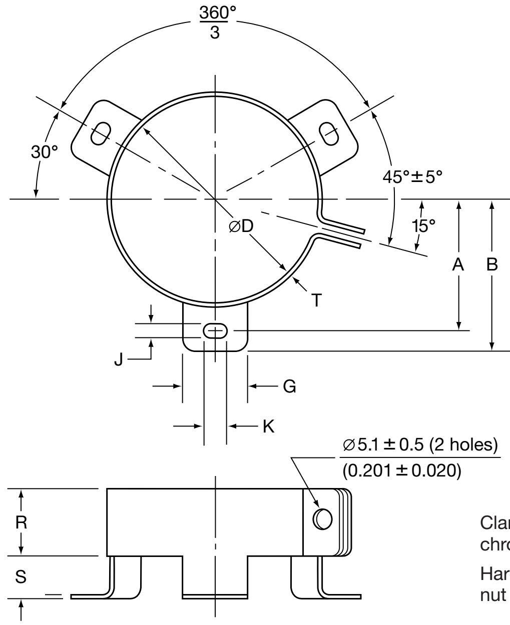
Terminal Specifications

Terminal Code	Available Case Diameter		Thread Size	Minimum Thread Depth	J ±0.020 (0.5)	H ±0.080 (2.0)	øS ±0.010 (0.25)	øT ±0.010 (0.25)
	øD Code	øD inches (mm)						
HP	C-E	1.375 – 3.000 (35.0 – 76.2)	10-32 NF-2B	0.375 (9.5)	0.250 (6.4)	L+J	0.313 (8.0)	0.438 (11.1)
LP	C-E	1.375 – 3.000 (35.0 – 76.2)	10-32 NF-2B	0.219 (5.6)	0.063 (1.6)	L+J	0.313 (8.0)	—
HL	C-E	1.375 – 3.000 (35.0 – 76.2)	M5x0.8-6H	0.375 (9.5)	0.250 (6.4)	L+J	0.313 (8.0)	0.438 (11.1)
ML	C-E	1.375 – 3.000 (35.0 – 76.2)	M5x0.8-6H	0.219 (5.6)	0.063 (1.6)	L+J	0.313 (8.0)	0.438 (11.1)
CD	D-E	2.500 – 3.000 (63.5 – 76.2)	M5x0.8-6H	0.335 (8.5)	0.200 (5.0)	L+J	0.512 (13.0)	0.740 (18.8)
CP	D-F	2.500 – 3.500 (63.5 – 89.0)	¼-28 NF-2B	0.344 (8.7)	0.093 (2.4)	L+J	0.689 (17.5)	—
CH	D-F	2.500 – 3.500 (63.5 – 89.0)	¼-28 NF-2B	0.468 (11.9)	0.250 (6.4)	L+J	0.689 (17.5)	—
CA	D-F	2.500 – 3.500 (63.5 – 89.0)	M6x1-6H	0.344 (8.7)	0.093 (2.4)	L+J	0.689 (17.5)	—
CS	D-F	2.500 – 3.500 (63.5 – 89.0)	M6x1-6H	0.468 (11.9)	0.250 (6.4)	L+J	0.689 (17.5)	—

Mounting Hardware - Screw Terminals

Type C: Three-Footed Clamp

Unit: mm (inches)



Clamp: Zinc with silver trivalent chromate post treatment.

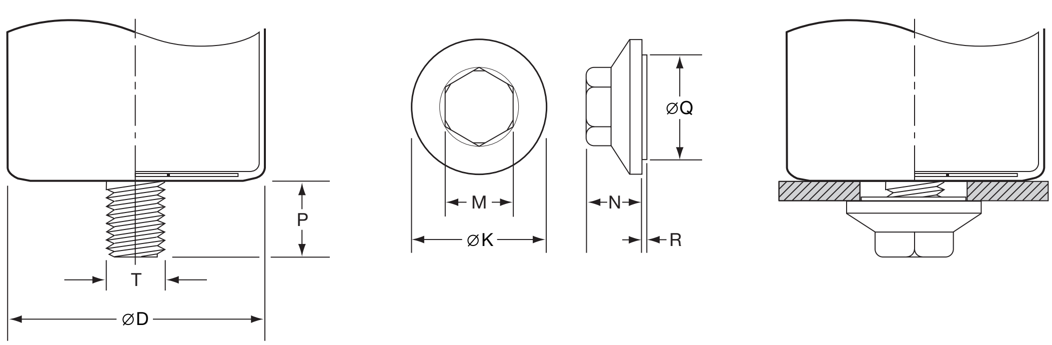
Hardware: Screw, washer and hexagon nut included with each clamp.

Type C: Clamp Dimensions

Mounting Code	Case øD	A ±1.0 (0.040)	B ±1.0 (0.040)	G ±1.0 (0.040)	J ±0.5 (0.020)	K ±0.5 (0.020)	R ±1.0 (0.040)	S ±1.0 (0.040)	T ±0.5 (0.020)
See Note	35.0 (1.375)	—	—	—	—	—	—	—	—
C	50.8 (2.000)	31.8 (1.250)	36.5 (1.437)	13.3 (0.524)	4.5 (0.177)	7.1 (0.280)	19.1 (0.751)	9.5 (0.374)	0.8 (0.032)
C	63.5 (2.500)	38.1 (1.500)	42.9 (1.689)	13.3 (0.524)	4.5 (0.177)	7.1 (0.280)	19.1 (0.751)	9.5 (0.374)	0.8 (0.032)
C	76.2 (3.000)	44.5 (1.750)	49.2 (1.937)	13.3 (0.524)	4.5 (0.177)	7.1 (0.280)	19.1 (0.751)	9.5 (0.374)	1.0 (0.040)
C	89.0 (3.500)	50.8 (2.000)	56.5 (2.224)	16.0 (0.630)	4.5 (0.177)	8.0 (0.313)	21.0 (0.827)	9.0 (0.354)	1.0 (0.040)

Note: Type B two-footed clamp available upon request for Ø35, Ø50.8, Ø63.5 and Ø76.2. Consult UCC for specifications.

Type S: Stud Mounting



Type S: Stud Mounting Dimensions

Mounting Code	P ±1.0 (0.040)	T Thread Size	M ±1.0 (0.040)	N ±1.0 (0.040)	øK ±2.0 (0.080)	øQ ±1.0 (0.040)	R ±1.0 (0.040)
S	16.0 (0.630)	M12	19.0 (0.748)	18.0 (0.709)	30.0 (1.181)	22.0 (0.866)	1.40 (0.055)

Part Numbering System for U32D Series

When ordering, always specify complete 18-field global part number.

18 Fields

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
E	3	2	D	2	0	1	H	P	N	1	0	3	M	D	A	5	M

9 Supplement Code. Field 18.
- C = PET insulation with end disk.
- F = Coated can.
- M = Pb-free PVC insulation with end disk.

8 Case Size. Fields 15, 16 and 17.
The single letter diameter code is inserted in field 15.
- A = Ø35mm (Ø1.375")
- C = Ø50.8mm (Ø2.000")
- D = Ø63.5mm (Ø2.500")
- E = Ø76.2mm (Ø3.000")
- F = Ø89mm (Ø3.500")

The double character length code is inserted in fields 16 and 17. For lengths ≤99mm, insert the actual length rounded to nearest millimeter. For lengths of 100mm or more, insert the appropriate alpha numeric code as indicated below.
- 41 = 41mm (1.625")
- 48 = 48mm (1.875")
- 54 = 54mm (2.125")
- 67 = 67mm (2.625")
- 79 = 79mm (3.125")
- 92 = 92mm (3.625")
- A5 = 105mm (4.125")
- B7 = 117mm (4.625")
- D0 = 130mm (5.125")
- E3 = 143mm (5.625")
- N0 = 220mm (8.625")

7 Capacitance Tolerance. Field 14.
- M = ±20%

6 Capacitance. Fields 11, 12 and 13.
Expressed in Microfarads. The first two digits are significant figures inserted in fields 11 and 12, and the third digit inserted in field 13 indicates the number of zeros for capacitance of 10µF or more. R indicates the decimal point for capacitance less than 10µF (e.g. 1R0 = 1.0µF; 100 = 10µF; 101 = 100µF; 102 = 1,000µF; 103 = 10,000µF).

5 Mounting Hardware. Field 10.
- N = None.
- B = Two-footed clamp.
- C = Three-footed clamp.
- S = Stud mount.

4 Terminal Type. Fields 8 and 9.
- HP = High post 10-32 NF-2B screw thread.
- LP = Low post 10-32 NF-2B screw thread.
- HL = High post M5x0.8 screw thread.
- ML = Low post M5x0.8 screw thread.
- CD = UTE M5x0.8 screw thread.
- CP = Low post 1/4-28 NF-2B screw thread.
- CH = High post 1/4-28 NF-2B screw thread.
- CA = Low post M6x1 screw thread.
- CS = High post M6x1 screw thread.

3 DC Rated Voltage. Fields 5, 6 and 7.
Expressed in Volts. The first two digits are significant figures inserted in fields 5 and 6, and the third digit inserted in field 7 indicates the number of zeros for rated voltage of 10VDC or more. R indicates the decimal point for rated voltage less than 10VDC (e.g. 2R0 = 2.0VDC; 200 = 20VDC; 201 = 200VDC).

2 Series Name. Fields 2, 3 and 4.
Enter the 3-letter/digit series name in fields 2, 3 and 4. If the series name is only 2 letters/digits, place a dash in field 4. For a series name with more than 3 letters/digits, refer to the individual series for the appropriate 3-field series name.

1 Capacitor Type. Field 1.
Aluminum Electrolytic Capacitor (Polar).

U32D Series

Standard Voltage Ratings - Screw Terminals

Rated Voltage (WVDC)	Capacitance (µF)	Global Part Number†	Nominal Case Size* D × L (inches)	Case Size Code	Maximum ESR (mΩ) at +25°C, 120Hz	Rated Ripple Current (A rms) at +85°C, 120Hz
6.3 Volts 8 Volts Surge	39,000	E32D6R3HPN393MA41M	1.375 × 1.625	A41	39.9	7.03
	68,000	E32D6R3HPN683MA54M	1.375 × 2.125	A54	24.0	9.62
	82,000	E32D6R3HPN823MA67M	1.375 × 2.625	A67	19.5	10.87
	120,000	E32D6R3HPN124MA79M	1.375 × 3.125	A79	14.5	13.76
	150,000	E32D6R3HPN154MA92M	1.375 × 3.625	A92	12.2	15.53
	180,000	E32D6R3HPN184MAA5M	1.375 × 4.125	AA5	11.8	18.10
	220,000	E32D6R3HPN224MAD0M	1.375 × 5.125	AD0	9.1	20.93
	82,000	E32D6R3HPN823MC48M	2.000 × 1.875	C48	22.1	11.19
	120,000	E32D6R3HPN124MC54M	2.000 × 2.125	C54	16.2	13.53
	180,000	E32D6R3HPN184MC67M	2.000 × 2.625	C67	11.3	17.11
	220,000	E32D6R3HPN224MC79M	2.000 × 3.125	C79	9.2	20.41
	330,000	E32D6R3HPN334MC92M	2.000 × 3.625	C92	7.7	24.76
	390,000	E32D6R3HPN394MCA5M	2.000 × 4.125	CA5	6.4	27.19
	470,000	E32D6R3HPN474MCB7M	2.000 × 4.625	CB7	6.0	30.87
	560,000	E32D6R3HPN564MCE3M	2.000 × 5.625	CE3	4.9	35.78
	390,000	E32D6R3HPN394MD79M	2.500 × 3.125	D79	8.7	22.54
	560,000	E32D6R3HPN564MDA5M	2.500 × 4.125	DA5	6.3	29.81
	820,000	E32D6R3HPN824MDB7M	2.500 × 4.625	DB7	5.7	32.97
	680,000	E32D6R3HPN684ME92M	3.000 × 3.625	E92	8.3	26.88
	820,000	E32D6R3HPN824MEA5M	3.000 × 4.125	EA5	7.2	30.40
	1,000,000	E32D6R3HPN105MEB7M	3.000 × 4.625	EB7	6.6	33.32
	1,200,000	E32D6R3HPN125MED0M	3.000 × 5.125	ED0	6.1	36.04
	2,200,000	E32D6R3HPN225MEN0M	3.000 × 8.625	EN0	4.0	56.03
10 Volts 13 Volts Surge	33,000	E32D100HPN333MA41M	1.375 × 1.625	A41	39.7	7.03
	56,000	E32D100HPN563MA54M	1.375 × 2.125	A54	24.3	9.55
	68,000	E32D100HPN683MA67M	1.375 × 2.625	A67	19.6	10.79
	100,000	E32D100HPN104MA79M	1.375 × 3.125	A79	14.6	13.71
	120,000	E32D100HPN124MA92M	1.375 × 3.625	A92	12.5	14.66
	150,000	E32D100HPN154MAB7M	1.375 × 4.625	AB7	10.4	18.83
	180,000	E32D100HPN184MAD0M	1.375 × 5.125	AD0	9.2	20.80
	68,000	E32D100HPN683MC48M	2.000 × 1.875	C48	22.2	11.13
	100,000	E32D100HPN104MC54M	2.000 × 2.125	C54	16.3	13.48
	150,000	E32D100HPN154MC67M	2.000 × 2.625	C67	11.4	17.11
	180,000	E32D100HPN184MC79M	2.000 × 3.125	C79	9.3	20.28
	270,000	E32D100HPN274MC92M	2.000 × 3.625	C92	7.8	24.76
	390,000	E32D100HPN394MCB7M	2.000 × 4.625	CB7	6.0	30.55
	470,000	E32D100HPN474MCE3M	2.000 × 5.625	CE3	4.9	35.78
	330,000	E32D100HPN334MD79M	2.500 × 3.125	D79	8.8	22.40
	470,000	E32D100HPN474MDA5M	2.500 × 4.125	DA5	6.4	29.81
	560,000	E32D100HPN564MDB7M	2.500 × 4.625	DB7	5.7	33.95
	680,000	E32D100HPN684MDD0M	2.500 × 5.125	DD0	5.3	36.68
	560,000	E32D100HPN564ME92M	3.000 × 3.625	E92	8.3	26.88
	680,000	E32D100HPN684MEA5M	3.000 × 4.125	EA5	7.2	30.40
	820,000	E32D100HPN824MEB7M	3.000 × 4.625	EB7	6.5	33.32
	1,000,000	E32D100HPN105MED0M	3.000 × 5.125	ED0	6.1	36.04
	1,800,000	E32D100HPN185MEN0M	3.000 × 8.625	EN0	4.0	56.03
16 Volts 20 Volts Surge	22,000	E32D160HPN223MA41M	1.375 × 1.625	A41	41.4	6.26
	39,000	E32D160HPN393MA54M	1.375 × 2.125	A54	27.3	8.68
	47,000	E32D160HPN473MA67M	1.375 × 2.625	A67	19.9	9.80
	68,000	E32D160HPN683MA79M	1.375 × 3.125	A79	15.0	12.48
	82,000	E32D160HPN823MA92M	1.375 × 3.625	A92	12.8	14.04
	100,000	E32D160HPN104MAA5M	1.375 × 4.125	AA5	11.1	16.47
	120,000	E32D160HPN124MAD0M	1.375 × 5.125	AD0	9.5	19.11
	150,000	E32D160HPN154MAE3M	1.375 × 5.625	AE3	9.3	21.33
	47,000	E32D160HPN473MC48M	2.000 × 1.875	C48	22.7	10.18
	68,000	E32D160HPN683MC54M	2.000 × 2.125	C54	16.7	12.38
	100,000	E32D160HPN104MC67M	2.000 × 2.625	C67	11.7	15.75
	120,000	E32D160HPN124MC79M	2.000 × 3.125	C79	9.6	18.66

†For terminal, mounting and construction options, refer to the part numbering system for descriptions and codes.
*** Refer to diagram of dimensions for detailed case size specifications.**

Standard Voltage Ratings - Screw Terminals

Rated Voltage (WVDC)	Capacitance (µF)	Global Part Number†	Nominal Case Size* D × L (inches)	Case Size Code	Maximum ESR (mΩ) at +25°C, 120Hz	Rated Ripple Current (A rms) at +85°C, 120Hz
16 Volts **20 Volts Surge**	180,000	E32D160HPN184MC92M	2.000 × 3.625	C92	7.5	22.89
	220,000	E32D160HPN224MCA5M	2.000 × 4.125	CA5	7.0	25.40
	270,000	E32D160HPN274MCB7M	2.000 × 4.625	CB7	6.1	28.80
	330,000	E32D160HPN334MCE3M	2.000 × 5.625	CE3	5.2	33.82
	220,000	E32D160HPN224MD79M	2.500 × 3.125	D79	8.9	21.75
	330,000	E32D160HPN334MDA5M	2.500 × 4.125	DA5	6.5	28.62
	390,000	E32D160HPN394MDB7M	2.500 × 4.625	DB7	5.9	32.66
	470,000	E32D160HPN474MDD0M	2.500 × 5.125	DD0	5.4	34.54
	390,000	E32D160HPN394ME92M	3.000 × 3.625	E92	8.5	26.07
	470,000	E32D160HPN474MEA5M	3.000 × 4.125	EA5	7.4	29.56
	560,000	E32D160HPN564MEB7M	3.000 × 4.625	EB7	6.7	32.56
	680,000	E32D160HPN684MED0M	3.000 × 5.125	ED0	6.2	35.45
	820,000	E32D160HPN824MEE3M	3.000 × 5.625	EE3	5.4	37.58
	1,200,000	E32D160HPN125MEN0M	3.000 × 8.625	EN0	4.0	55.32
25 Volts **32 Volts Surge**	15,000	E32D250HPN153MA41M	1.375 × 1.625	A41	41.3	6.27
	22,000	E32D250HPN223MA54M	1.375 × 2.125	A54	27.7	8.20
	33,000	E32D250HPN333MA67M	1.375 × 2.625	A67	19.5	9.88
	47,000	E32D250HPN473MA79M	1.375 × 3.125	A79	16.6	12.53
	56,000	E32D250HPN563MA92M	1.375 × 3.625	A92	12.8	13.71
	68,000	E32D250HPN683MAA5M	1.375 × 4.125	AA5	12.3	16.47
	82,000	E32D250HPN823MAD0M	1.375 × 5.125	AD0	9.4	19.11
	33,000	E32D250HPN333MC48M	2.000 × 1.875	C48	22.4	10.23
	47,000	E32D250HPN473MC54M	2.000 × 2.125	C54	16.6	12.42
	68,000	E32D250HPN683MC67M	2.000 × 2.625	C67	11.7	15.68
	82,000	E32D250HPN823MC79M	2.000 × 3.125	C79	9.6	18.76
	120,000	E32D250HPN124MC92M	2.000 × 3.625	C92	7.6	22.73
	180,000	E32D250HPN184MCB7M	2.000 × 4.625	CB7	6.1	28.80
	220,000	E32D250HPN224MCE3M	2.000 × 5.625	CE3	5.3	33.82
	150,000	E32D250HPN154MD79M	2.500 × 3.125	D79	8.9	21.63
	220,000	E32D250HPN224MDA5M	2.500 × 4.125	DA5	6.5	28.62
	270,000	E32D250HPN274MDB7M	2.500 × 4.625	DB7	5.9	32.66
	330,000	E32D250HPN334MDE3M	2.500 × 5.625	DE3	4.9	37.88
	270,000	E32D250HPN274ME92M	3.000 × 3.625	E92	8.6	25.92
	330,000	E32D250HPN334MEA5M	3.000 × 4.125	EA5	7.5	29.16
	390,000	E32D250HPN394MEB7M	3.000 × 4.625	EB7	6.8	32.31
	470,000	E32D250HPN474MED0M	3.000 × 5.125	ED0	6.3	35.16
	820,000	E32D250HPN824MEN0M	3.000 × 8.625	EN0	4.1	55.32
35 Volts **44 Volts Surge**	10,000	E32D350HPN103MA41M	1.375 × 1.625	A41	45.8	5.94
	18,000	E32D350HPN183MA54M	1.375 × 2.125	A54	26.7	8.33
	22,000	E32D350HPN223MA67M	1.375 × 2.625	A67	21.6	9.40
	33,000	E32D350HPN333MA79M	1.375 × 3.125	A79	15.7	12.14
	39,000	E32D350HPN393MA92M	1.375 × 3.625	A92	13.6	13.60
	47,000	E32D350HPN473MAA5M	1.375 × 4.125	AA5	11.8	15.95
	56,000	E32D350HPN563MAB7M	1.375 × 4.625	AB7	10.4	17.35
	68,000	E32D350HPN683MAE3M	1.375 × 5.625	AE3	8.9	20.57
	22,000	E32D350HPN223MC48M	2.000 × 1.875	C48	24.1	9.86
	33,000	E32D350HPN333MC54M	2.000 × 2.125	C54	17.4	12.15
	47,000	E32D350HPN473MC67M	2.000 × 2.625	C67	12.4	15.34
	68,000	E32D350HPN683MC79M	2.000 × 3.125	C79	9.4	18.76
	82,000	E32D350HPN823MC92M	2.000 × 3.625	C92	7.9	22.26
	100,000	E32D350HPN104MCA5M	2.000 × 4.125	CA5	6.9	24.82
	120,000	E32D350HPN124MCB7M	2.000 × 4.625	CB7	6.1	28.03
	150,000	E32D350HPN154MCE3M	2.000 × 5.625	CE3	5.2	33.12
	100,000	E32D350HPN104MD79M	2.500 × 3.125	D79	8.8	21.88
	150,000	E32D350HPN154MDA5M	2.500 × 4.125	DA5	6.5	28.84
	220,000	E32D350HPN224MDB7M	2.500 × 4.625	DB7	5.8	32.08

† For terminal, mounting and construction options, refer to the part numbering system for descriptions and codes.
*** Refer to diagram of dimensions for detailed case size specifications.**

Standard Voltage Ratings - Screw Terminals

Rated Voltage (WVDC)	Capacitance (µF)	Global Part Number†	Nominal Case Size* D × L (inches)	Case Size Code	Maximum ESR (mΩ) at +25°C, 120Hz	Rated Ripple Current (A rms) at +85°C, 120Hz
35 Volts 44 Volts Surge	220,000	E32D350HPN224ME92M	3.000 × 3.625	E92	8.3	25.19
	270,000	E32D350HPN274MEB7M	3.000 × 4.625	EB7	6.6	32.81
	330,000	E32D350HPN334MED0M	3.000 × 5.125	ED0	6.2	35.45
	390,000	E32D350HPN394MEE3M	3.000 × 5.625	EE3	5.4	37.90
	560,000	E32D350HPN564MEN0M	3.000 × 8.625	EN0	4.0	56.03
50 Volts 63 Volts Surge	5,600	E32D500HPN562MA41M	1.375 × 1.625	A41	52.2	5.66
	10,000	E32D500HPN103MA54M	1.375 × 2.125	A54	30.3	7.25
	15,000	E32D500HPN153MA67M	1.375 × 2.625	A67	21.3	9.01
	18,000	E32D500HPN183MA79M	1.375 × 3.125	A79	17.9	10.92
	22,000	E32D500HPN223MA92M	1.375 × 3.625	A92	15.1	12.58
	27,000	E32D500HPN273MAA5M	1.375 × 4.125	AA5	12.9	15.23
	33,000	E32D500HPN333MAB7M	1.375 × 4.625	AB7	12.5	17.22
	39,000	E32D500HPN393MAE3M	1.375 × 5.625	AE3	9.7	20.56
	15,000	E32D500HPN153MC48M	2.000 × 1.875	C48	24.3	10.01
	18,000	E32D500HPN183MC54M	2.000 × 2.125	C54	19.4	11.50
	27,000	E32D500HPN273MC67M	2.000 × 2.625	C67	13.4	14.97
	39,000	E32D500HPN393MC79M	2.000 × 3.125	C79	10.1	19.30
	56,000	E32D500HPN563MC92M	2.000 × 3.625	C92	8.5	22.56
	68,000	E32D500HPN683MCB7M	2.000 × 4.625	CB7	6.5	27.67
	82,000	E32D500HPN823MCD0M	2.000 × 5.125	CD0	5.8	29.50
	100,000	E32D500HPN104MCE3M	2.000 × 5.625	CE3	5.6	34.03
	68,000	E32D500HPN683MD79M	2.500 × 3.125	D79	9.4	24.55
	100,000	E32D500HPN104MDA5M	2.500 × 4.125	DA5	6.8	31.43
	120,000	E32D500HPN124MDB7M	2.500 × 4.625	DB7	5.9	34.04
	150,000	E32D500HPN154MDE3M	2.500 × 5.625	DE3	5.1	37.63
	120,000	E32D500HPN124ME92M	3.000 × 3.625	E92	8.9	33.88
	150,000	E32D500HPN154MEA5M	3.000 × 4.125	EA5	7.8	36.22
	180,000	E32D500HPN184MEB7M	3.000 × 4.625	EB7	6.5	38.22
	220,000	E32D500HPN224MEE3M	3.000 × 5.625	EE3	5.7	44.44
	330,000	E32D500HPN334MEN0M	3.000 × 8.625	EN0	4.0	65.97
63 Volts 79 Volts Surge	4,700	E32D630HPN472MA41M	1.375 × 1.625	A41	57.1	5.18
	6,800	E32D630HPN682MA54M	1.375 × 2.125	A54	33.8	6.68
	10,000	E32D630HPN103MA67M	1.375 × 2.625	A67	23.9	7.36
	12,000	E32D630HPN123MA79M	1.375 × 3.125	A79	20.1	8.92
	15,000	E32D630HPN153MA92M	1.375 × 3.625	A92	16.6	10.39
	18,000	E32D630HPN183MAA5M	1.375 × 4.125	AA5	14.3	12.44
	22,000	E32D630HPN223MAB7M	1.375 × 4.625	AB7	12.3	14.06
	27,000	E32D630HPN273MAD0M	1.375 × 5.125	AD0	12.1	16.36
	10,000	E32D630HPN103MC48M	2.000 × 1.875	C48	26.7	8.18
	12,000	E32D630HPN123MC54M	2.000 × 2.125	C54	21.5	9.39
	22,000	E32D630HPN223MC67M	2.000 × 2.625	C67	14.8	13.52
	27,000	E32D630HPN273MC79M	2.000 × 3.125	C79	10.8	16.06
	39,000	E32D630HPN393MC92M	2.000 × 3.625	C92	9.1	20.62
	47,000	E32D630HPN473MCB7M	2.000 × 4.625	CB7	6.9	23.00
	56,000	E32D630HPN563MCD0M	2.000 × 5.125	CD0	6.2	26.34
	68,000	E32D630HPN683MCE3M	2.000 × 5.625	CE3	6.0	30.31
	47,000	E32D630HPN473MD79M	2.500 × 3.125	D79	9.6	22.05
	68,000	E32D630HPN683MDA5M	2.500 × 4.125	DA5	6.9	29.84
	82,000	E32D630HPN823MDB7M	2.500 × 4.625	DB7	6.2	29.93
	100,000	E32D630HPN104MDE3M	2.500 × 5.625	DE3	5.2	32.23
	82,000	E32D630HPN823ME92M	3.000 × 3.625	E92	8.9	29.71
	100,000	E32D630HPN104MEA5M	3.000 × 4.125	EA5	7.7	34.67
	120,000	E32D630HPN124MEB7M	3.000 × 4.625	EB7	6.9	35.58
	150,000	E32D630HPN154MEE3M	3.000 × 5.625	EE3	5.7	39.63
	220,000	E32D630HPN224MEN0M	3.000 × 8.625	EN0	4.0	53.86

†For terminal, mounting and construction options, refer to the part numbering system for descriptions and codes.
*** Refer to diagram of dimensions for detailed case size specifications.**

Standard Voltage Ratings - Screw Terminals

Rated Voltage (WVDC)	Capacitance (µF)	Global Part Number†	Nominal Case Size* D×L (inches)	Case Size Code	Maximum ESR (mΩ) at +25°C, 120Hz	Rated Ripple Current (A rms) at +85°C, 120Hz
80 Volts 100 Volts Surge	2,200	E32D800HPN222MA41M	1.375 × 1.625	A41	67.0	4.09
	3,900	E32D800HPN392MA54M	1.375 × 2.125	A54	44.2	5.84
	4,700	E32D800HPN472MA67M	1.375 × 2.625	A67	31.7	6.51
	6,800	E32D800HPN682MA79M	1.375 × 3.125	A79	23.0	8.67
	8,200	E32D800HPN822MA92M	1.375 × 3.625	A92	19.5	9.92
	10,000	E32D800HPN103MAA5M	1.375 × 4.125	AA5	19.0	10.36
	12,000	E32D800HPN123MAD0M	1.375 × 5.125	AD0	14.0	12.19
	4,700	E32D800HPN472MC48M	2.000 × 1.875	C48	34.3	6.27
	6,800	E32D800HPN682MC54M	2.000 × 2.125	C54	24.6	7.90
	10,000	E32D800HPN103MC67M	2.000 × 2.625	C67	17.0	10.19
	12,000	E32D800HPN123MC79M	2.000 × 3.125	C79	14.0	11.97
	18,000	E32D800HPN183MC92M	2.000 × 3.625	C92	10.4	15.66
	22,000	E32D800HPN223MCA5M	2.000 × 4.125	CA5	9.9	18.36
	27,000	E32D800HPN273MCB7M	2.000 × 4.625	CB7	8.5	21.35
	33,000	E32D800HPN333MCE3M	2.000 × 5.625	CE3	7.2	25.86
	22,000	E32D800HPN223MD79M	2.500 × 3.125	D79	10.6	16.52
	33,000	E32D800HPN333MDA5M	2.500 × 4.125	DA5	7.6	22.84
	39,000	E32D800HPN393MDB7M	2.500 × 4.625	DB7	6.8	23.76
	47,000	E32D800HPN473MDD0M	2.500 × 5.125	DD0	6.1	25.31
	39,000	E32D800HPN393ME92M	3.000 × 3.625	E92	8.9	23.66
	47,000	E32D800HPN473MEA5M	3.000 × 4.125	EA5	7.7	27.45
	56,000	E32D800HPN563MEB7M	3.000 × 4.625	EB7	6.9	31.38
	68,000	E32D800HPN683MED0M	3.000 × 5.125	ED0	6.4	33.51
	120,000	E32D800HPN124MEN0M	3.000 × 8.625	EN0	4.2	52.62
100 Volts 125 Volts Surge	1,500	E32D101HPN152MA41M	1.375 × 1.625	A41	80.9	4.14
	2,700	E32D101HPN272MA54M	1.375 × 2.125	A54	45.9	5.95
	3,900	E32D101HPN392MA67M	1.375 × 2.625	A67	37.2	7.26
	4,700	E32D101HPN472MA79M	1.375 × 3.125	A79	27.1	8.82
	5,600	E32D101HPN562MA92M	1.375 × 3.625	A92	23.1	10.04
	6,800	E32D101HPN682MAA5M	1.375 × 4.125	AA5	19.5	11.03
	8,200	E32D101HPN822MAB7M	1.375 × 4.625	AB7	19.2	11.80
	10,000	E32D101HPN103MAE3M	1.375 × 5.625	AE3	14.1	13.44
	3,900	E32D101HPN392MC48M	2.000 × 1.875	C48	39.9	6.59
	4,700	E32D101HPN472MC54M	2.000 × 2.125	C54	28.7	7.59
	6,800	E32D101HPN682MC67M	2.000 × 2.625	C67	20.0	9.70
	10,000	E32D101HPN103MC79M	2.000 × 3.125	C79	14.5	12.62
	12,000	E32D101HPN123MC92M	2.000 × 3.625	C92	12.2	14.77
	15,000	E32D101HPN153MCA5M	2.000 × 4.125	CA5	10.2	17.51
	18,000	E32D101HPN183MCB7M	2.000 × 4.625	CB7	9.8	20.13
	22,000	E32D101HPN223MCE3M	2.000 × 5.625	CE3	7.5	24.38
	15,000	E32D101HPN153MD79M	2.500 × 3.125	D79	11.9	15.26
	22,000	E32D101HPN223MDA5M	2.500 × 4.125	DA5	8.5	20.85
	27,000	E32D101HPN273MDB7M	2.500 × 4.625	DB7	7.4	24.22
	33,000	E32D101HPN333MDD0M	2.500 × 5.125	DD0	6.6	28.05
	39,000	E32D101HPN393MDE3M	2.500 × 5.625	DE3	6.3	31.82
	27,000	E32D101HPN273ME92M	3.000 × 3.625	E92	9.3	21.56
	33,000	E32D101HPN333MEA5M	3.000 × 4.125	EA5	8.0	25.20
	39,000	E32D101HPN393MEB7M	3.000 × 4.625	EB7	7.2	28.69
	47,000	E32D101HPN473MED0M	3.000 × 5.125	ED0	6.6	30.09
	56,000	E32D101HPN563MEE3M	3.000 × 5.625	EE3	6.1	34.25
	82,000	E32D101HPN823MEN0M	3.000 × 8.625	EN0	4.3	50.23
160 Volts 200 Volts Surge	820	E32D161HPN821MA41M	1.375 × 1.625	A41	184.8	2.50
	1,500	E32D161HPN152MA54M	1.375 × 2.125	A54	101.2	3.62
	1,800	E32D161HPN182MA67M	1.375 × 2.625	A67	83.3	4.03
	2,700	E32D161HPN272MA79M	1.375 × 3.125	A79	56.8	5.46
	3,900	E32D161HPN392MAA5M	1.375 × 4.125	AA5	40.0	7.47
	4,700	E32D161HPN472MAD0M	1.375 × 5.125	AD0	33.4	8.81
	5,600	E32D161HPN562MAE3M	1.375 × 5.625	AE3	28.6	10.06

†For terminal, mounting and construction options, refer to the part numbering system for descriptions and codes.
*** Refer to diagram of dimensions for detailed case size specifications.**

U32D Series

Standard Voltage Ratings - Screw Terminals

Rated Voltage (WVDC)	Capacitance (µF)	Global Part Number†	Nominal Case Size* D × L (inches)	Case Size Code	Maximum ESR (mΩ) at +25°C, 120Hz	Rated Ripple Current (A rms) at +85°C, 120Hz
160 Volts 200 Volts Surge	2,200	E32D161HPN222MC48M	2.000 × 1.875	C48	74.6	4.29
	2,700	E32D161HPN272MC54M	2.000 × 2.125	C54	59.6	4.98
	3,900	E32D161HPN392MC67M	2.000 × 2.625	C67	41.1	6.36
	5,600	E32D161HPN562MC79M	2.000 × 3.125	C79	29.4	8.18
	6,800	E32D161HPN682MC92M	2.000 × 3.625	C92	24.0	9.63
	8,200	E32D161HPN822MCA5M	2.000 × 4.125	CA5	20.5	11.21
	10,000	E32D161HPN103MCB7M	2.000 × 4.625	CB7	17.0	12.99
	12,000	E32D161HPN123MCE3M	2.000 × 5.625	CE3	14.3	15.60
	8,200	E32D161HPN822MD79M	2.500 × 3.125	D79	22.6	11.28
	12,000	E32D161HPN123MDA5M	2.500 × 4.125	DA5	15.8	15.40
	18,000	E32D161HPN183MDB7M	2.500 × 4.625	DB7	11.8	19.77
	18,000	E32D161HPN183ME92M	3.000 × 3.625	E92	14.7	19.68
	22,000	E32D161HPN223MEB7M	3.000 × 4.625	EB7	11.3	24.09
	27,000	E32D161HPN273MED0M	3.000 × 5.125	ED0	9.9	27.93
	47,000	E32D161HPN473MEN0M	3.000 × 8.625	EN0	6.2	46.58
200 Volts 250 Volts Surge	680	E32D201HPN681MA41M	1.375 × 1.625	A41	192.4	2.28
	1,000	E32D201HPN102MA54M	1.375 × 2.125	A54	128.5	2.96
	1,500	E32D201HPN152MA67M	1.375 × 2.625	A67	86.3	3.68
	1,800	E32D201HPN182MA79M	1.375 × 3.125	A79	71.8	4.46
	2,200	E32D201HPN222MA92M	1.375 × 3.625	A92	59.1	5.14
	2,700	E32D201HPN272MAA5M	1.375 × 4.125	AA5	48.7	6.22
	3,300	E32D201HPN332MAB7M	1.375 × 4.625	AB7	40.4	7.03
	3,900	E32D201HPN392MAD0M	1.375 × 5.125	AD0	34.7	8.03
	1,500	E32D201HPN152MC48M	2.000 × 1.875	C48	110.7	4.09
	2,200	E32D201HPN222MC54M	2.000 × 2.125	C54	63.1	5.19
	3,300	E32D201HPN332MC67M	2.000 × 2.625	C67	42.2	6.76
	3,900	E32D201HPN392MC79M	2.000 × 3.125	C79	35.2	7.88
	5,600	E32D201HPN562MC92M	2.000 × 3.625	C92	25.1	10.09
	8,200	E32D201HPN822MCB7M	2.000 × 4.625	CB7	17.8	13.59
	10,000	E32D201HPN103MCE3M	2.000 × 5.625	CE3	14.8	16.44
	6,800	E32D201HPN682MD79M	2.500 × 3.125	D79	23.6	10.27
	10,000	E32D201HPN103MDA5M	2.500 × 4.125	DA5	16.5	14.06
	12,000	E32D201HPN123MDB7M	2.500 × 4.625	DB7	13.8	16.14
	15,000	E32D201HPN153MDE3M	2.500 × 5.625	DE3	11.5	19.74
	12,000	E32D201HPN123ME92M	3.000 × 3.625	E92	16.4	16.07
	15,000	E32D201HPN153MEA5M	3.000 × 4.125	EA5	13.7	18.99
	18,000	E32D201HPN183MEB7M	3.000 × 4.625	EB7	11.9	21.79
	22,000	E32D201HPN223MEE3M	3.000 × 5.625	EE3	9.8	26.29
	33,000	E32D201HPN333MEN0M	3.000 × 8.625	EN0	6.8	39.03
250 Volts 300 Volts Surge	470	E32D251HPN471MA41M	1.375 × 1.625	A41	273.0	1.89
	820	E32D251HPN821MA54M	1.375 × 2.125	A54	155.3	2.68
	1,200	E32D251HPN122MA67M	1.375 × 2.625	A67	106.5	3.29
	1,500	E32D251HPN152MA79M	1.375 × 3.125	A79	85.3	3.53
	1,800	E32D251HPN182MA92M	1.375 × 3.625	A92	71.3	4.02
	2,200	E32D251HPN222MAA5M	1.375 × 4.125	AA5	58.8	4.86
	2,700	E32D251HPN272MAB7M	1.375 × 4.625	AB7	48.5	5.51
	3,300	E32D251HPN332MAE3M	1.375 × 5.625	AE3	40.0	6.69
	1,200	E32D251HPN122MC48M	2.000 × 1.875	C48	112.1	3.17
	1,500	E32D251HPN152MC54M	2.000 × 2.125	C54	88.4	3.71
	2,200	E32D251HPN222MC67M	2.000 × 2.625	C67	60.1	4.78
	3,300	E32D251HPN332MC79M	2.000 × 3.125	C79	41.0	6.28
	3,900	E32D251HPN392MC92M	2.000 × 3.625	C92	34.6	7.29
	4,700	E32D251HPN472MCA5M	2.000 × 4.125	CA5	29.0	8.49
	5,600	E32D251HPN562MCB7M	2.000 × 4.625	CB7	24.7	9.72
	6,800	E32D251HPN682MCD0M	2.000 × 5.125	CD0	20.7	11.24
	5,600	E32D251HPN562MD79M	2.500 × 3.125	D79	27.7	9.32
	8,200	E32D251HPN822MDA5M	2.500 × 4.125	DA5	19.3	12.73

†For terminal, mounting and construction options, refer to the part numbering system for descriptions and codes.
*** Refer to diagram of dimensions for detailed case size specifications.**

Standard Voltage Ratings - Screw Terminals

Rated Voltage (WVDC)	Capacitance (µF)	Global Part Number†	Nominal Case Size* D × L (inches)	Case Size Code	Maximum ESR (mΩ) at +25°C, 120Hz	Rated Ripple Current (A rms) at +85°C, 120Hz
250 Volts 300 Volts Surge	10,000	E32D251HPN103MDB7M	2.500 × 4.625	DB7	18.5	14.74
	12,000	E32D251HPN123MDE3M	2.500 × 5.625	DE3	13.6	17.65
	10,000	E32D251HPN103ME92M	3.000 × 3.625	E92	18.8	14.67
	12,000	E32D251HPN123MEA5M	3.000 × 4.125	EA5	15.9	16.99
	15,000	E32D251HPN153MED0M	3.000 × 5.125	ED0	12.7	20.82
	18,000	E32D251HPN183MEE3M	3.000 × 5.625	EE3	11.2	23.78
	27,000	E32D251HPN273MEN0M	3.000 × 8.625	EN0	7.7	35.30
315 Volts 365 Volts Surge	220	E32D3B1HPN221MA41M	1.375 × 1.625	A41	750.3	1.59
	330	E32D3B1HPN331MA54M	1.375 × 2.125	A54	492.0	2.08
	470	E32D3B1HPN471MA67M	1.375 × 2.625	A67	343.8	2.52
	680	E32D3B1HPN681MA79M	1.375 × 3.125	A79	237.8	3.36
	820	E32D3B1HPN821MA92M	1.375 × 3.625	A92	197.2	3.14
	1,000	E32D3B1HPN102MAA5M	1.375 × 4.125	AA5	161.9	8.46
	1,200	E32D3B1HPN122MAD0M	1.375 × 5.125	AD0	134.9	9.96
	470	E32D3B1HPN471MC48M	2.000 × 1.875	C48	354.0	2.80
	680	E32D3B1HPN681MC54M	2.000 × 2.125	C54	243.1	3.53
	1,000	E32D3B1HPN102MC67M	2.000 × 2.625	C67	164.1	3.72
	1,200	E32D3B1HPN122MC79M	2.000 × 3.125	C79	135.9	4.37
	1,800	E32D3B1HPN182MC92M	2.000 × 3.625	C92	91.0	5.72
	2,200	E32D3B1HPN222MCA5M	2.000 × 4.125	CA5	75.0	6.70
	2,700	E32D3B1HPN272MCB7M	2.000 × 4.625	CB7	61.3	7.80
	3,300	E32D3B1HPN332MCE3M	2.000 × 5.625	CE3	50.3	9.44
	2,200	E32D3B1HPN222MD79M	2.500 × 3.125	D79	77.0	6.75
	3,300	E32D3B1HPN332MDA5M	2.500 × 4.125	DA5	51.7	9.32
	3,900	E32D3B1HPN392MDB7M	2.500 × 4.625	DB7	43.7	10.63
	4,700	E32D3B1HPN472MDD0M	2.500 × 5.125	DD0	36.9	12.22
	3,900	E32D3B1HPN392ME92M	3.000 × 3.625	E92	45.7	10.58
	4,700	E32D3B1HPN472MEA5M	3.000 × 4.125	EA5	38.2	12.28
	5,600	E32D3B1HPN562MEB7M	3.000 × 4.625	EB7	32.4	14.03
	6,800	E32D3B1HPN682MED0M	3.000 × 5.125	ED0	27.2	16.19
	8,200	E32D3B1HPN822MEE3M	3.000 × 5.625	EE3	23.1	18.53
	12,000	E32D3B1HPN123MEN0M	3.000 × 8.625	EN0	16.0	27.17
350 Volts 400 Volts Surge	180	E32D351HPN181MA41M	1.375 × 1.625	A41	882.3	1.43
	330	E32D351HPN331MA54M	1.375 × 2.125	A54	475.0	2.08
	470	E32D351HPN471MA67M	1.375 × 2.625	A67	332.0	2.52
	560	E32D351HPN561MA79M	1.375 × 3.125	A79	277.6	3.05
	680	E32D351HPN681MA92M	1.375 × 3.625	A92	228.5	3.36
	820	E32D351HPN821MAA5M	1.375 × 4.125	AA5	189.6	3.43
	1,000	E32D351HPN102MAB7M	1.375 × 4.625	AB7	156.0	3.87
	1,200	E32D351HPN122MAD0M	1.375 × 5.125	AD0	130.0	4.45
	470	E32D351HPN471MC48M	2.000 × 1.875	C48	342.0	2.80
	680	E32D351HPN681MC54M	2.000 × 2.125	C54	235.0	3.53
	1,000	E32D351HPN102MC67M	2.000 × 2.625	C67	156.0	3.72
	1,200	E32D351HPN122MC79M	2.000 × 3.125	C79	131.3	4.37
	1,800	E32D351HPN182MC92M	2.000 × 3.625	C92	88.0	5.72
	2,200	E32D351HPN222MCB7M	2.000 × 4.625	CB7	71.9	7.04
	2,700	E32D351HPN272MCD0M	2.000 × 5.125	CD0	59.0	8.18
	2,200	E32D351HPN222MD79M	2.500 × 3.125	D79	75.0	6.75
	3,300	E32D351HPN332MDA5M	2.500 × 4.125	DA5	50.0	9.32
	3,900	E32D351HPN392MDB7M	2.500 × 4.625	DB7	42.0	10.63
	4,700	E32D351HPN472MDE3M	2.500 × 5.625	DE3	35.0	12.76
	3,900	E32D351HPN392ME92M	3.000 × 3.625	E92	44.0	10.58
	4,700	E32D351HPN472MEA5M	3.000 × 4.125	EA5	37.0	12.28
	5,600	E32D351HPN562MEB7M	3.000 × 4.625	EB7	32.0	14.03
	6,800	E32D351HPN682MED0M	3.000 × 5.125	ED0	27.0	16.19
	10,000	E32D351HPN103MEN0M	3.000 × 8.625	EN0	17.9	24.81

† For terminal, mounting and construction options, refer to the part numbering system for descriptions and codes.
*** Refer to diagram of dimensions for detailed case size specifications.**

Standard Voltage Ratings - Screw Terminals

Rated Voltage (WVDC)	Capacitance (µF)	Global Part Number†	Nominal Case Size* D × L (inches)	Case Size Code	Maximum ESR (mΩ) at +25°C, 120Hz	Rated Ripple Current (A rms) at +85°C, 120Hz
350 Volts 400 Volts Surge	5,600	E32D351LLN562MFA5M	3.500 × 4.125	FA5	35.0	15.40
	6,800	E32D351LLN682MFB7M	3.500 × 4.625	FB7	30.0	17.28
	8,200	E32D351LLN822MFE3M	3.500 × 5.625	FE3	24.0	21.00
400 Volts 450 Volts Surge	180	E32D401HPN181MA41M	1.375 × 1.625	A41	806.0	1.43
	270	E32D401HPN271MA54M	1.375 × 2.125	A54	528.4	1.88
	390	E32D401HPN391MA67M	1.375 × 2.625	A67	364.1	2.30
	470	E32D401HPN471MA79M	1.375 × 3.125	A79	301.2	2.79
	680	E32D401HPN681MA92M	1.375 × 3.625	A92	209.0	2.86
	820	E32D401HPN821MAB7M	1.375 × 4.625	AB7	172.9	3.50
	1,000	E32D401HPN102MAD0M	1.375 × 5.125	AD0	142.0	4.06
	390	E32D401HPN391MC48M	2.000 × 1.875	C48	374.9	2.55
	560	E32D401HPN561MC54M	2.000 × 2.125	C54	259.0	3.21
	820	E32D401HPN821MC67M	2.000 × 2.625	C67	176.0	3.37
	1,000	E32D401HPN102MC79M	2.000 × 3.125	C79	143.3	3.99
	1,500	E32D401HPN152MC92M	2.000 × 3.625	C92	96.0	5.22
	2,200	E32D401HPN222MCB7M	2.000 × 4.625	CB7	66.0	7.04
	2,700	E32D401HPN272MCE3M	2.000 × 5.625	CE3	54.0	8.54
	1,800	E32D401HPN182MD79M	2.500 × 3.125	D79	82.0	6.10
	2,700	E32D401HPN272MDA5M	2.500 × 4.125	DA5	55.0	8.43
	3,300	E32D401HPN332MDB7M	2.500 × 4.625	DB7	45.4	9.78
	3,900	E32D401HPN392MDD0M	2.500 × 5.125	DD0	39.0	11.13
	3,300	E32D401HPN332ME92M	3.000 × 3.625	E92	48.0	9.73
	3,900	E32D401HPN392MEA5M	3.000 × 4.125	EA5	40.3	11.18
	4,700	E32D401HPN472MEB7M	3.000 × 4.625	EB7	34.0	12.86
	5,600	E32D401HPN562MED0M	3.000 × 5.125	ED0	29.0	14.69
	10,000	E32D401HPN103MEN0M	3.000 × 8.625	EN0	17.0	24.81
	4,700	E32D401LLN472MFA5M	3.500 × 4.125	FA5	36.0	15.19
	5,600	E32D401LLN562MFB7M	3.500 × 4.625	FB7	32.0	16.73
	6,800	E32D401LLN682MFE3M	3.500 × 5.625	FE3	25.0	20.58

†For terminal, mounting and construction options, refer to the part numbering system for descriptions and codes.
*** Refer to diagram of dimensions for detailed case size specifications.**

STTH200L06TV

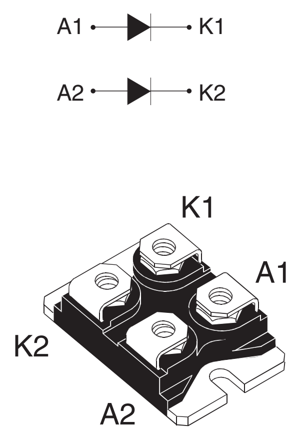
Turbo 2 ultrafast high voltage rectifier

Features

- Ultrafast switching
- Low reverse current
- Low thermal resistance
- Reduces switching and conduction losses

Description

The STTH200L06TV, which is using ST Turbo 2 600 V technology, is specially suited for use in switching power supplies, and industrial applications (such as welding), as rectification diode.



ISOTOP
STTH200L06TV1

Table 1. Device summary

Symbol	Value
$I_{F(AV)}$	Up to 2 x 120 A
V_{RRM}	600 V
T_j	150 °C
V_F (typ)	0.95 V
t_{rr} (max)	80 ns

TM: ISOTOP is a trademark of STMicroelectronics

1 Characteristics

Table 2. Absolute ratings (limiting values, per diode)

Symbol	Parameter			Value	Unit
V_{RRM}	Repetitive peak reverse voltage			600	V
$I_{F(RMS)}$	Forward rms current			180	A
$I_{F(AV)}$	Average forward current, $\delta = 0.5$	$T_c = 65$ °C	Per diode	100	A
		$T_c = 35$ °C	Per diode	120	A
I_{FSM}	Surge non repetitive forward current	$t_p = 10$ ms Sinusoidal		800	A
T_{stg}	Storage temperature range			-55 to + 150	°C
T_j	Maximum operating junction temperature			150	°C

Table 3. Thermal parameter

Symbol	Parameter		Maximum	Unit
$R_{th(j-c)}$	Junction to case	Per diode	0.60	°C/W
		Total	0.35	
$R_{th(c)}$	Coupling		0.1	

When the diodes 1 and 2 are used simultaneously:

$\Delta T_{j\ (diode1)} = P_{(diode1)} \times R_{th(j-c)\ (per\ diode)} + P_{(diode2)} \times R_{th(c)}$

Table 4. Static electrical characteristics (per diode)

Symbol	Parameter	Test conditions		Min.	Typ.	Max.	Unit
I_R(1)	Reverse leakage current	$T_j = 25$ °C	$V_R = V_{RRM}$			100	µA
		$T_j = 125$ °C			100	1000	
V_F(2)	Forward voltage drop	$T_j = 25$ °C	$I_F = 100$ A			1.55	V
		$T_j = 150$ °C			0.95	1.20	

1. Pulse test: $t_p = 5$ ms, $\delta < 2$ %
2. Pulse test: $t_p = 380$ µs, $\delta < 2$ %

To evaluate the maximum conduction losses use the following equation:
$P = 0.93 \times I_{F(AV)} + 0.0027\ I_F{}^2{}_{(RMS)}$

Table 5. Dynamic characteristics (per diode)

Symbol	Parameter	Test conditions		Min.	Typ.	Max.	Unit
t_{rr}	Reverse recovery time	T_j = 25 °C	I_F = 0.5 A, I_{rr} = 0.25 A, I_R = 1 A			80	ns
			I_F = 1 A, dI_F/dt = 50 A/µs, V_R = 30 V		85	120	
I_{RM}	Reverse recovery current	T_j = 125 °C	I_F = 100 A, dI_F/dt = 400 A/µs, dI_F/dt = 100 A/µs		15	20	A
t_{fr}	Forward recovery time	T_j = 25 °C	I_F = 100 A, dI_F/dt = 200 A/µs V_{FR} = 1.1 x V_{Fmax}			700	ns
V_{FP}	Forward recovery voltage	T_j = 25 °C	I_F = 100 A, dI_F/dt = 200 A/µs V_{FR} = 1.1 x V_{Fmax}		3.4		V

Figure 1. Conduction losses versus average forward current (per diode)

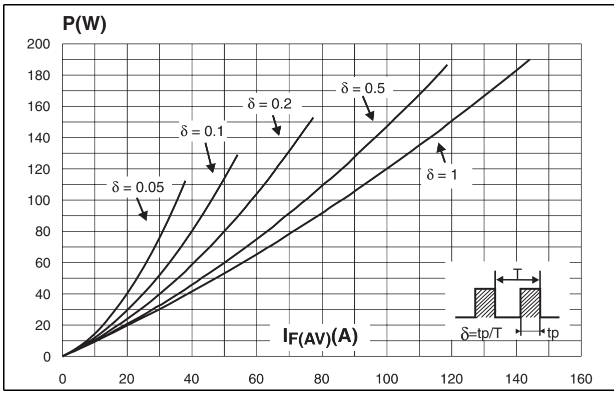


Figure 2. Forward voltage drop versus forward current (per diode)

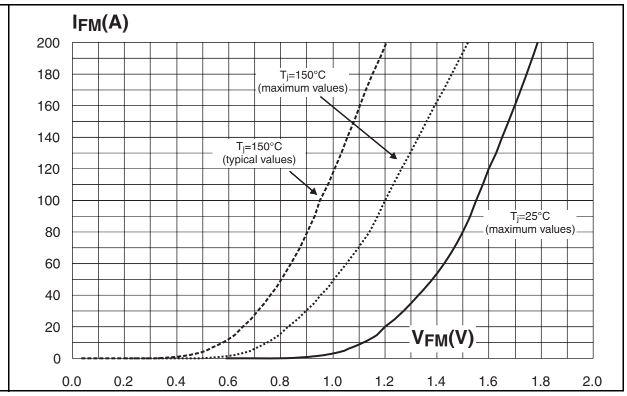


Figure 3. Relative variation of thermal impedance junction to case versus pulse duration

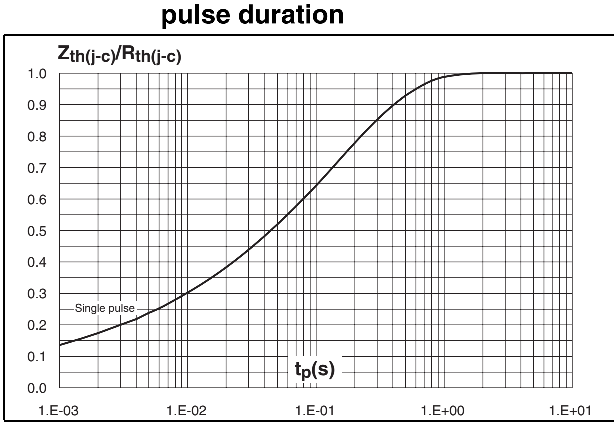


Figure 4. Peak reverse recovery current versus dI_F/dt (typical values, per diode)

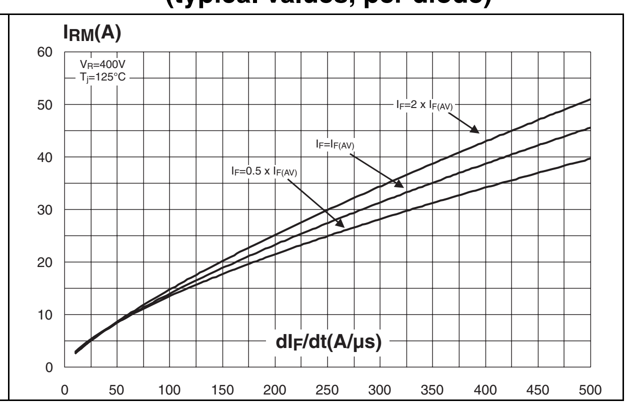


Figure 5. Reverse recovery time versus dI_F/dt (typical values, per diode)

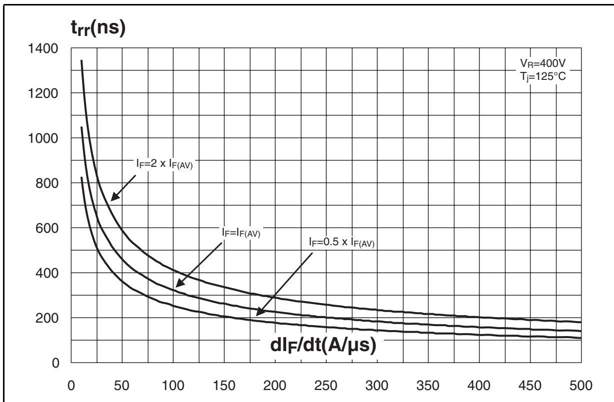


Figure 6. Reverse recovery charges versus dI_F/dt (typical values, per diode)

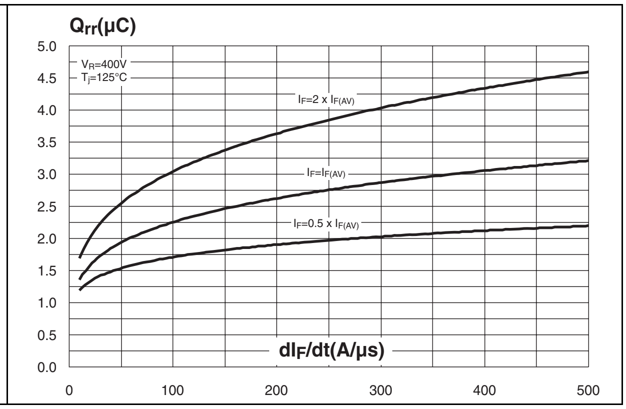


Figure 7. Reverse recovery softness factor versus dI_F/dt (typical values, per diode)

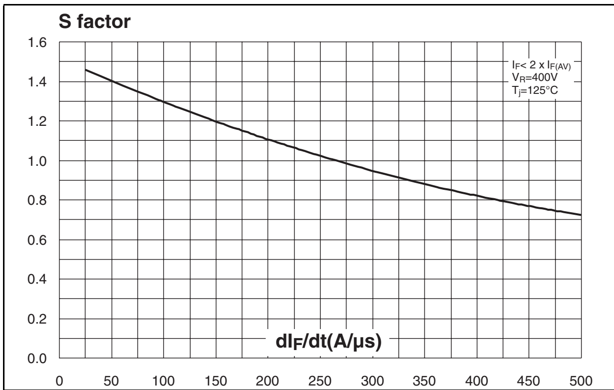


Figure 8. Relative variations of dynamic parameters versus junction temperature

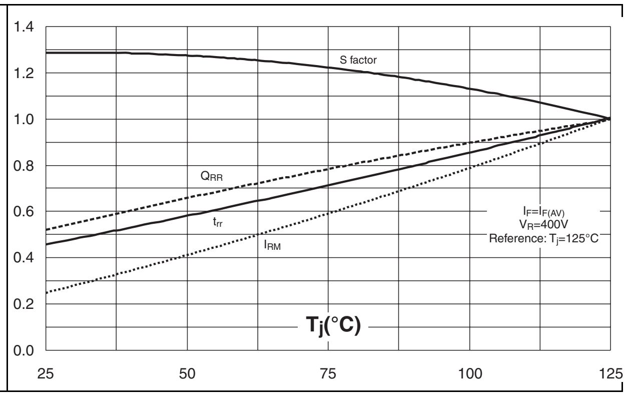


Figure 9. Transient peak forward voltage versus dI_F/dt (typical values, per diode)

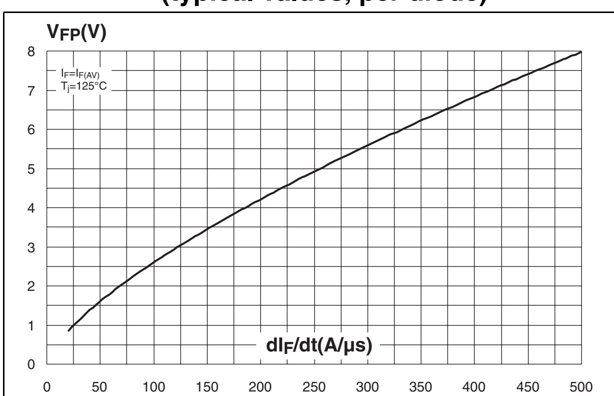


Figure 10. Forward recovery time versus dI_F/dt (typical values, per diode)

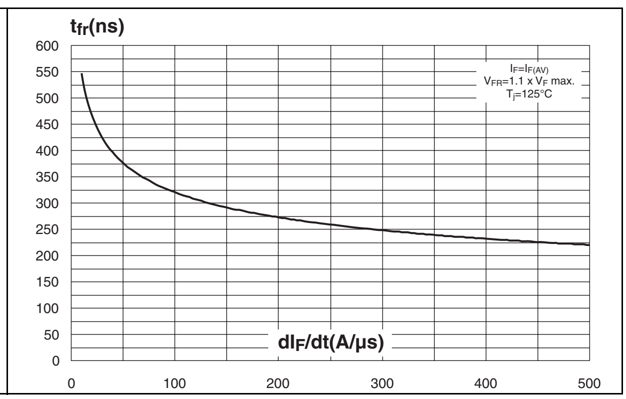
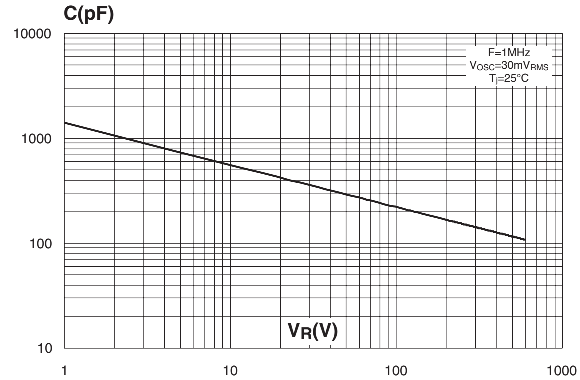


Figure 11. Junction capacitance versus reverse voltage applied (typical values, per diode)

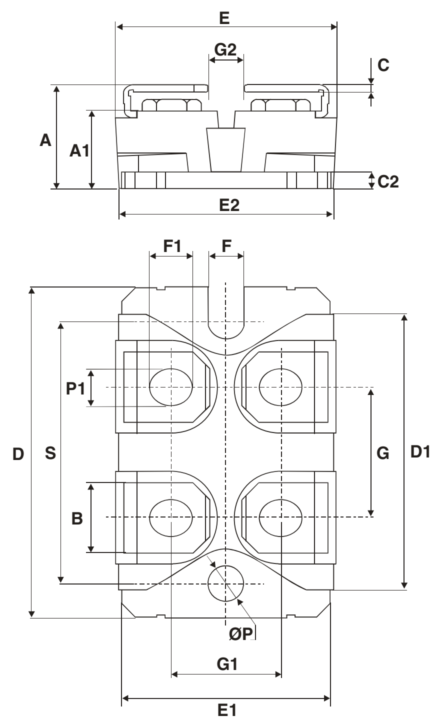


2 Package information

- Epoxy meets UL94, V0
- Cooling method: by conduction (C)

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: www.st.com. ECOPACK® is an ST trademark.

Table 6. ISOTOP dimensions



Ref.	Dimensions			
	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	11.80	12.20	0.465	0.480
A1	8.90	9.10	0.350	0.358
B	7.8	8.20	0.307	0.323
C	0.75	0.85	0.030	0.033
C2	1.95	2.05	0.077	0.081
D	37.80	38.20	1.488	1.504
D1	31.50	31.70	1.240	1.248
E	25.15	25.50	0.990	1.004
E1	23.85	24.15	0.939	0.951
E2	24.80 typ.		0.976 typ.	
G	14.90	15.10	0.587	0.594
G1	12.60	12.80	0.496	0.504
G2	3.50	4.30	0.138	0.169
F	4.10	4.30	0.161	0.169
F1	4.60	5.00	0.181	0.197
P	4.00	4.30	0.157	0.69
P1	4.00	4.40	0.157	0.173
S	30.10	30.30	1.185	1.193

3 Ordering information

Table 7. Ordering information

Order code	Marking	Package	Weight	Base qty	Delivery mode
STTH200L06TV1	STTH200L06TV1	ISOTOP	27 g (without screws)	10 (with screws)	Tube

4 Revision history

Table 8. Document revision history

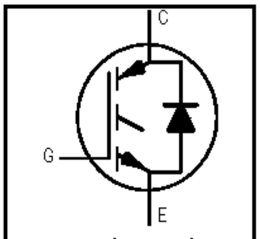
Date	Revision	Changes
07-Sep-2004	1	First issue.
05-Sep-2011	2	Updated *Figure 6.*

International
IOR Rectifier

PD- 95233

IRG4PF50WDPbF

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE



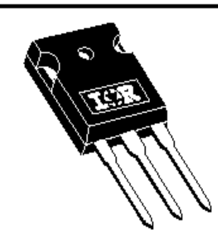
V_{CES} = 900V

$V_{CE(on)\ typ.}$ = 2.25V

@V_{GE} = 15V, I_C = 28A

Features

- Optimized for use in Welding and Switch-Mode Power Supply applications
- Industry benchmark switching losses improve efficiency of all power supply topologies
- 50% reduction of Eoff parameter
- Low IGBT conduction losses
- Latest technology IGBT design offers tighter parameter distribution coupled with exceptional reliability
- IGBT co-packaged with HEXFRED™ ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package
- **Lead-Free**


TO-247AC

Benefits

- Lower switching losses allow more cost-effective operation and hence efficient replacement of larger-die MOSFETs up to 100kHz
- HEXFRED™ diodes optimized for performance with IGBTs. Minimized recovery characteristics reduce noise, EMI and switching losses

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	900	V
I_C @ T_C = 25°C	Continuous Collector Current	51	A
I_C @ T_C = 100°C	Continuous Collector Current	28	
I_{CM}	Pulsed Collector Current ①	204	
I_{LM}	Clamped Inductive Load Current ②	204	
I_F @ T_C = 100°C	Diode Continuous Forward Current	16	
I_{FM}	Diode Maximum Forward Current	204	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	——	——	0.64	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	——	——	0.83	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	40	
Wt	Weight	——	6 (0.21)	——	g (oz)

04/30/04

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	900	—	—	V	V_{GE} = 0V, I_C = 250µA
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.295	—	V/°C	V_{GE} = 0V, I_C = 3.5mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.25	2.7	V	I_C = 28A, V_{GE} = 15V
		—	2.74	—		I_C = 60A, See Fig. 2, 5
		—	2.12	—		I_C = 28A, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		$V_{CE} = V_{GE}$, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	$V_{CE} = V_{GE}$, I_C = 250µA
g_{fe}	Forward Transconductance ④	26	39	—	S	V_{CE} = 50V, I_C = 28A
I_{CES}	Zero Gate Voltage Collector Current	—	—	500	µA	V_{GE} = 0V, V_{CE} = 900V
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C
		—	—	6.5	mA	V_{GE} = 0V, V_{CE} = 900V, T_J = 150°C
V_{FM}	Diode Forward Voltage Drop	—	2.5	3.5	V	I_C = 16A, See Fig. 13
		—	2.1	3.0		I_C = 16A, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	—	160	240	nC	I_C = 28A	
Q_{ge}	Gate - Emitter Charge (turn-on)	—	19	29		V_{CC} = 400V, See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	53	80		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	—	71	—	ns	T_J = 25°C	
t_r	Rise Time	—	50	—		I_C = 28A, V_{CC} = 720V	
$t_{d(off)}$	Turn-Off Delay Time	—	150	220		V_{GE} = 15V, R_G = 5.0Ω	
t_f	Fall Time	—	110	170		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	—	2.63	—	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	—	1.34	—		See Fig. 9, 10, 18	
E_{ts}	Total Switching Loss	—	3.97	5.3			
$t_{d(on)}$	Turn-On Delay Time	—	69	—	ns	T_J = 150°C, See Fig. 11, 18	
t_r	Rise Time	—	52	—		I_C = 28A, V_{CC} = 720V	
$t_{d(off)}$	Turn-Off Delay Time	—	270	—		V_{GE} = 15V, R_G = 5.0Ω	
t_f	Fall Time	—	190	—		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	—	6.0	—	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	—	3300	—	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	—	200	—		V_{CC} = 30V, See Fig. 7	
C_{res}	Reverse Transfer Capacitance	—	45	—		f = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	—	90	135	ns	T_J = 25°C, See Fig. 14	
		—	164	245		T_J = 125°C	I_F = 16A
I_{rr}	Diode Peak Reverse Recovery Current	—	5.8	10	A	T_J = 25°C, See Fig. 15	
		—	8.3	15		T_J = 125°C	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	260	675	nC	T_J = 25°C, See Fig. 16	
		—	680	1838		T_J = 125°C	di/dt = 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	—	120	—	A/µs	T_J = 25°C, See Fig. 17	
		—	76	—		T_J = 125°C	

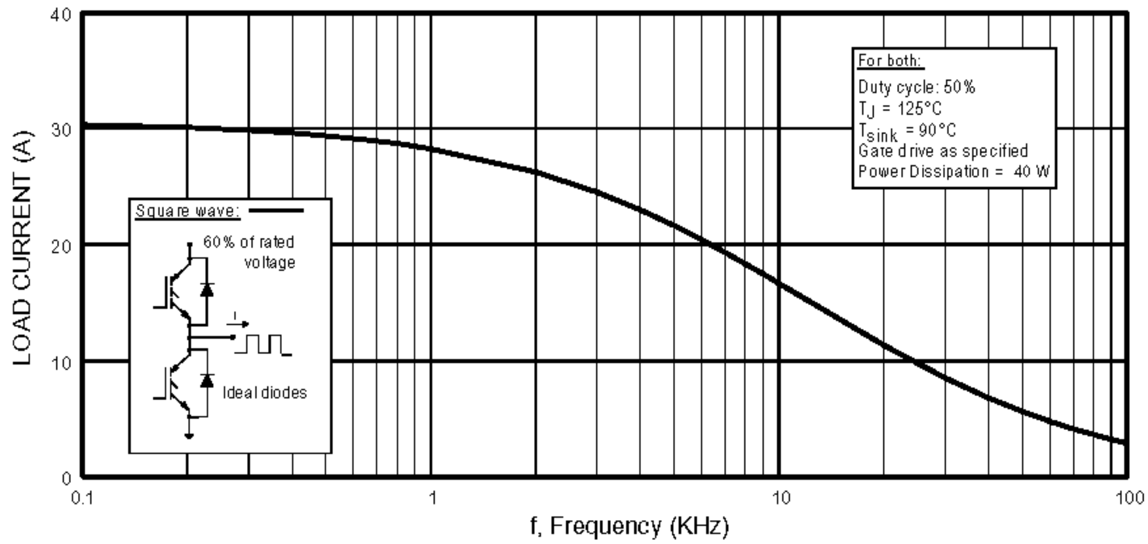


Fig. 1 - Typical Load Current vs. Frequency
(Load Current = I_{RMS} of fundamental)

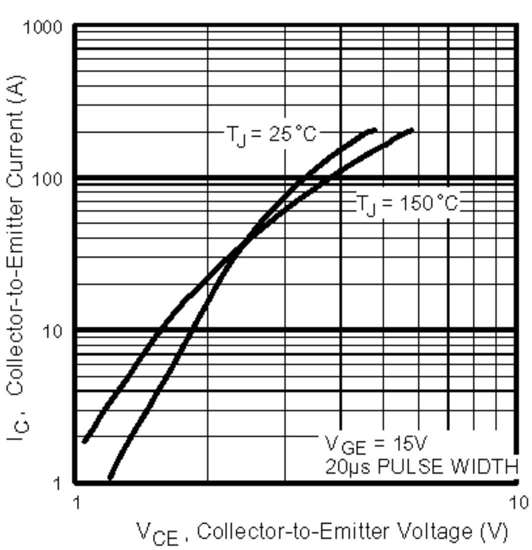


Fig. 2 - Typical Output Characteristics

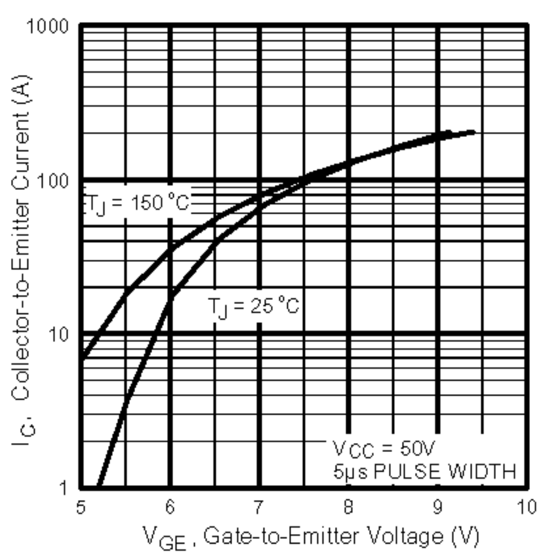


Fig. 3 - Typical Transfer Characteristics

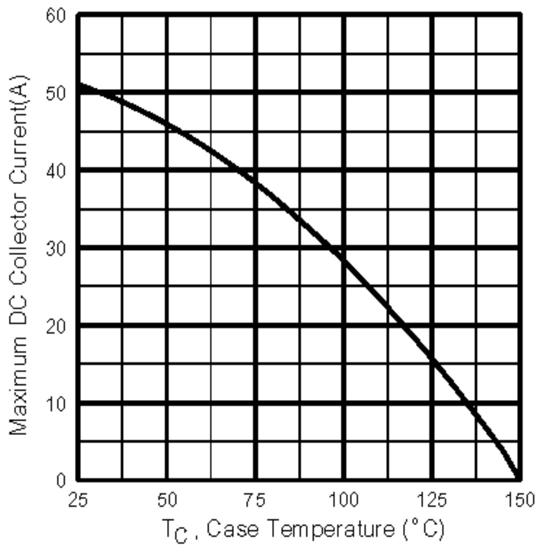


Fig. 4 - Maximum Collector Current vs. Case Temperature

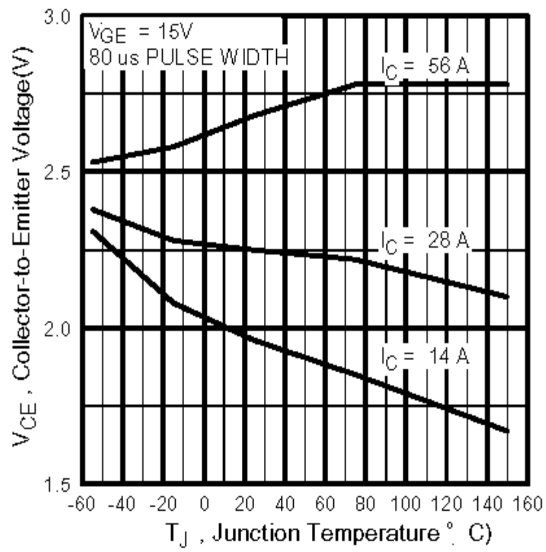


Fig. 5 - Collector-to-Emitter Voltage vs. Junction Temperature

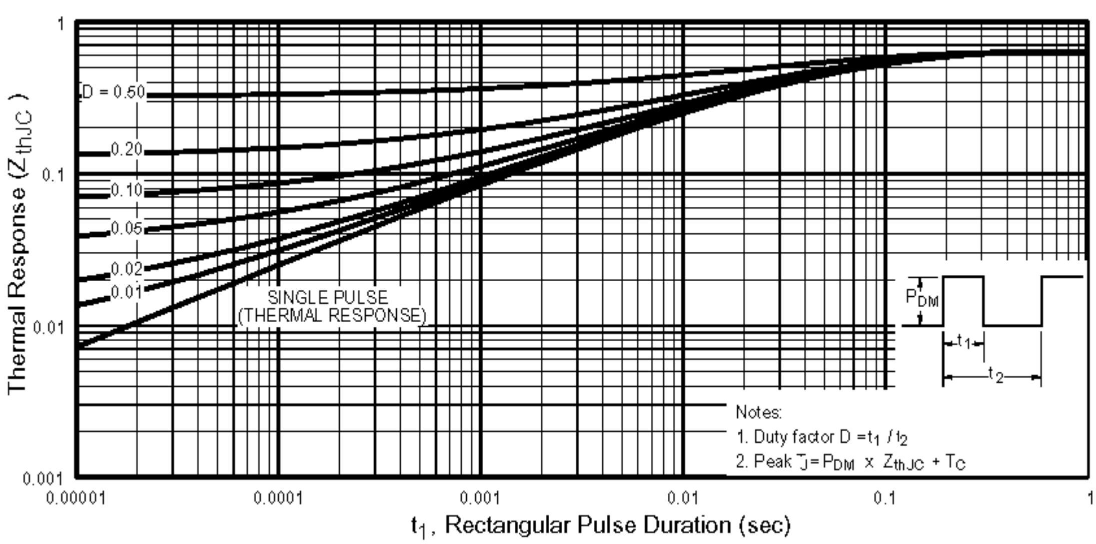


Fig. 6 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

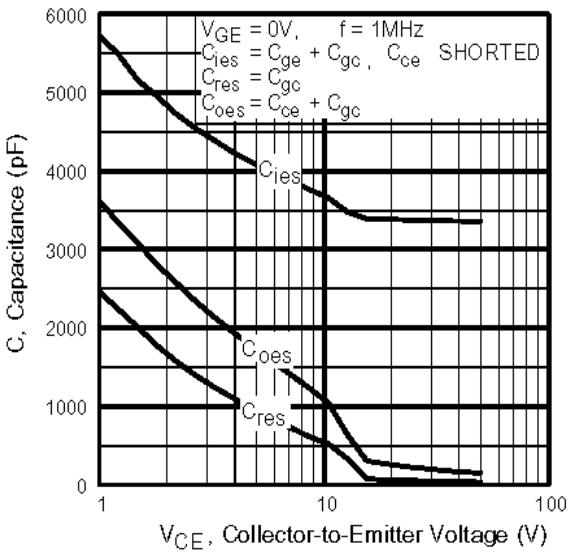


Fig. 7 - Typical Capacitance vs. Collector-to-Emitter Voltage

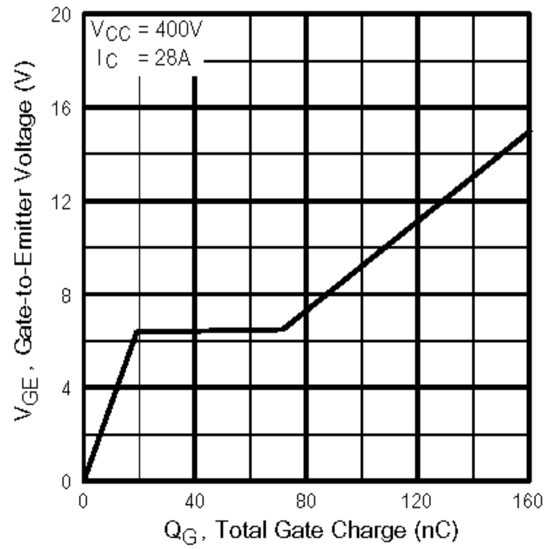


Fig. 8 - Typical Gate Charge vs. Gate-to-Emitter Voltage

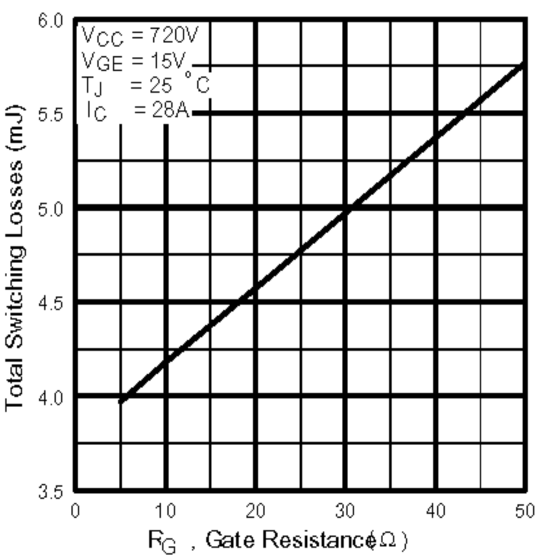


Fig. 9 - Typical Switching Losses vs. Gate Resistance

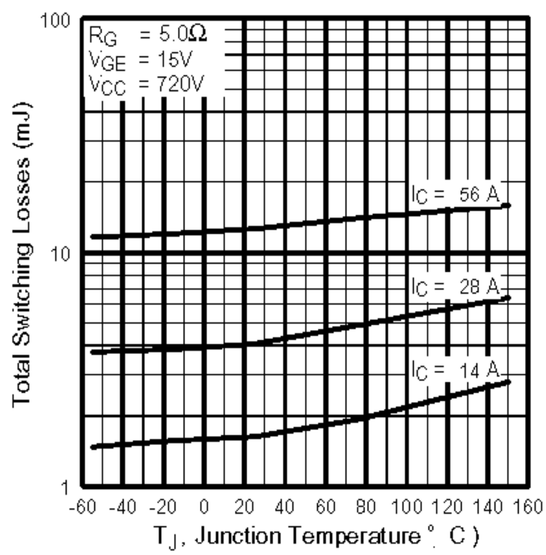


Fig. 10 - Typical Switching Losses vs. Junction Temperature

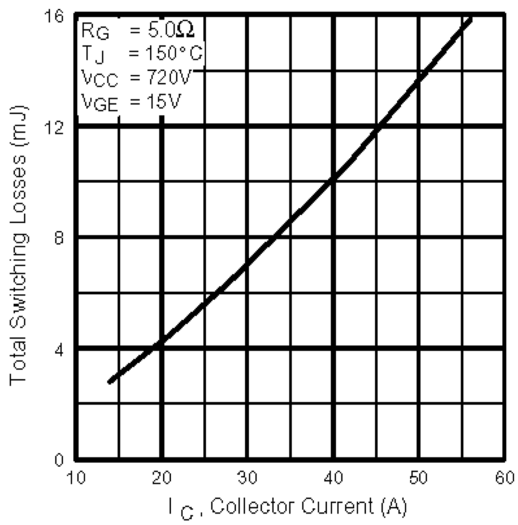


Fig. 11 - Typical Switching Losses vs. Collector-to-Emitter Current

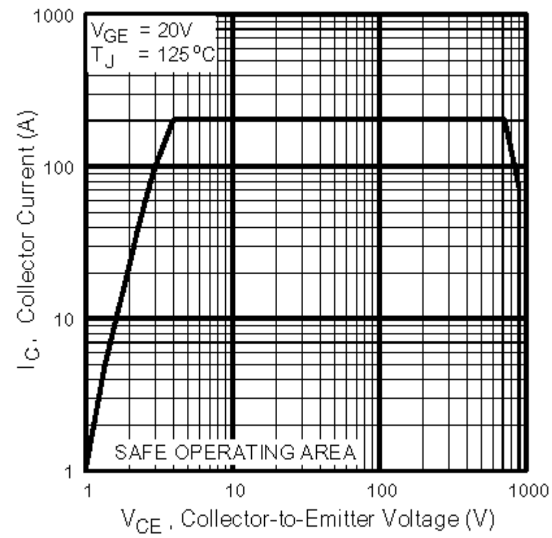


Fig. 12 - Turn-Off SOA

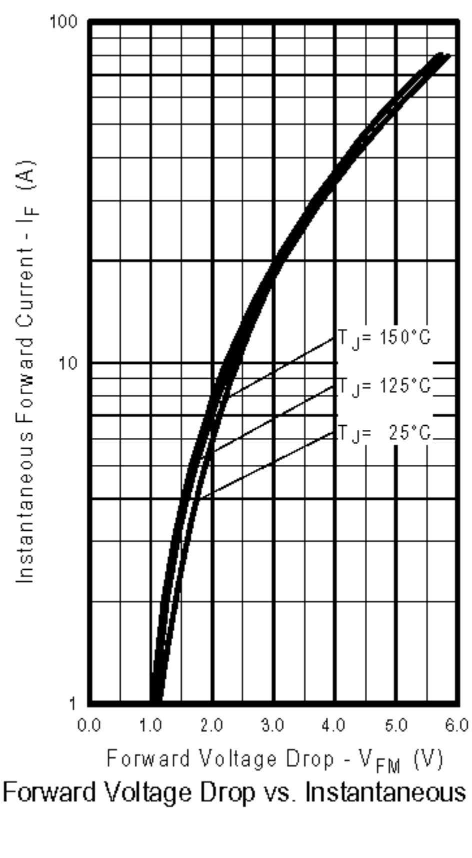


Fig. 13 - Typical Forward Voltage Drop vs. Instantaneous Forward Current

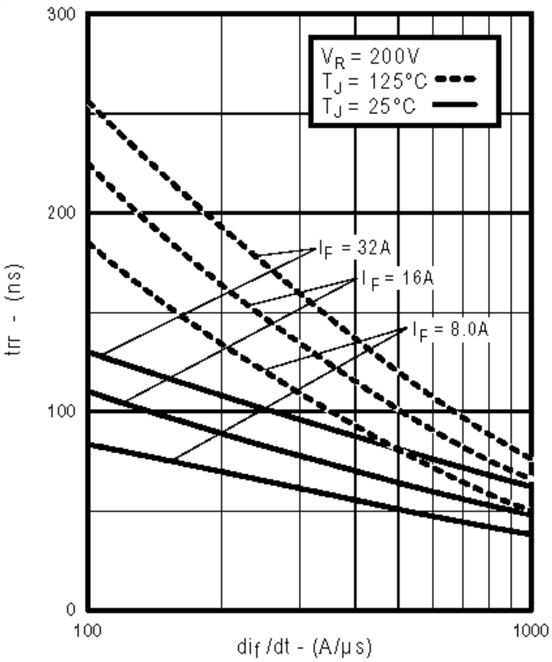


Fig. 14 - Typical Reverse Recovery vs. di_f/dt

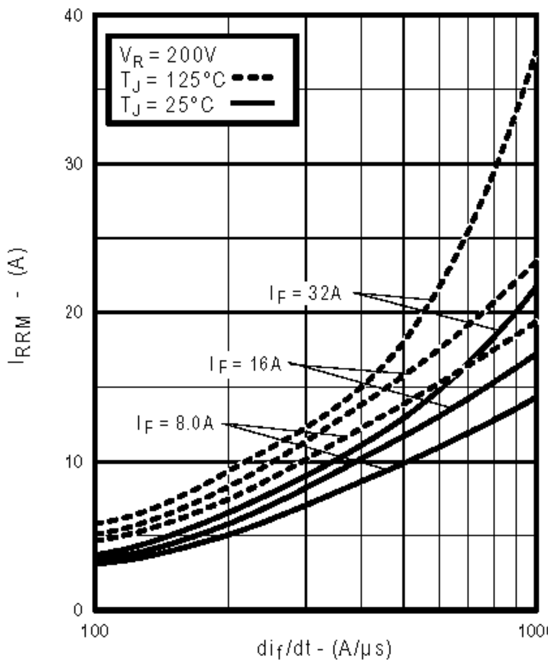


Fig. 15 - Typical Recovery Current vs. di_f/dt

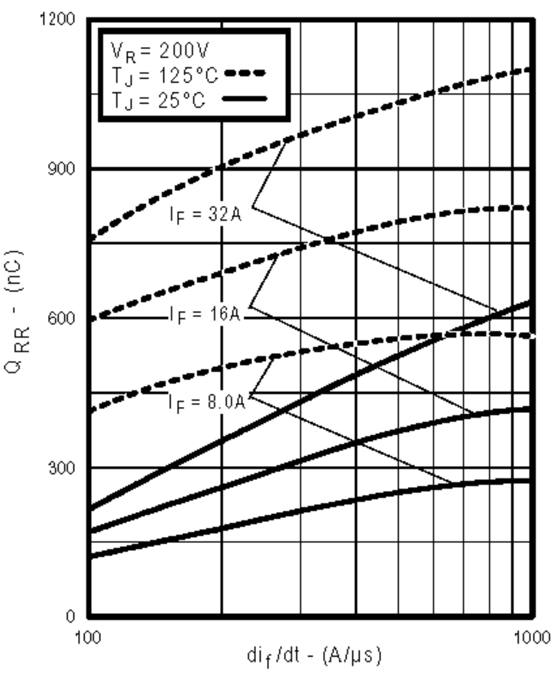


Fig. 16 - Typical Stored Charge vs. di_f/dt

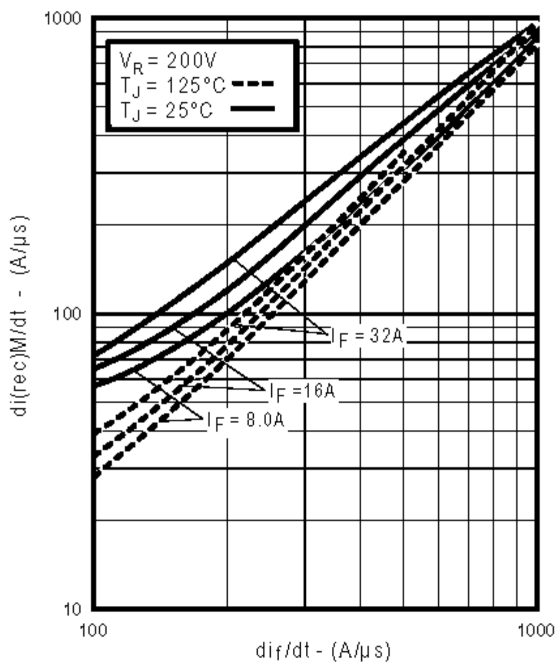


Fig. 17 - Typical $di_{(rec)M}/dt$ vs. di_f/dt

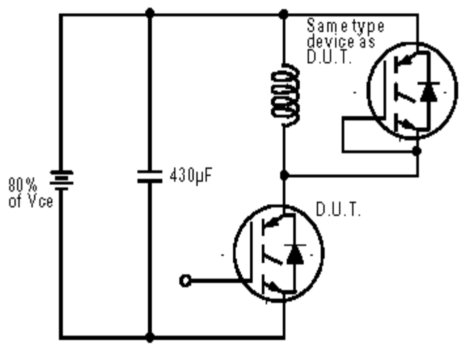


Fig. 18a - Test Circuit for Measurement of I_{LM}, E_{on}, $E_{off(diode)}$, t_{rr}, Q_{rr}, I_{rr}, $t_{d(on)}$, t_r, $t_{d(off)}$, t_f

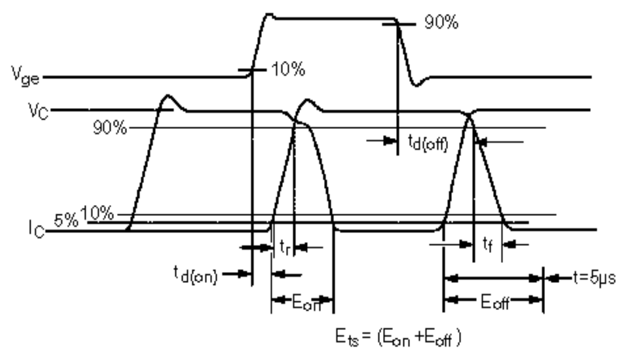


Fig. 18b - Test Waveforms for Circuit of Fig. 18a, Defining E_{off}, $t_{d(off)}$, t_f

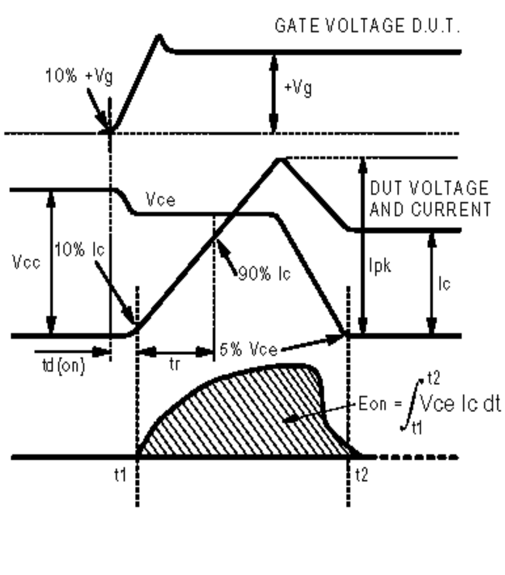


Fig. 18c - Test Waveforms for Circuit of Fig. 18a, Defining E_{on}, $t_{d(on)}$, t_r

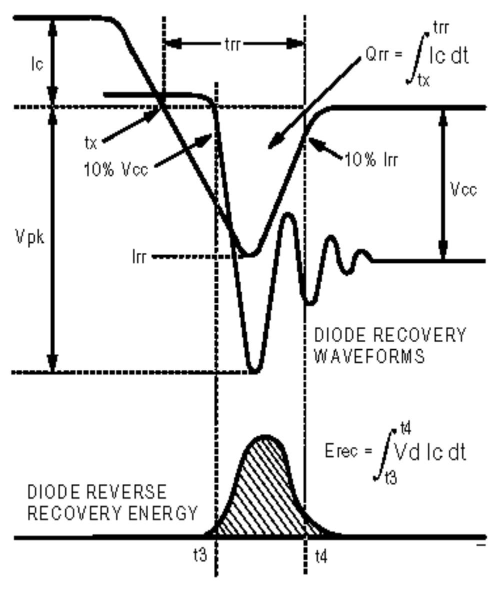


Fig. 18d - Test Waveforms for Circuit of Fig. 18a, Defining E_{rec}, t_{rr}, Q_{rr}, I_{rr}

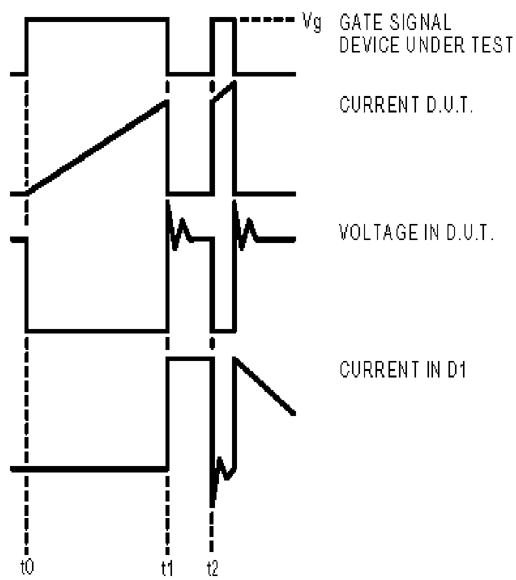


Figure 18e. Macro Waveforms for Figure 18a's Test Circuit

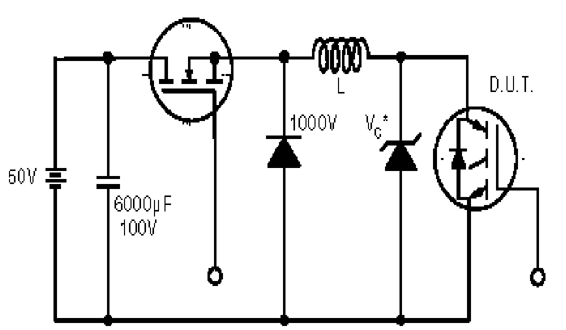


Figure 19. Clamped Inductive Load Test Circuit

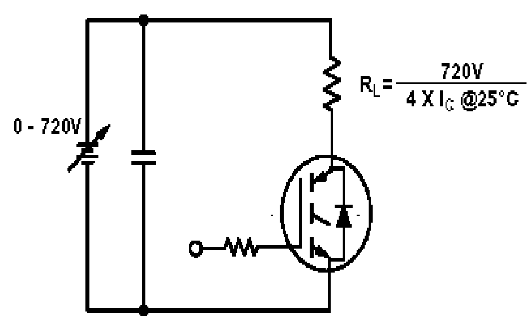
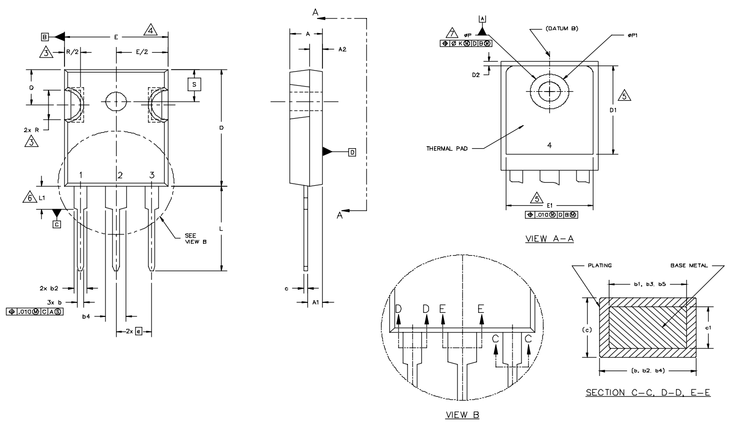


Figure 20. Pulsed Collector Current Test Circuit

TO-247AC Package Outline

Dimensions are shown in millimeters (inches)



NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M 1994.
2. DIMENSIONS ARE SHOWN IN INCHES [MILLIMETERS]
3. CONTOUR OF SLOT OPTIONAL.
4. DIMENSION D & E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED .005" (0.127) PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTERMOST EXTREMES OF THE PLASTIC BODY.
5. THERMAL PAD CONTOUR OPTIONAL WITHIN DIMENISONS D1 & E1.
6. LEAD FINISH UNCONTROLLED IN L1.
7. øP TO HAVE A MAXIMUM DRAFT ANGLE OF 1.5 ° TO THE TOP OF THE PART WITH A MAXIMUM HOLE DIAMETER OF .154" [3.91].
8. OUTLINE CONFORMS TO JEDEC OUTLINE TO-247 WITH THE EXCEPTION OF DIMENSION c

SYMBOL	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN.	MAX.	MIN.	MAX.	
A	.183	.209	4.65	5.31	
A1	.087	.102	2.21	2.59	
A2	.059	.098	1.50	2.49	
b	.039	.055	0.99	1.40	
b1	.039	.053	0.99	1.35	
b2	.065	.094	1.65	2.39	
b3	.065	.092	1.65	2.37	
b4	.102	.135	2.59	3.43	
b5	.102	.133	2.59	3.38	
c	.015	.034	0.38	0.86	
c1	.015	.030	0.38	0.76	
D	.776	.815	19.71	20.70	4
D1	.515	–	13.08	–	5
D2	.020	.030	0.51	0.76	
E	.602	.625	15.29	15.87	4
E1	.540	–	15.72	–	
e	.215 BSC		5.46 BSC		
øk	.010		2.54		
L	.559	.634	14.20	16.10	
L1	.146	.169	3.71	4.29	
N	3		7.62 BSC		
øP	.140	.144	3.56	3.66	
øP1	–	.275	–	6.98	
Q	.209	.224	5.31	5.69	
R	.178	.216	4.52	5.49	
S	.217 BSC		5.51 BSC		

LEAD ASSIGNMENTS

HEXFET
1 – GATE
2.– DRAIN
3.– SOURCE
4 – DRAIN

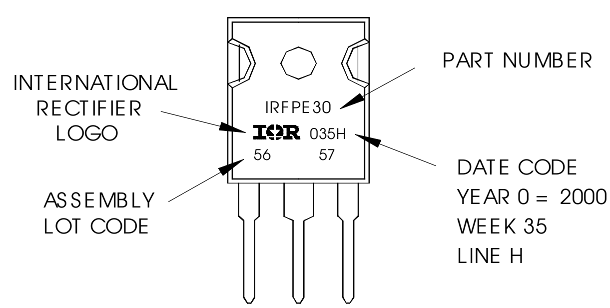
IGBTs, CoPACK
1.– GATE
2.– COLLECTOR
3.– EMITTER
4 – COLLECTOR

DIODES
1.– ANODE/OPEN
2.– CATHODE
3 – ANODE

TO-247AC Part Marking Information

EXAMPLE: THIS IS AN IRFPE30
WITH ASSEMBLY
LOT CODE 5657
ASSEMBLED ON WW 35, 2000
IN THE ASSEMBLY LINE "H"

Note: "P" in assembly line position indicates "Lead-Free"



Data and specifications subject to change without notice.

International
IOR Rectifier

IR WORLD HEADQUARTERS: 233 Kansas St., El Segundo, California 90245, USA Tel: (310) 252-7105
TAC Fax: (310) 252-7903
Visit us at www.irf.com for sales contact information. 04/04

Note: For the most current drawings please refer to the IR website at:
http://www.irf.com/package/

89 Series

Metal-Mite® Aluminum Housed Axial Term. Wirewound, 1% Tolerance

The 89 Series is a high-performance axial type resistor. These molded-construction metal-housed resistors are available in higher power ratings than standard axial resistors and are better suited to withstanding vibration, shock and harsh environmental conditions.

The 89 Series Metal-Mite® resistors are aluminum housed to maintain high stability during operation and to permit secure mounting to chassis surfaces.

The metal housing also provides heat-sinking capabilities.

FEATURES

- High Stability: ±0.5% ΔR.
- High power to size ratio.
- Metal housing allows chassis mounting and provides heat sink capability.

As of September 2006, the 89 Series is no longer offered as Mil. Spec.

SPECIFICATIONS

Material

Housing: Metal, anodized aluminum.

Internal Coating: Silicone.

Core: Ceramic.

Terminals: Solder-coated axial.

Derating: Linearly from 100% @ +25°C to 0% @ +275°C.

Electrical

Tolerance: ±1% and ±5% (other tolerances available).

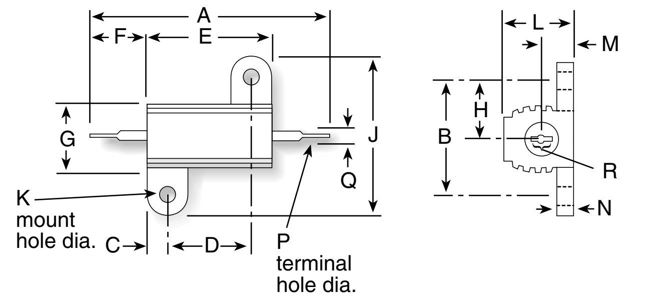
Power rating: Rating is based on chassis mounting area and temperature stability. Proper heat sink as follows: 5W and 10W units, 4” x 6” x 2” x .040” Aluminum chassis; 25W units, 5” x 7” x 2” x .040” Aluminum chassis; 50W units, 12” x 12” x .059” Aluminum panel.

Maximum ohmic values: See chart.

Overload: 5 times rated wattage for 5 seconds.

Temperature coefficient:
Under 1Ω: ±90 ppm/°C
1 to 9.99Ω: ±50 ppm/°C
10Ω and over: ±20 ppm/°C.

Dielectric withstanding voltage: 5W and 10W rating,1000 VAC; 25 and 50W ratings, 2250 VAC.



Series	Wattage	Ohms	Voltage
805	5	0.10-25K	210
810	10	0.10-50K	320
825	25	0.005-75K	520
850	50	0.005-100K	1170

Non-Inductive versions available. Insert “N” before tolerance code. Example: 850NF560

	5 watt	10 watt	25 watt	50 watt
Series (Industrial)	**805**	**810**	**825**	**850**
Dimensions				
Dim. A (in. ±0.062 / mm ±1.57)	1.125 / 28.59	1.375 / 34.93	1.938 / 49.23	2.781 / 70.64
Dim. B (in. ±0.010 / mm ±0.25)	0.490 / 12.45	0.625 / 15.88	0.781 / 19.84	0.844 / 21.44
Dim. C (in. ±0.031 / mm ±0.79)	0.078 / 1.98	0.094 / 2.39	0.172 / 4.37	0.188 / 4.78
Dim. D (in. ±0.010 / mm ±0.25)	0.444 / 11.28	0.562 / 14.28	0.719 / 18.26	1.562 / 39.68
Dim. E (in. ±0.062 / mm ±1.57)	0.600 / 15.24	0.750 / 19.05	1.062 / 26.98	1.938 / 49.23
Dim. F (in. ±0.062 / mm ±1.57)	0.266 / 6.76	0.312 / 7.93	0.438 / 11.13	0.438 / 11.13
Dim. G (in. ±0.062 / mm ±1.57)	0.334 / 8.48	0.438 / 11.13	0.531 / 13.49	0.594 / 15.09
Dim. H (in. ±0.031 / mm ±0.79)	0.245 / 6.22	0.312 / 7.93	0.391 / 9.93	0.422 / 10.72
Dim. J (in. ±0.031 / mm ±0.79)	0.646 / 16.41	0.812 / 20.63	1.094 / 27.79	1.156 / 29.36
Dim. K (in. ±0.005 / mm ±0.13)	0.093 / 2.36	0.094 / 2.39	0.125 / 3.18	0.125 / 3.18
Dim. L (in. ±0.031 / mm ±0.79)	0.320 / 8.13	0.406 / 10.31	0.562 / 14.28	0.625 / 15.88
Dim. M (in. ±0.062 / mm ±1.57)	0.133 / 3.38	0.203 / 5.16	0.281 / 7.14	0.312 / 7.92
Dim. N (in. ±0.031 / mm ±0.79)	0.065 / 1.65	0.094 / 2.39	0.094 / 2.39	0.094 / 2.39
Dim. P (in. ±0.005 / mm ±0.13)	0.050 / 1.27	0.085 / 2.16	0.085 / 2.16	0.085 / 2.16
Q min AWG	16	12	12	12
Dim. R (in., min/mm, min)	0.085/ 2.16	0.140/ 3.56	0.140/ 3.56	0.140/ 3.56

ORDERING INFORMATION

Non-Inductive Winding
Optional (blank = std. winding)

805 N F 5R0 E

Series
805 = 5 Watt
810 = 10 watt
825 = 25 watt
850 = 50 watt

Tolerance
F = 1%
J = 5%

Ohms
R005= 0.005Ω
R10 = 0.1Ω
1R0 = 1.0Ω
250 = 250Ω
1K0 = 1,000Ω
1K5 = 1,500Ω
25K = 25,000Ω

RoHS
Compliant

STANDARD PART NUMBERS

Ohmic value	Part No. Suffix	805F (5 W)	810F (10 W)	825F (25 W)	850F (50 W)
0.005	R005			✔	✔
0.010	R010			✔	✔
0.025	R025			✔	✔
0.1	R10			✔	✔
0.3	R30			✔	✜
0.5	R50			✔	✜
0.7	R70			✜	✜
1.0	1R0	✔	✔	✔	✔
1.5	1R5	✜	✔		
2.0	2R0	✜	✔	✔	✔
3.0	3R0	✔	✔	✔	✔
4.0	4R0	✜	✔		
5.0	5R0	✔	✔	✔	✔
10.0	10R	✔	✔	✔	✔
15.0	15R	✔	✔	✔	✔

Ohmic value	Part No. Suffix	805F (5 W)	810F (10 W)	825F (25 W)	850F (50 W)
20	20R	✔	✔		
25	25R	✔	✔	✔	✔
30	30R	✜	✜		
40	40R	✜	✔		
50	50R	✔	✔	✔	✔
75	75R	✔	✜	✔	✔
100	100	✔	✔	✔	✔
150	150	✔	✔	✔	✔
200	200	✜	✜	✔	✔
250	250	✔	✔	✔	✔
300	300	✔	✜		
400	400	✜	✜		
500	500	✔	✜	✔	✔
750	750	✜	✜	✔	✔
1,000	1K0	✜	✔	✔	✔

Ohmic value	Part No. Suffix	805F (5 W)	810F (10 W)	825F (25 W)	850F (50 W)
1,500	1K5	✔	✜	✜	✔
2,000	2K0	✔	✔	✜	✜
2,500	2K5	✔	✔		
3,000	3K0	✜	✔	✔	✜
3,500	3K5	✜	✜		
4,000	4K0	✔	✔		
4,500	4K5	✜	✜		
5,000	5K0	✔	✔	✔	✔
6,000	6K0	✜	✜		
10,000	10K	✔	✜	✔	✔
15,000	15K	✔	✔	✜	✜
20,000	20K	✜	✜		
25,000	25K	✔	✜	✜	✜
50,000	50K		✜		
75,000	75K			✜	
100,000	100K				✜

✔ = Standard values
✜ = Non-standard values subject to minimum handling charge per item

Shaded values involve very fine resistance wire and should not be used in critical applications without burn-in and/or thermal cycling.

Check product availability at **www.ohmite.com**

MC34071,2,4,A
MC33071,2,4,A

Single Supply 3.0 V to 44 V Operational Amplifiers

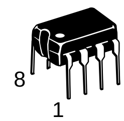
Quality bipolar fabrication with innovative design concepts are employed for the MC33071/72/74, MC34071/72/74 series of monolithic operational amplifiers. This series of operational amplifiers offer 4.5 MHz of gain bandwidth product, 13 V/μs slew rate and fast settling time without the use of JFET device technology. Although this series can be operated from split supplies, it is particularly suited for single supply operation, since the common mode input voltage range includes ground potential (V_{EE}). With a Darlington input stage, this series exhibits high input resistance, low input offset voltage and high gain. The all NPN output stage, characterized by no deadband crossover distortion and large output voltage swing, provides high capacitance drive capability, excellent phase and gain margins, low open loop high frequency output impedance and symmetrical source/sink AC frequency response.

The MC33071/72/74, MC34071/72/74 series of devices are available in standard or prime performance (A Suffix) grades and are specified over the commercial, industrial/vehicular or military temperature ranges. The complete series of single, dual and quad operational amplifiers are available in plastic DIP, SOIC and TSSOP surface mount packages.

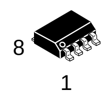
- Wide Bandwidth: 4.5 MHz
- High Slew Rate: 13 V/μs
- Fast Settling Time: 1.1 μs to 0.1%
- Wide Single Supply Operation: 3.0 V to 44 V
- Wide Input Common Mode Voltage Range: Includes Ground (V_{EE})
- Low Input Offset Voltage: 3.0 mV Maximum (A Suffix)
- Large Output Voltage Swing: –14.7 V to +14 V (with ±15 V Supplies)
- Large Capacitance Drive Capability: 0 pF to 10,000 pF
- Low Total Harmonic Distortion: 0.02%
- Excellent Phase Margin: 60°
- Excellent Gain Margin: 12 dB
- Output Short Circuit Protection
- ESD Diodes/Clamps Provide Input Protection for Dual and Quad

ON Semiconductor™

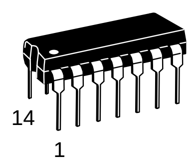
http://onsemi.com



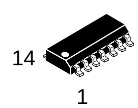
PDIP–8
P SUFFIX
CASE 626



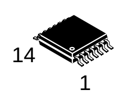
SO–8
D SUFFIX
CASE 751



PDIP–14
P SUFFIX
CASE 646



SO–14
D SUFFIX
CASE 751A



TSSOP–14
DTB SUFFIX
CASE 948G

ORDERING INFORMATION

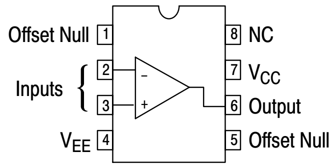
See detailed ordering and shipping information in the package dimensions section on page 17 of this data sheet.

DEVICE MARKING INFORMATION

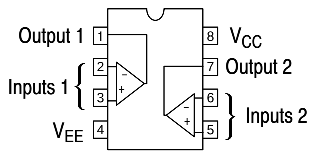
See general marking information in the device marking section on page 18 of this data sheet.

PIN CONNECTIONS

CASE 626/CASE 751

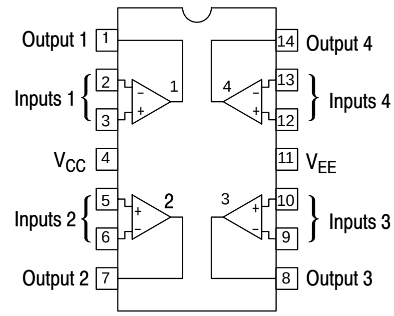


(Single, Top View)



(Dual, Top View)

CASE 646/CASE 751A/CASE 948G



(Quad, Top View)

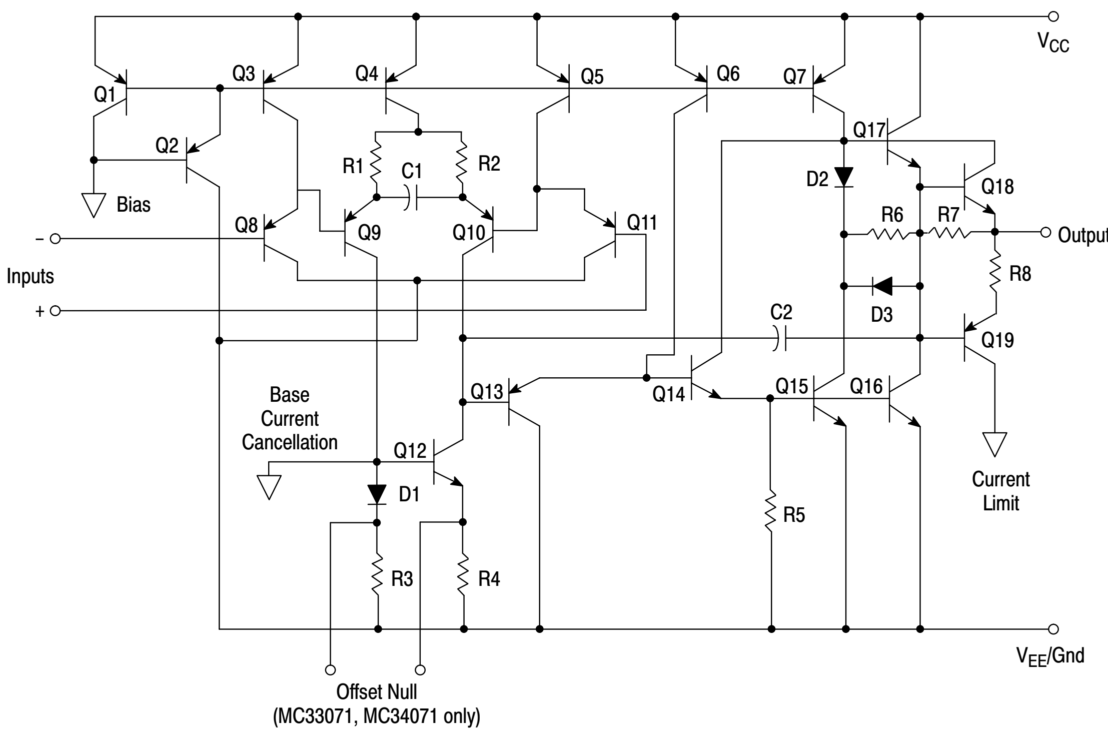


Figure 1. Representative Schematic Diagram
(Each Amplifier)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage (from V_{EE} to V_{CC})	V_S	+44	V
Input Differential Voltage Range	V_{IDR}	Note 1	V
Input Voltage Range	V_{IR}	Note 1	V
Output Short Circuit Duration (Note 2)	t_{SC}	Indefinite	sec
Operating Junction Temperature	T_J	+150	°C
Storage Temperature Range	T_{stg}	–60 to +150	°C

1. Either or both input voltages should not exceed the magnitude of V_{CC} or V_{EE}.
2. Power dissipation must be considered to ensure maximum junction temperature (T_J) is not exceeded (see Figure 2).

ELECTRICAL CHARACTERISTICS (V_{CC} = +15 V, V_{EE} = –15 V, R_L = connected to ground, unless otherwise noted. See Note 3 for $T_A = T_{low}$ to T_{high})

Characteristics	Symbol	A Suffix			Non–Suffix			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage (R_S = 100 Ω, V_{CM} = 0 V, V_O = 0 V) V_{CC} = +15 V, V_{EE} = –15 V, T_A = +25°C V_{CC} = +5.0 V, V_{EE} = 0 V, T_A = +25°C V_{CC} = +15 V, V_{EE} = –15 V, $T_A = T_{low}$ to T_{high}	V_{IO}	 – – –	 0.5 0.5 –	 3.0 3.0 5.0	 – – –	 1.0 1.5 –	 5.0 5.0 7.0	mV
Average Temperature Coefficient of Input Offset Voltage R_S = 10 Ω, V_{CM} = 0 V, V_O = 0 V, $T_A = T_{low}$ to T_{high}	$\Delta V_{IO}/\Delta T$	–	10	–	–	10	–	µV/°C
Input Bias Current (V_{CM} = 0 V, V_O = 0 V) T_A = +25°C $T_A = T_{low}$ to T_{high}	I_{IB}	 – –	 100 –	 500 700	 – –	 100 –	 500 700	nA
Input Offset Current (V_{CM} = 0 V, V_O = 0V) T_A = +25°C $T_A = T_{low}$ to T_{high}	I_{IO}	 – –	 6.0 –	 50 300	 – –	 6.0 –	 75 300	nA
Input Common Mode Voltage Range T_A = +25°C $T_A = T_{low}$ to T_{high}	V_{ICR}	 V_{EE} to (V_{CC} –1.8) V_{EE} to (V_{CC} –2.2)			 V_{EE} to (V_{CC} –1.8) V_{EE} to (V_{CC} –2.2)			V
Large Signal Voltage Gain (V_O = ±10 V, R_L = 2.0 kΩ) T_A = +25°C $T_A = T_{low}$ to T_{high}	A_{VOL}	 50 25	 100 –	 – –	 25 20	 100 –	 – –	V/mV
Output Voltage Swing (V_{ID} = ±1.0 V) V_{CC} = +5.0 V, V_{EE} = 0 V, R_L = 2.0 kΩ, T_A = +25°C V_{CC} = +15 V, V_{EE} = –15 V, R_L = 10 kΩ, T_A = +25°C V_{CC} = +15 V, V_{EE} = –15 V, R_L = 2.0 kΩ, $T_A = T_{low}$ to T_{high}	V_{OH}	 3.7 13.6 13.4	 4.0 14 –	 – – –	 3.7 13.6 13.4	 4.0 14 –	 – – –	V
V_{CC} = +5.0 V, V_{EE} = 0 V, R_L = 2.0 kΩ, T_A = +25°C V_{CC} = +15 V, V_{EE} = –15 V, R_L = 10 kΩ, T_A = +25°C V_{CC} = +15 V, V_{EE} = –15 V, R_L = 2.0 kΩ, $T_A = T_{low}$ to T_{high}	V_{OL}	– – –	0.1 –14.7 –	0.3 –14.3 –13.5	– – –	0.1 –14.7 –	0.3 –14.3 –13.5	V
Output Short Circuit Current (V_{ID} = 1.0 V, V_O = 0 V, T_A = 25°C) Source Sink	I_{SC}	 10 20	 30 30	 – –	 10 20	 30 30	 – –	mA
Common Mode Rejection $R_S \le$ 10 kΩ, $V_{CM} = V_{ICR}$, T_A = 25°C	CMR	80	97	–	70	97	–	dB
Power Supply Rejection (R_S = 100 Ω) V_{CC}/V_{EE} = +16.5 V/–16.5 V to +13.5 V/–13.5 V, T_A = 25°C	PSR	80	97	–	70	97	–	dB
Power Supply Current (Per Amplifier, No Load) V_{CC} = +5.0 V, V_{EE} = 0 V, V_O = +2.5 V, T_A = +25°C V_{CC} = +15 V, V_{EE} = –15 V, V_O = 0 V, T_A = +25°C V_{CC} = +15 V, V_{EE} = –15 V, V_O = 0 V, $T_A = T_{low}$ to T_{high}	I_D	 – – –	 1.6 1.9 –	 2.0 2.5 2.8	 – – –	 1.6 1.9 –	 2.0 2.5 2.8	mA

3. T_{low} = –40°C for MC33071, 2, 4, /A; = 0°C for MC34071, 2, 4, /A; = –40°C for MC34072, 4/V
T_{high} = +85°C for MC33071, 2, 4, /A; = +70°C for MC34071, 2, 4, /A; = +125°C for MC34072, 4/V

AC ELECTRICAL CHARACTERISTICS (V_{CC} = +15 V, V_{EE} = –15 V, R_L = connected to ground. T_A = +25°C, unless otherwise noted.)

Characteristics	Symbol	A Suffix			Non–Suffix			Unit
		Min	Typ	Max	Min	Typ	Max	
Slew Rate (V_{in} = –10 V to +10 V, R_L = 2.0 kΩ, C_L = 500 pF)	SR							V/µs
A_V = +1.0		8.0	10	–	8.0	10	–	
A_V = –1.0		–	13	–	–	13	–	
Setting Time (10 V Step, A_V = –1.0)	t_s							µs
To 0.1% (+1/2 LSB of 9–Bits)		–	1.1	–	–	1.1	–	
To 0.01% (+1/2 LSB of 12–Bits)		–	2.2	–	–	2.2	–	
Gain Bandwidth Product (f = 100 kHz)	GBW	3.5	4.5	–	3.5	4.5	–	MHz
Power Bandwidth A_V = +1.0, R_L = 2.0 kΩ, V_O = 20 V_{pp}, THD = 5.0%	BW	–	160	–	–	160	–	kHz
Phase margin	f_m							Deg
R_L = 2.0 kΩ		–	60	–	–	60	–	
R_L = 2.0 kΩ, C_L = 300 pF		–	40	–	–	40	–	
Gain Margin	A_m							dB
R_L = 2.0 kΩ		–	12	–	–	12	–	
R_L = 2.0 kΩ, C_L = 300 pF		–	4.0	–	–	4.0	–	
Equivalent Input Noise Voltage R_S = 100 Ω, f = 1.0 kHz	e_n	–	32	–	–	32	–	$nV/\sqrt{Hz}$
Equivalent Input Noise Current f = 1.0 kHz	i_n	–	0.22	–	–	0.22	–	$pA/\sqrt{Hz}$
Differential Input Resistance V_{CM} = 0 V	R_{in}	–	150	–	–	150	–	MΩ
Differential Input Capacitance V_{CM} = 0 V	C_{in}	–	2.5	–	–	2.5	–	pF
Total Harmonic Distortion A_V = +10, R_L = 2.0 kΩ, 2.0 V_{pp} ≤ V_O ≤ 20 V_{pp}, f = 10 kHz	THD	–	0.02	–	–	0.02	–	%
Channel Separation (f = 10 kHz)	–	–	120	–	–	120	–	dB
Open Loop Output Impedance (f = 1.0 MHz)	$\lvert Z_O \rvert$	–	30	–	–	30	–	W

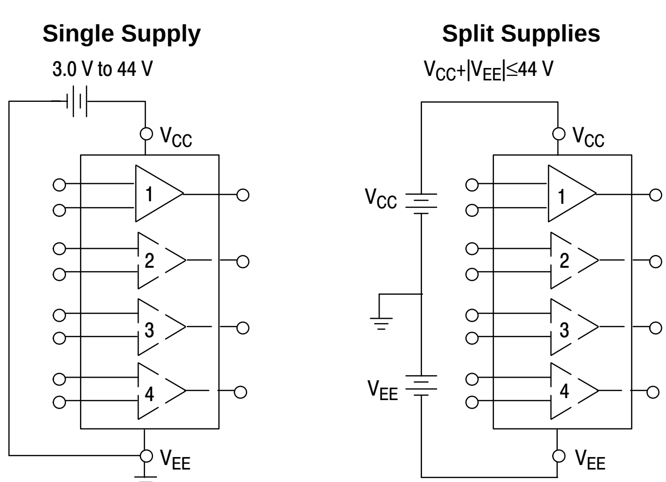
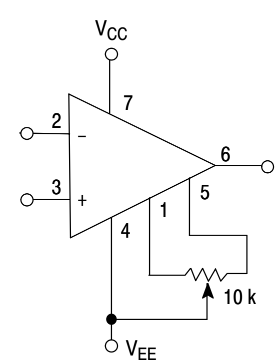


Figure 2. Power Supply Configurations



Offset nulling range is approximately ±80 mV with a 10 k potentiometer (MC33071, MC34071 only).

Figure 3. Offset Null Circuit

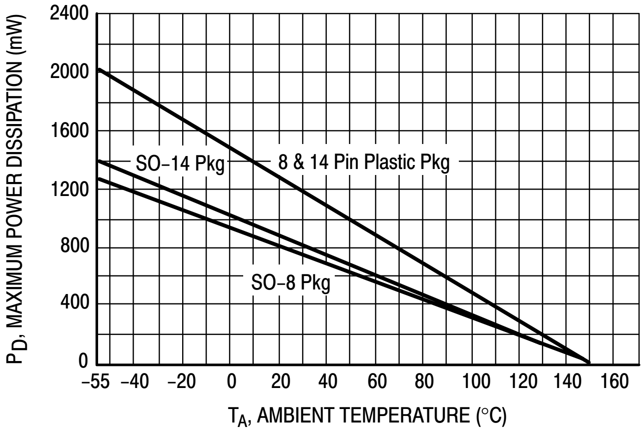


Figure 4. Maximum Power Dissipation versus Temperature for Package Types

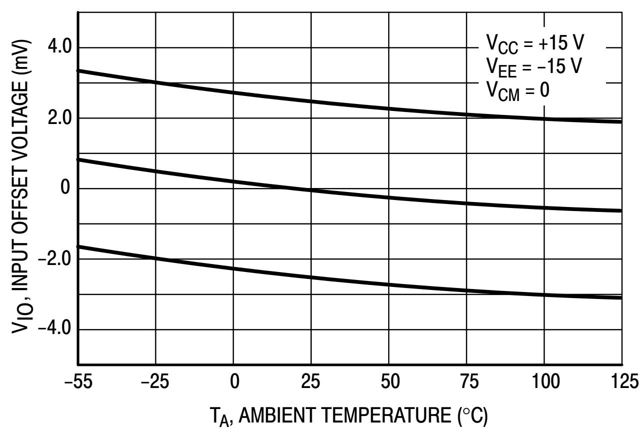


Figure 5. Input Offset Voltage versus Temperature for Representative Units

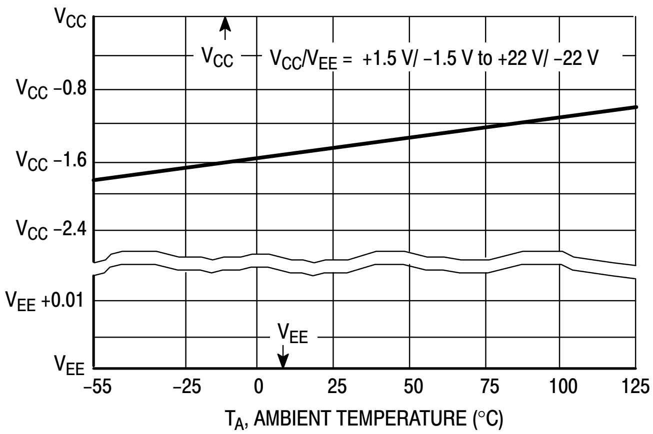


Figure 6. Input Common Mode Voltage Range versus Temperature

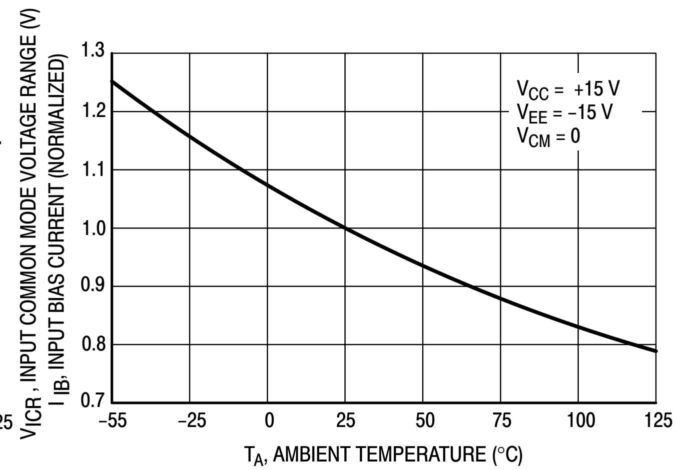


Figure 7. Normalized Input Bias Current versus Temperature

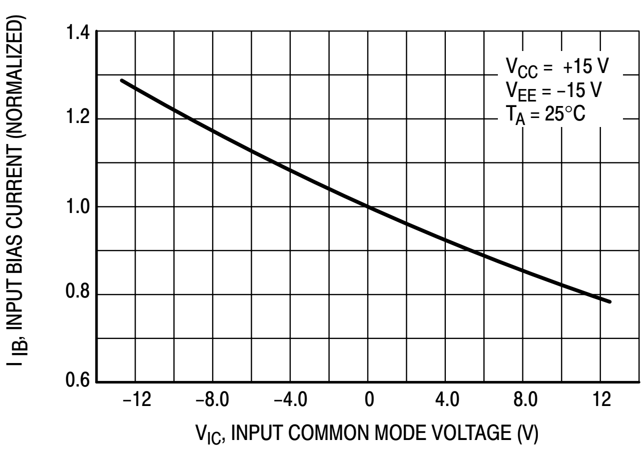


Figure 8. Normalized Input Bias Current versus Input Common Mode Voltage

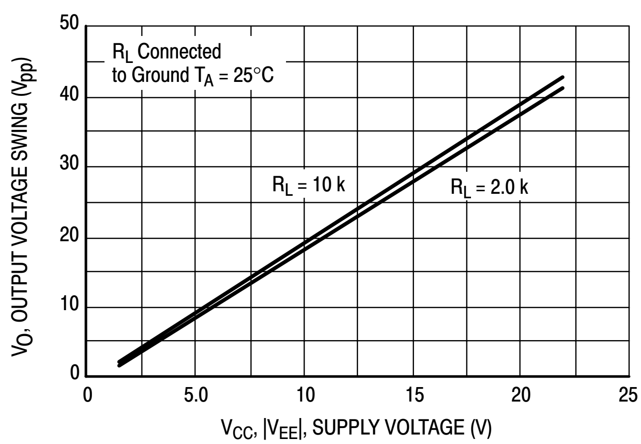
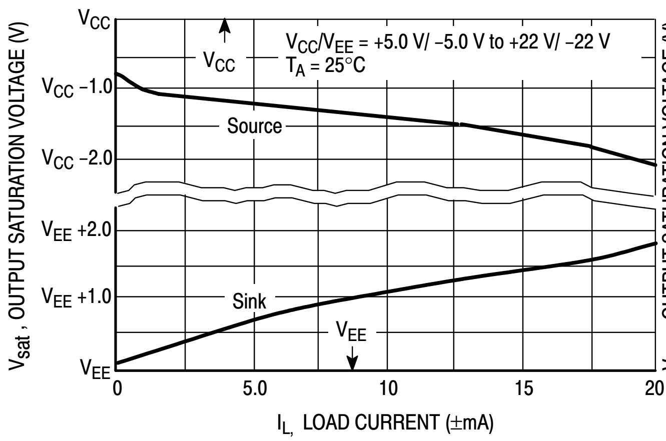


Figure 9. Split Supply Output Voltage Swing versus Supply Voltage



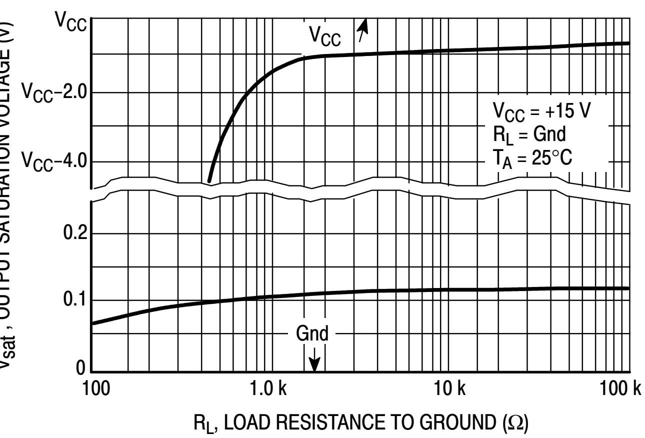
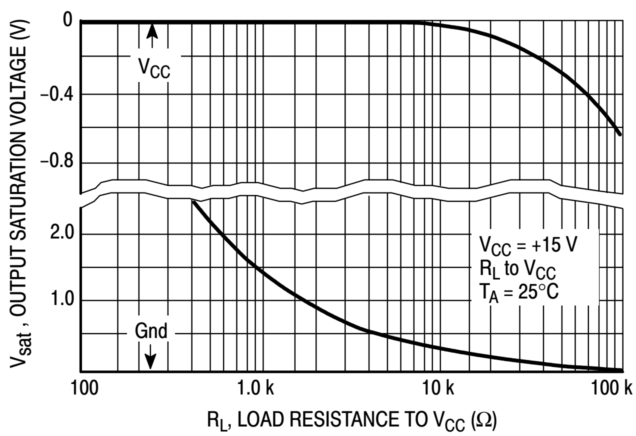


Figure 10. Single Supply Output Saturation versus Load Resistance to V_{CC}

Figure 11. Split Supply Output Saturation versus Load Current



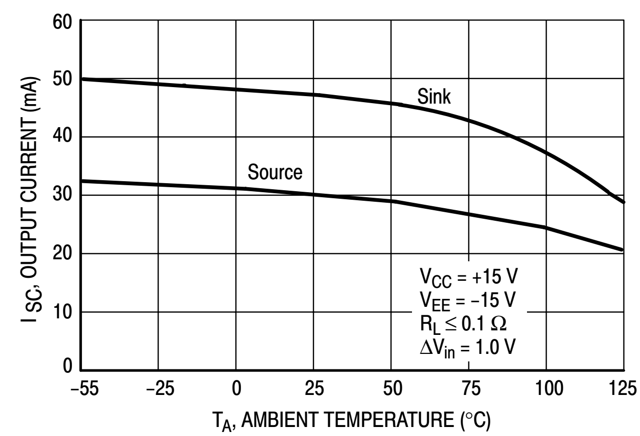
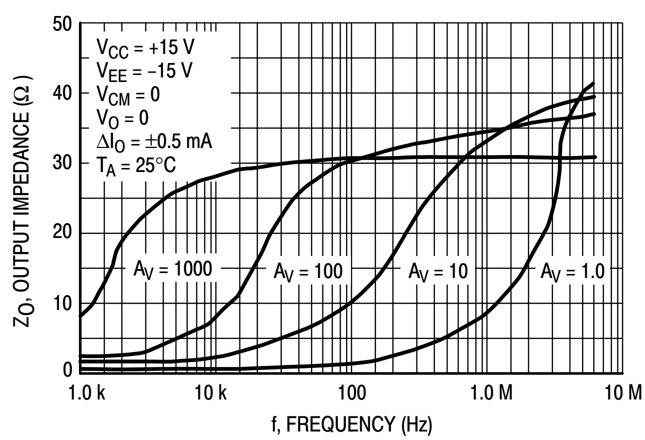


Figure 12. Single Supply Output Saturation versus Load Resistance to Ground

Figure 13. Output Short Circuit Current versus Temperature



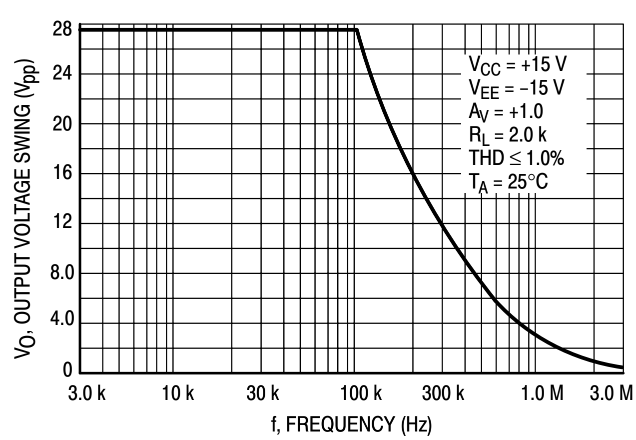


Figure 14. Output Impedance versus Frequency

Figure 15. Output Voltage Swing versus Frequency

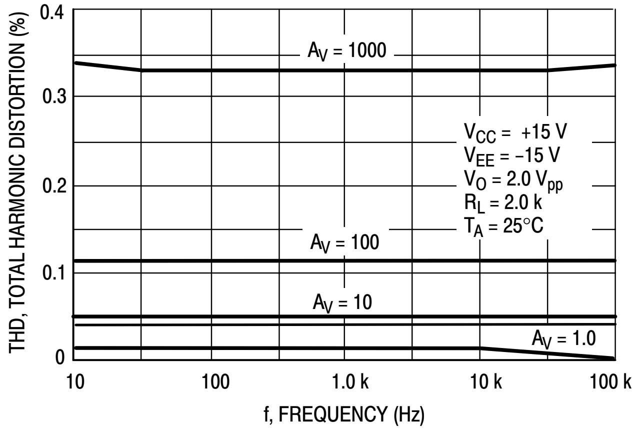


Figure 16. Total Harmonic Distortion versus Frequency

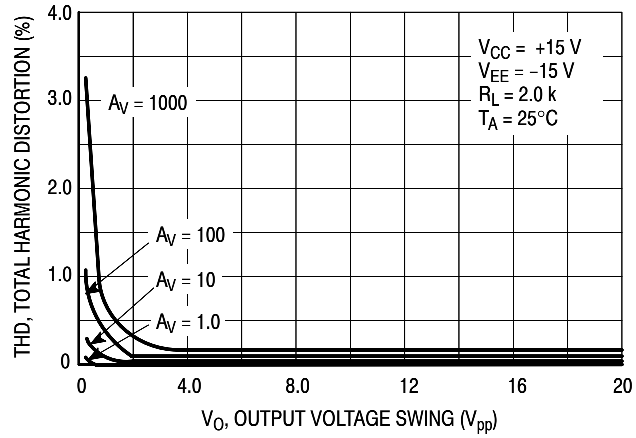


Figure 17. Total Harmonic Distortion versus Output Voltage Swing

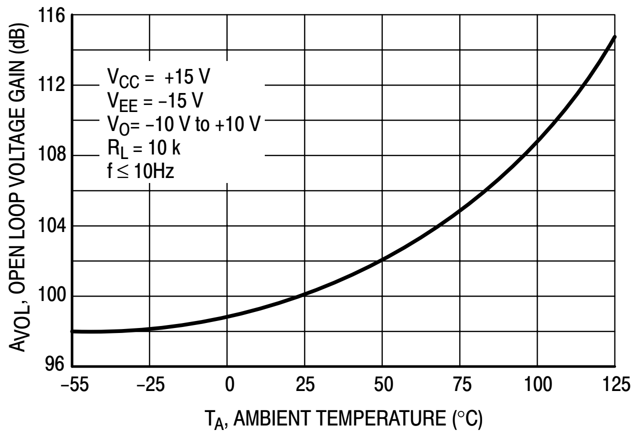


Figure 18. Open Loop Voltage Gain versus Temperature

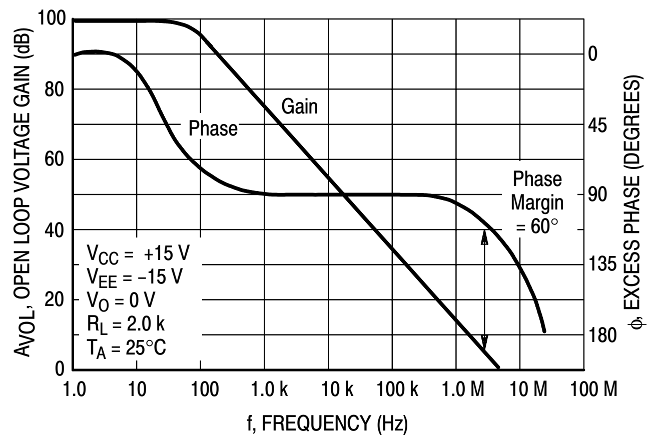


Figure 19. Open Loop Voltage Gain and Phase versus Frequency

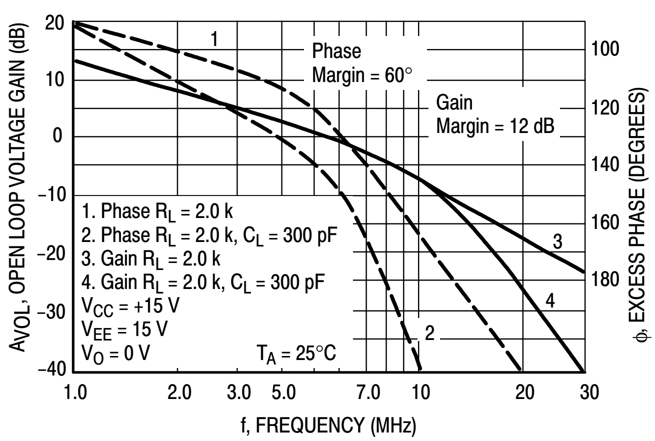


Figure 20. Open Loop Voltage Gain and Phase versus Frequency

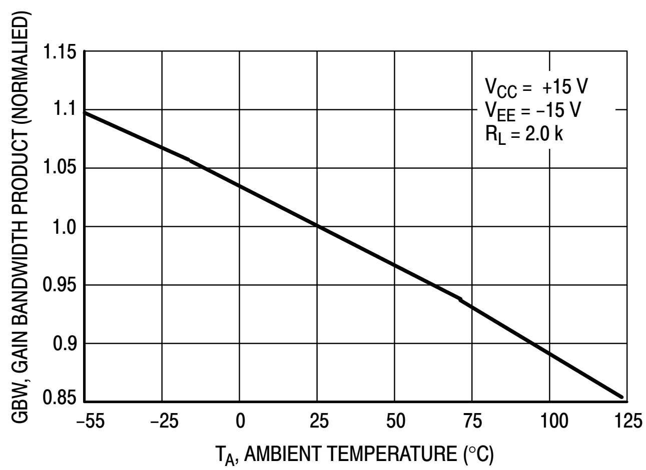


Figure 21. Normalized Gain Bandwidth Product versus Temperature

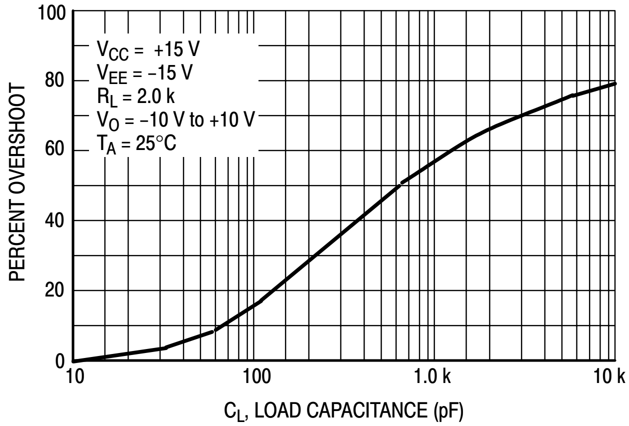


Figure 22. Percent Overshoot versus Load Capacitance

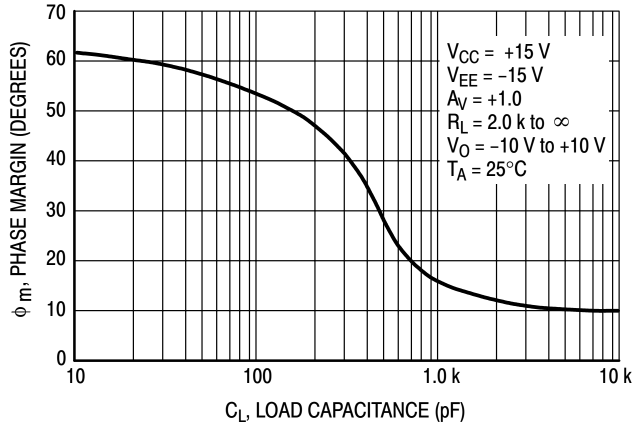


Figure 23. Phase Margin versus Load Capacitance

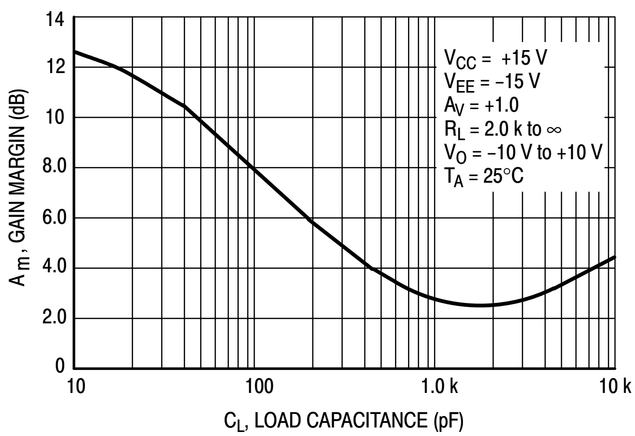


Figure 24. Gain Margin versus Load Capacitance

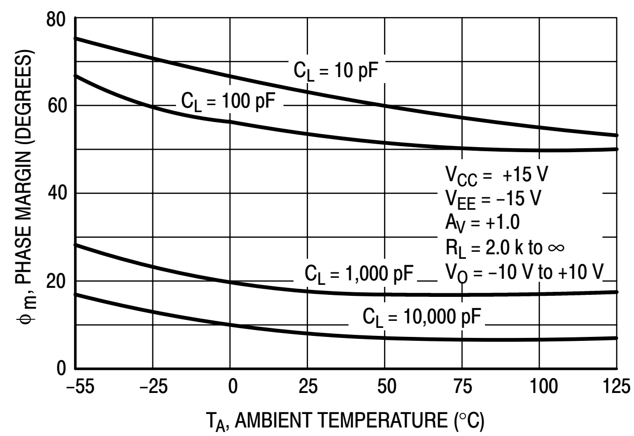


Figure 25. Phase Margin versus Temperature

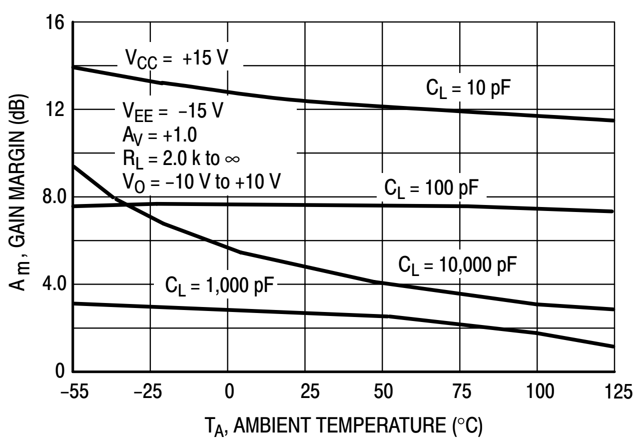


Figure 26. Gain Margin versus Temperature

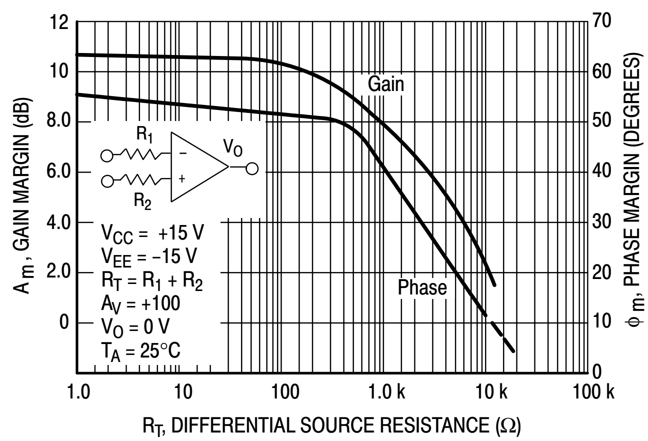


Figure 27. Phase Margin and Gain Margin versus Differential Source Resistance

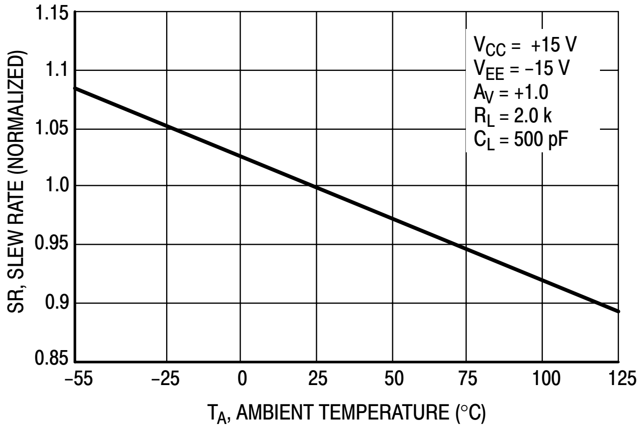


Figure 28. Normalized Slew Rate versus Temperature

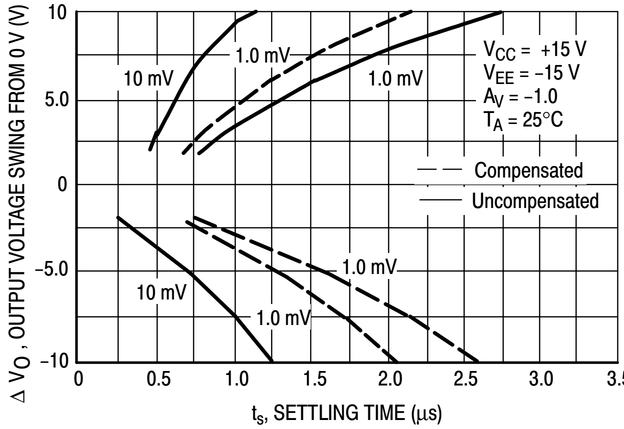


Figure 29. Output Settling Time

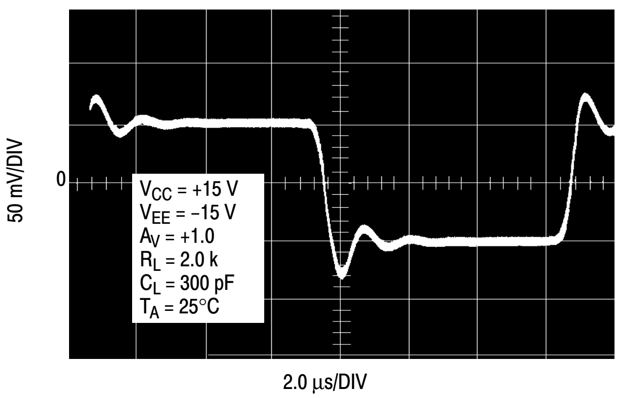


Figure 30. Small Signal Transient Response

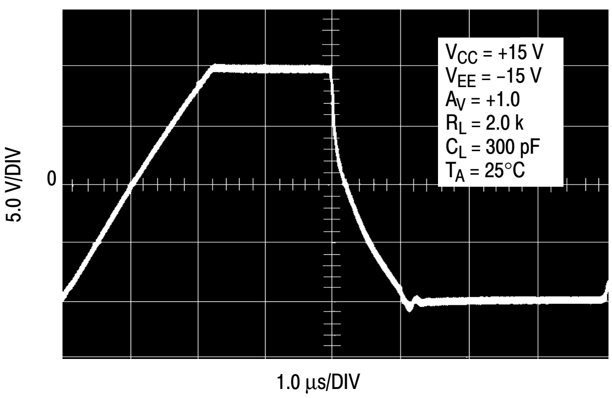


Figure 31. Large Signal Transient Response

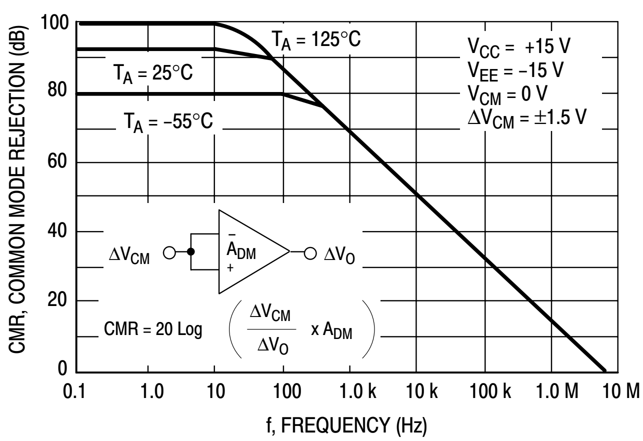


Figure 32. Common Mode Rejection versus Frequency

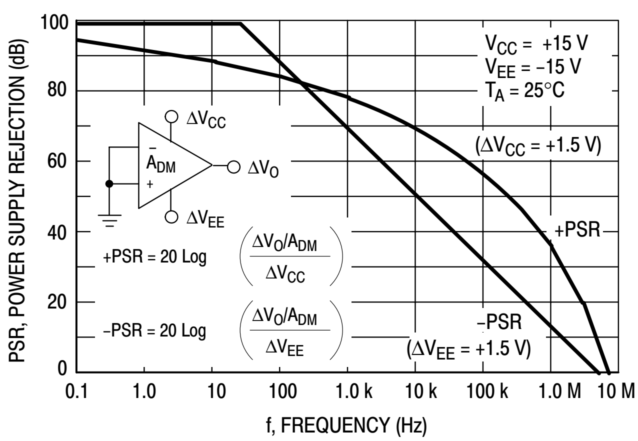


Figure 33. Power Supply Rejection versus Frequency

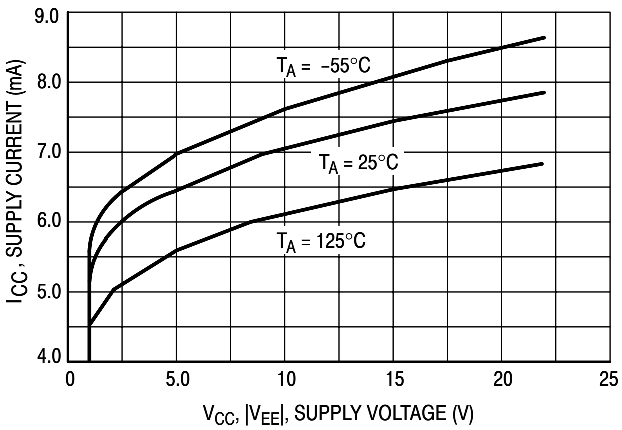


Figure 34. Supply Current versus Supply Voltage

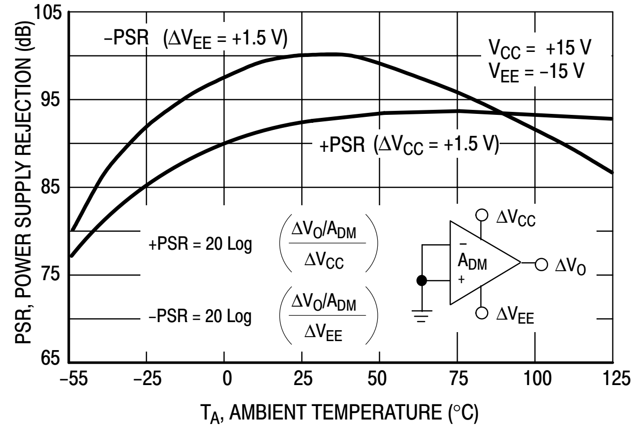


Figure 35. Power Supply Rejection versus Temperature

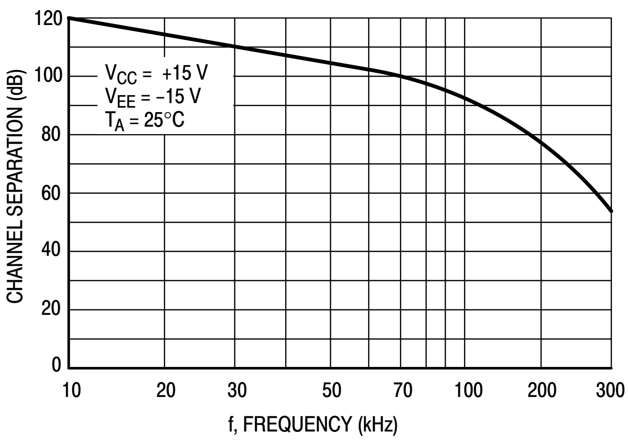


Figure 36. Channel Separation versus Frequency

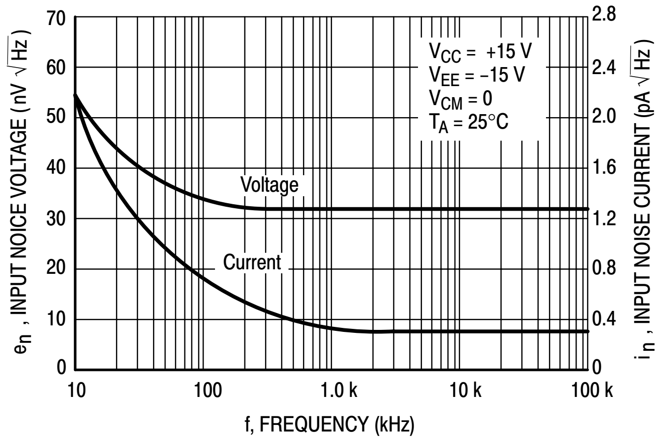


Figure 37. Input Noise versus Frequency

APPLICATIONS INFORMATION
CIRCUIT DESCRIPTION/PERFORMANCE FEATURES

Although the bandwidth, slew rate, and settling time of the MC34071 amplifier series are similar to op amp products utilizing JFET input devices, these amplifiers offer other additional distinct advantages as a result of the PNP transistor differential input stage and an all NPN transistor output stage.

Since the input common mode voltage range of this input stage includes the V_{EE} potential, single supply operation is feasible to as low as 3.0 V with the common mode input voltage at ground potential.

The input stage also allows differential input voltages up to ±44 V, provided the maximum input voltage range is not exceeded. Specifically, the input voltages must range between V_{EE} and V_{CC} supply voltages as shown by the maximum rating table. In practice, although not recommended, the input voltages can exceed the V_{CC} voltage by approximately 3.0 V and decrease below the V_{EE} voltage by 0.3 V without causing product damage, although output phase reversal may occur. It is also possible to source up to approximately 5.0 mA of current from V_{EE} through either inputs clamping diode without damage or latching, although phase reversal may again occur.

If one or both inputs exceed the upper common mode voltage limit, the amplifier output is readily predictable and may be in a low or high state depending on the existing input bias conditions.

Since the input capacitance associated with the small geometry input device is substantially lower (2.5 pF) than the typical JFET input gate capacitance (5.0 pF), better frequency response for a given input source resistance can be achieved using the MC34071 series of amplifiers. This performance feature becomes evident, for example, in fast settling D–to–A current to voltage conversion applications where the feedback resistance can form an input pole with the input capacitance of the op amp. This input pole creates a 2nd order system with the single pole op amp and is therefore detrimental to its settling time. In this context, lower input capacitance is desirable especially for higher

values of feedback resistances (lower current DACs). This input pole can be compensated for by creating a feedback zero with a capacitance across the feedback resistance, if necessary, to reduce overshoot. For 2.0 kΩ of feedback resistance, the MC34071 series can settle to within 1/2 LSB of 8 bits in 1.0 μs, and within 1/2 LSB of 12–bits in 2.2 μs for a 10 V step. In a inverting unity gain fast settling configuration, the symmetrical slew rate is ±13 V/μs. In the classic noninverting unity gain configuration, the output positive slew rate is +10 V/μs, and the corresponding negative slew rate will exceed the positive slew rate as a function of the fall time of the input waveform.

Since the bipolar input device matching characteristics are superior to that of JFETs, a low untrimmed maximum offset voltage of 3.0 mV prime and 5.0 mV downgrade can be economically offered with high frequency performance characteristics. This combination is ideal for low cost precision, high speed quad op amp applications.

The all NPN output stage, shown in its basic form on the equivalent circuit schematic, offers unique advantages over the more conventional NPN/PNP transistor Class AB output stage. A 10 kΩ load resistance can swing within 1.0 V of the positive rail (V_{CC}), and within 0.3 V of the negative rail (V_{EE}), providing a 28.7 V_{pp} swing from ±15 V supplies. This large output swing becomes most noticeable at lower supply voltages.

The positive swing is limited by the saturation voltage of the current source transistor Q_7, and V_{BE} of the NPN pull up transistor Q_{17}, and the voltage drop associated with the short circuit resistance, R_7. The negative swing is limited by the saturation voltage of the pull–down transistor Q_{16}, the voltage drop I_LR_6, and the voltage drop associated with resistance R_7, where I_L is the sink load current. For small valued sink currents, the above voltage drops are negligible, allowing the negative swing voltage to approach within millivolts of V_{EE}. For large valued sink currents (>5.0 mA), diode D3 clamps the voltage across R_6, thus limiting the negative swing to the saturation voltage of Q_{16}, plus the forward diode drop of D3 (≈V_{EE} +1.0 V). Thus for a given supply voltage, unprecedented peak–to–peak output voltage swing is possible as indicated by the output swing specifications.

If the load resistance is referenced to V_{CC} instead of ground for single supply applications, the maximum possible output swing can be achieved for a given supply voltage. For light load currents, the load resistance will pull the output to V_{CC} during the positive swing and the output will pull the load resistance near ground during the negative swing. The load resistance value should be much less than that of the feedback resistance to maximize pull up capability.

Because the PNP output emitter–follower transistor has been eliminated, the MC34071 series offers a 20 mA minimum current sink capability, typically to an output voltage of (V_{EE} +1.8 V). In single supply applications the output can directly source or sink base current from a common emitter NPN transistor for fast high current switching applications.

In addition, the all NPN transistor output stage is inherently fast, contributing to the bipolar amplifier's high gain bandwidth product and fast settling capability. The associated high frequency low output impedance (30 Ω typ @ 1.0 MHz) allows capacitive drive capability from 0 pF to 10,000 pF without oscillation in the unity closed loop gain configuration. The 60° phase margin and 12 dB gain margin as well as the general gain and phase characteristics are virtually independent of the source/sink output swing conditions. This allows easier system phase compensation, since output swing will not be a phase consideration. The high frequency characteristics of the MC34071 series also allow excellent high frequency active filter capability, especially for low voltage single supply applications.

Although the single supply specifications is defined at 5.0 V, these amplifiers are functional to 3.0 V @ 25°C although slight changes in parametrics such as bandwidth, slew rate, and DC gain may occur.

If power to this integrated circuit is applied in reverse polarity or if the IC is installed backwards in a socket, large unlimited current surges will occur through the device that may result in device destruction.

Special static precautions are not necessary for these bipolar amplifiers since there are no MOS transistors on the die.

As with most high frequency amplifiers, proper lead dress, component placement, and PC board layout should be exercised for optimum frequency performance. For example, long unshielded input or output leads may result in unwanted input–output coupling. In order to preserve the relatively low input capacitance associated with these amplifiers, resistors connected to the inputs should be immediately adjacent to the input pin to minimize additional stray input capacitance. This not only minimizes the input pole for optimum frequency response, but also minimizes extraneous “pick up” at this node. Supply decoupling with adequate capacitance immediately adjacent to the supply pin is also important, particularly over temperature, since many types of decoupling capacitors exhibit great impedance changes over temperature.

The output of any one amplifier is current limited and thus protected from a direct short to ground. However, under such conditions, it is important not to allow the device to exceed the maximum junction temperature rating. Typically for ±15 V supplies, any one output can be shorted continuously to ground without exceeding the maximum temperature rating.

(Typical Single Supply Applications V_{CC} = 5.0 V)

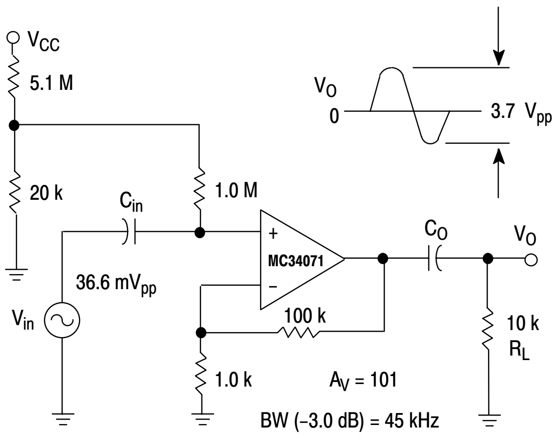


Figure 38. AC Coupled Noninverting Amplifier

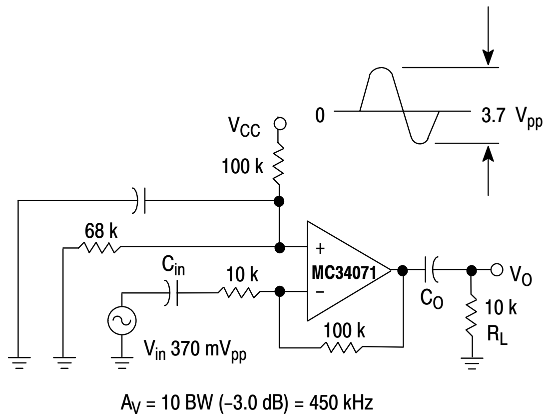


Figure 39. AC Coupled Inverting Amplifier

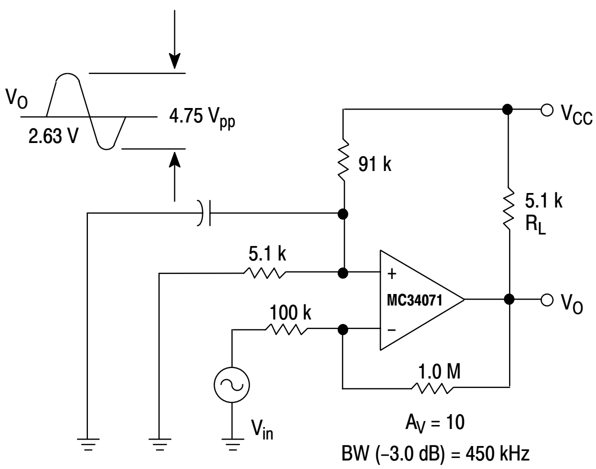


Figure 40. DC Coupled Inverting Amplifier Maximum Output Swing

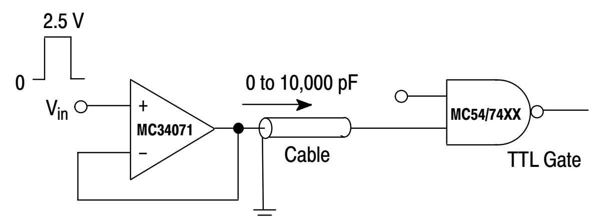


Figure 41. Unity Gain Buffer TTL Driver

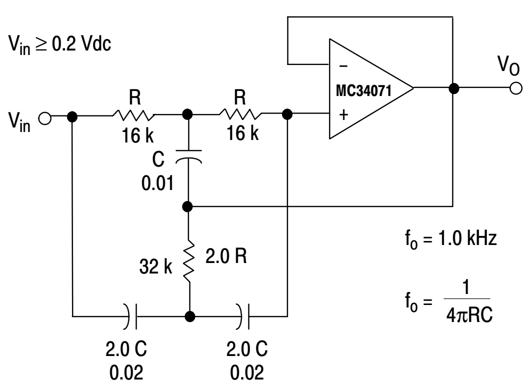
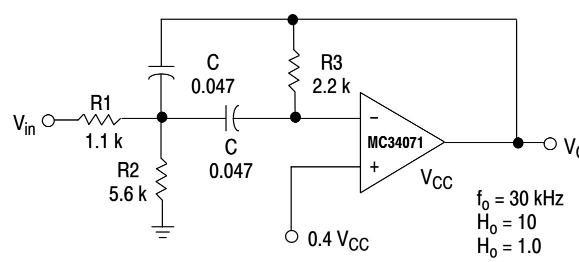


Figure 42. Active High–Q Notch Filter



Given f_o = Center Frequency
A_O = Gain at Center Frequency
Choose Value f_o, Q, A_o, C

Then: $R3 = \frac{Q}{\pi f_o C}$ $\quad R1 = \frac{R3}{2H_o}$ $\quad R2 = \frac{R1\,R3}{4Q^2R1-R3}$

For less than 10% error from operational amplifier $\frac{Q_o f_o}{GBW} < 0.1$

where f_o and GBW are expressed in Hz.
GBW = 4.5 MHz Typ.

Figure 43. Active Bandpass Filter

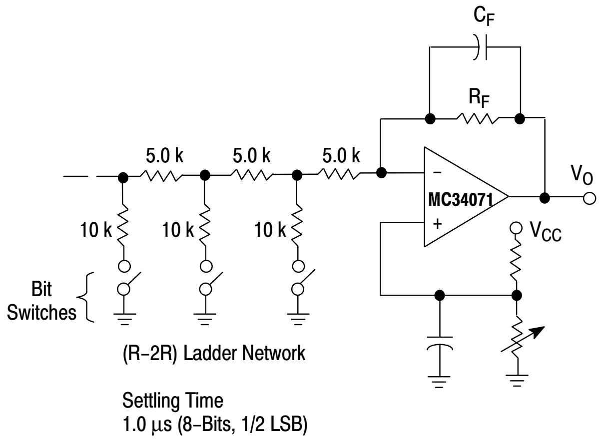


Figure 44. Low Voltage Fast D/A Converter

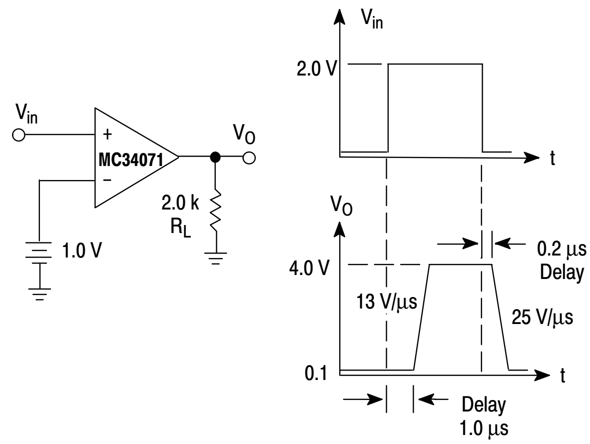


Figure 45. High Speed Low Voltage Comparator

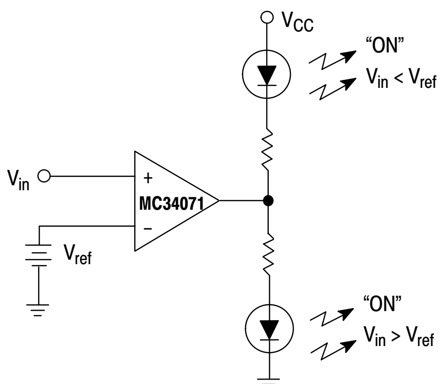


Figure 46. LED Driver

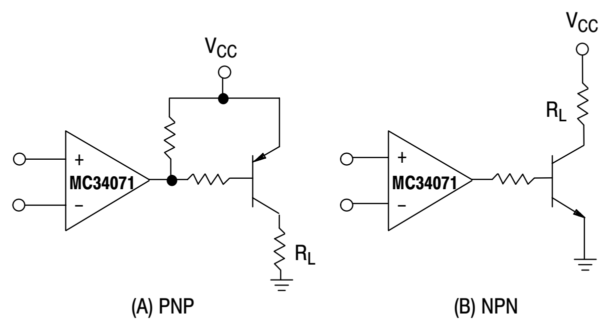


Figure 47. Transistor Driver

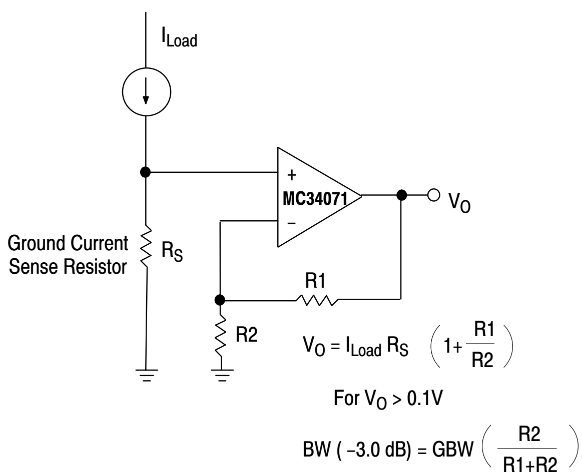


Figure 48. AC/DC Ground Current Monitor

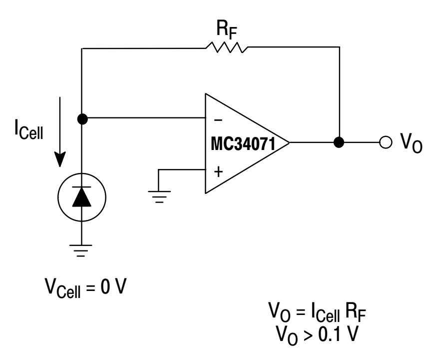


Figure 49. Photovoltaic Cell Amplifier

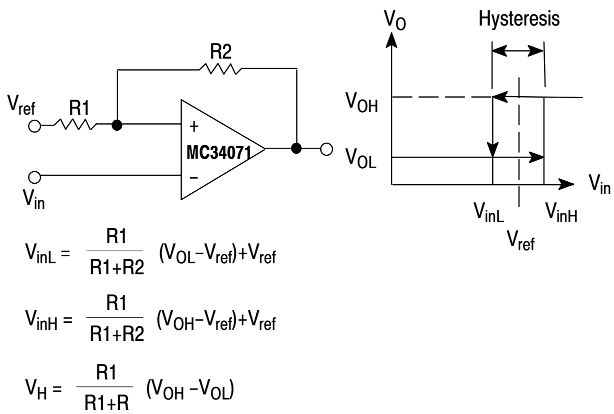


Figure 50. Low Input Voltage Comparator with Hysteresis

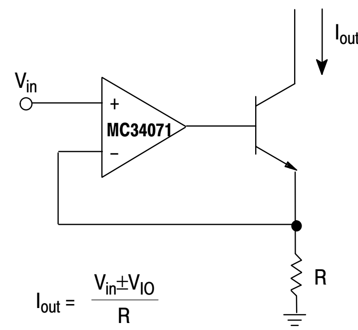


Figure 51. High Compliance Voltage to Sink Current Converter

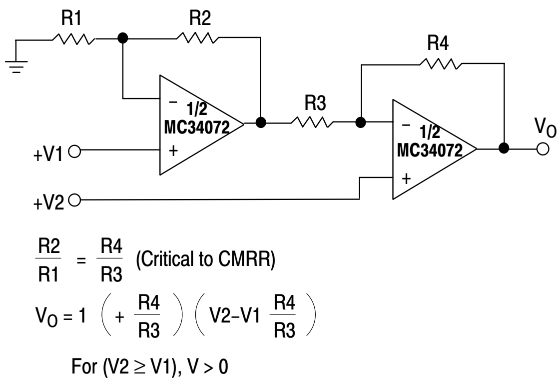


Figure 52. High Input Impedance Differential Amplifier

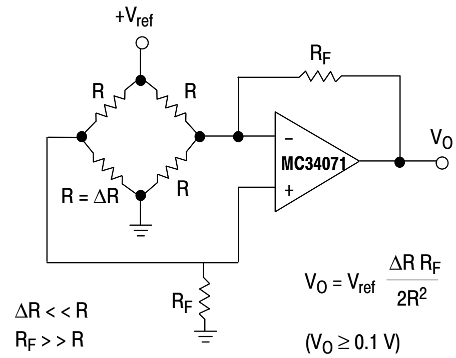


Figure 53. Bridge Current Amplifier

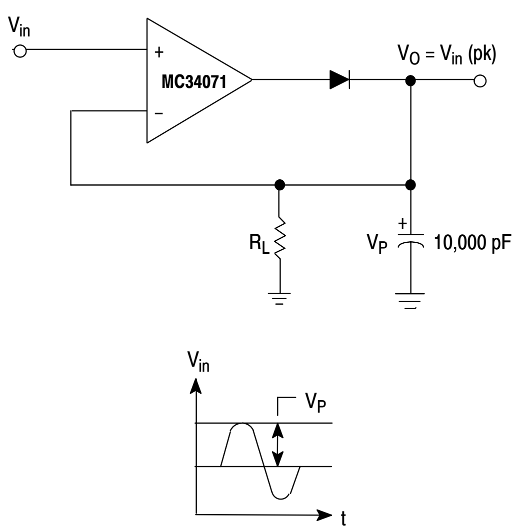


Figure 54. Low Voltage Peak Detector

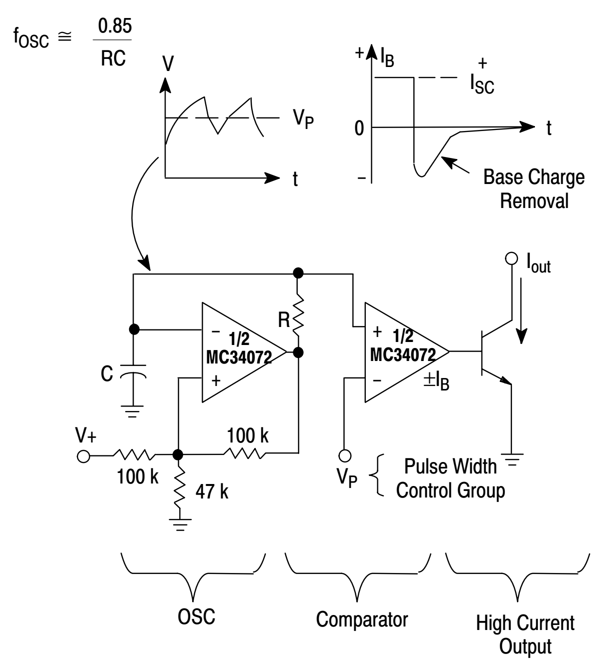


Figure 55. High Frequency Pulse Width Modulation

GENERAL ADDITIONAL APPLICATIONS INFORMATION $V_S = \pm 15.0$ V

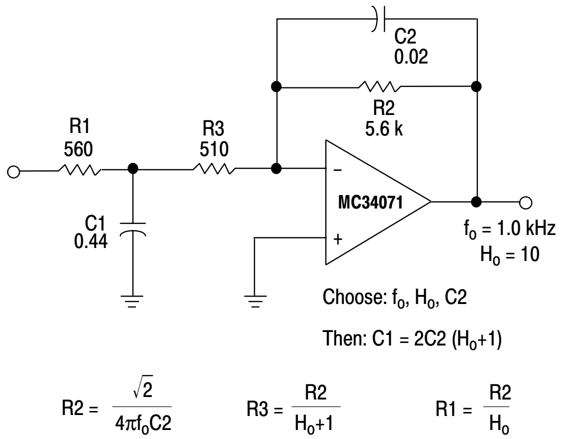


Figure 56. Second Order Low–Pass Active Filter

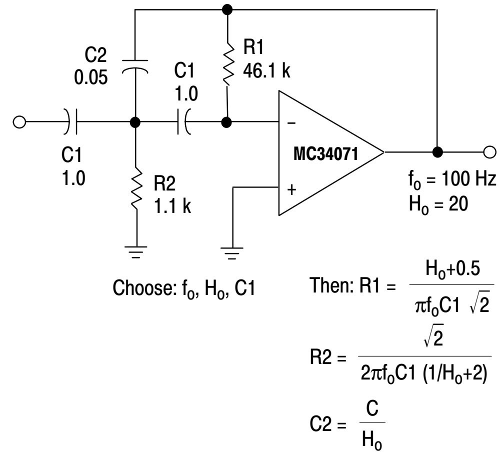


Figure 57. Second Order High–Pass Active Filter

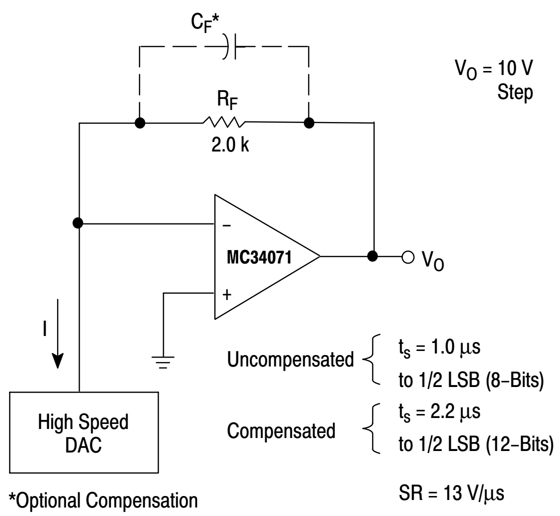


Figure 58. Fast Settling Inverter

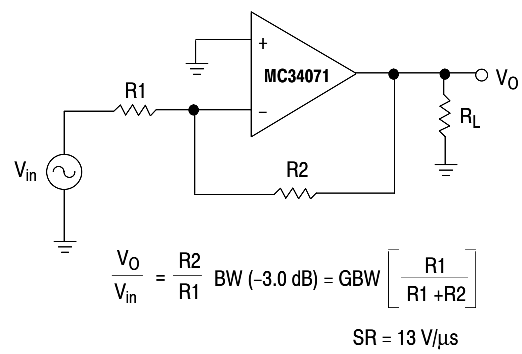


Figure 59. Basic Inverting Amplifier

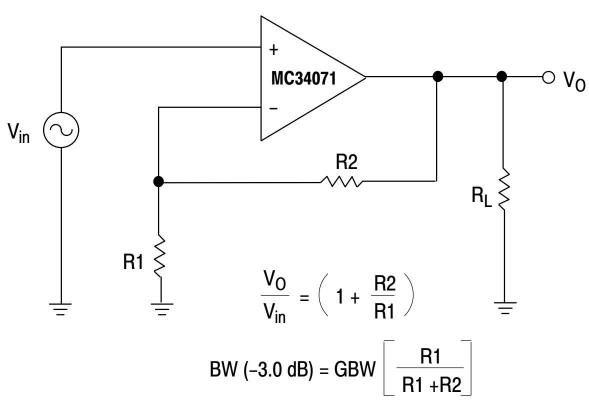


Figure 60. Basic Noninverting Amplifier

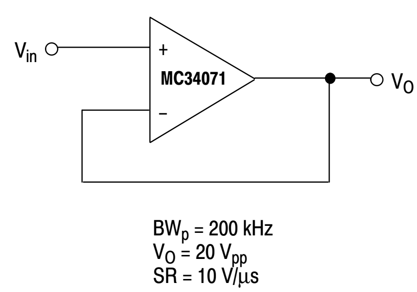


Figure 61. Unity Gain Buffer ($A_V = +1.0$)

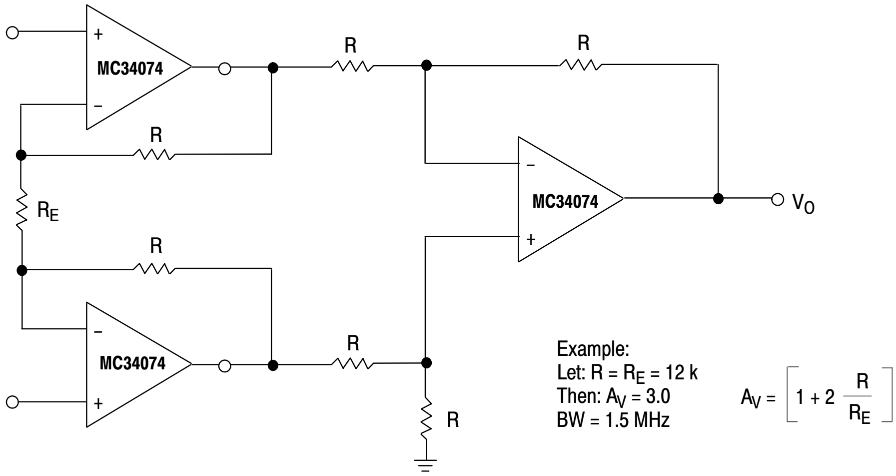
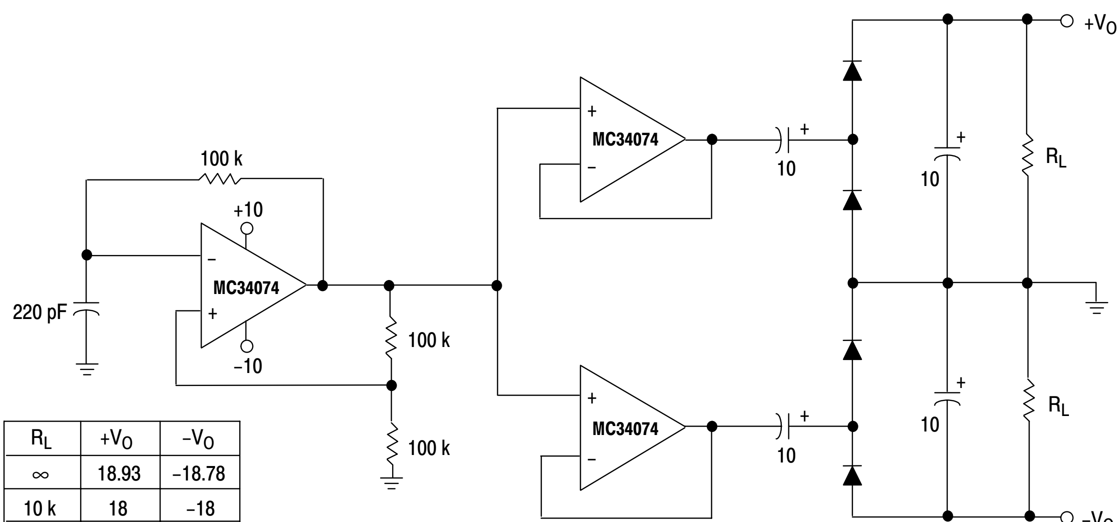


Figure 62. High Impedance Differential Amplifier



R_L	$+V_O$	$-V_O$
∞	18.93	−18.78
10 k	18	−18
5.0 k	15.4	−15.4

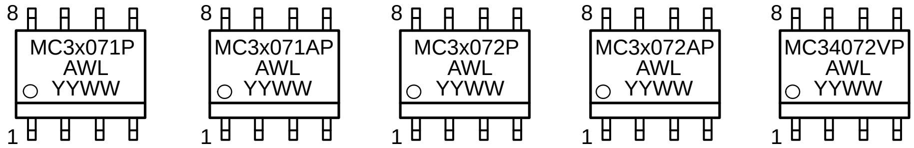
Figure 63. Dual Voltage Doubler

ORDERING INFORMATION

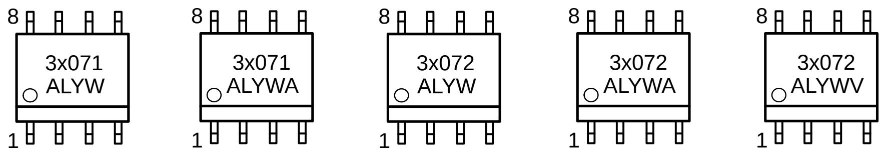
Op Amp Function	Device	Operating Temperature Range	Package	Shipping
Single	MC34071P, MC34071AP MC34071D, MC34071AD MC34071DR2, MC34071ADR2	T_A = 0° to +70°C	DIP–8 SO–8 SO–8 / Tape & Reel	50 Units / Rail 98 Units / Rail 2500 Units / Tape & Reel
	MC33071P, MC33071AP MC33071D, MC33071AD MC33071DR2, MC33071ADR2	T_A = –40° to +85°C	DIP–8 SO–8 SO–8 / Tape & Reel	50 Units / Rail 98 Units / Rail 2500 Units / Tape & Reel
Dual	MC34072P, MC34072AP MC34072D, MC34072AD MC34072DR2, MC34072ADR2	T_A = 0° to +70°C	DIP–8 SO–8 SO–8 / Tape & Reel	50 Units / Rail 98 Units / Rail 2500 Units / Tape & Reel
	MC33072P, MC33072AP MC33072D, MC33072AD MC33072DR2, MC33072ADR2	T_A = –40° to +85°C	DIP–8 SO–8 SO–8 / Tape & Reel	50 Units / Rail 98 Units / Rail 2500 Units / Tape & Reel
	MC34072VD MC34072VDR2 MC34072VP	T_A = –40° to +125°C	SO–8 SO–8 / Tape & Reel DIP–8	98 Units / Rail 2500 Units / Tape & Reel 50 Units / Rail
Quad	MC34074P, MC34074AP MC34074D, MC34074AD MC34074DR2, MC34074ADR2	T_A = 0° to +70°C	DIP–14 SO–14 SO–14 / Tape & Reel	25 Units / Rail 55 Units / Rail 2500 Units / Tape & Reel
	MC33074P, MC33074AP MC33074D, MC33074AD MC33074DR2, MC33074ADR2 MC33074DTB, MC33074ADTB MC33074DTBR2, MC33074ADTBR2	T_A = –40° to +85°C	DIP–14 SO–14 SO–14 / Tape & Reel TSSOP–14 TSSOP–14 / Tape & Reel	25 Units / Rail 55 Units / Rail 2500 Units / Tape & Reel 96 Units / Rail 2500 Units / Tape & Reel
	MC34074VD MC34074VDR2 MC34074VP	T_A = –40° to +125°C	SO–14 SO–14 / Tape & Reel DIP–14	55 Units / Rail 2500 Units / Tape & Reel 25 Units / Rail

MARKING DIAGRAMS

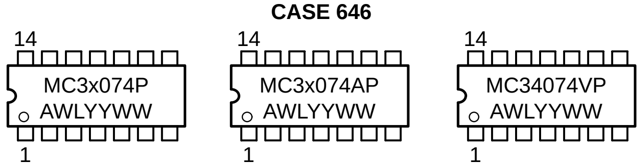
PDIP–8
P SUFFIX
CASE 626



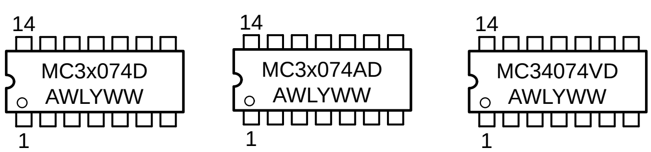
SO–8
D SUFFIX
CASE 751



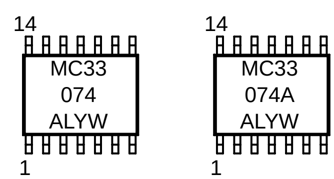
PDIP–14
P SUFFIX
CASE 646



SO–14
D SUFFIX
CASE 751A



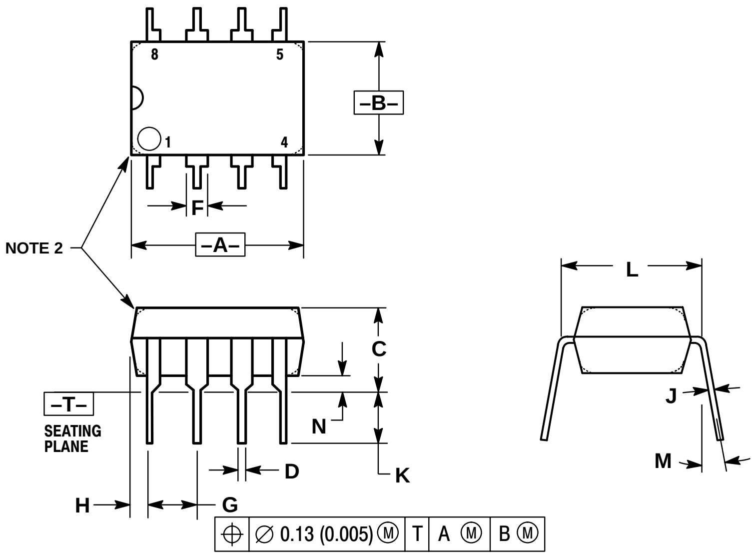
TSSOP–14
DTB SUFFIX
CASE 948G



x	= 3 or 4
A	= Assembly Location
WL, L	= Wafer Lot
YY, Y	= Year
WW, W	= Work Week

PACKAGE DIMENSIONS

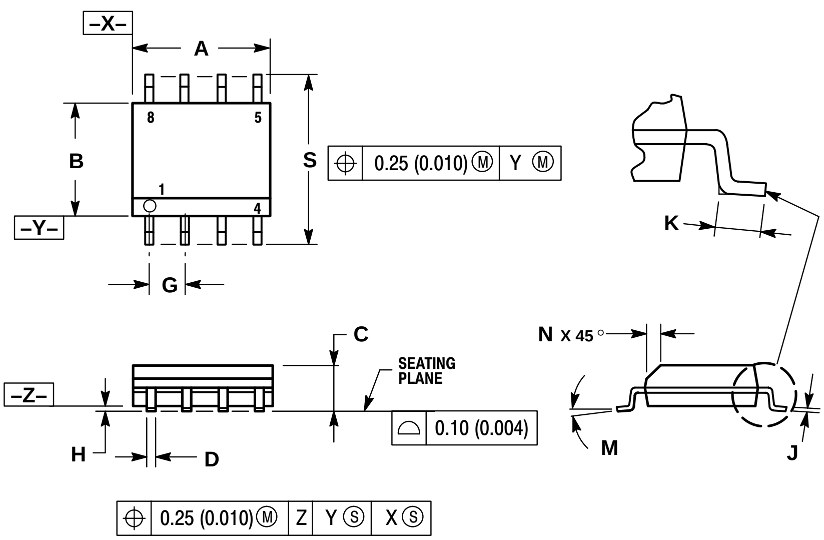
PDIP–8
P SUFFIX
CASE 626–05
ISSUE L



NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	---	10°	---	10°
N	0.76	1.01	0.030	0.040

SO–8
D SUFFIX
CASE 751–07
ISSUE W

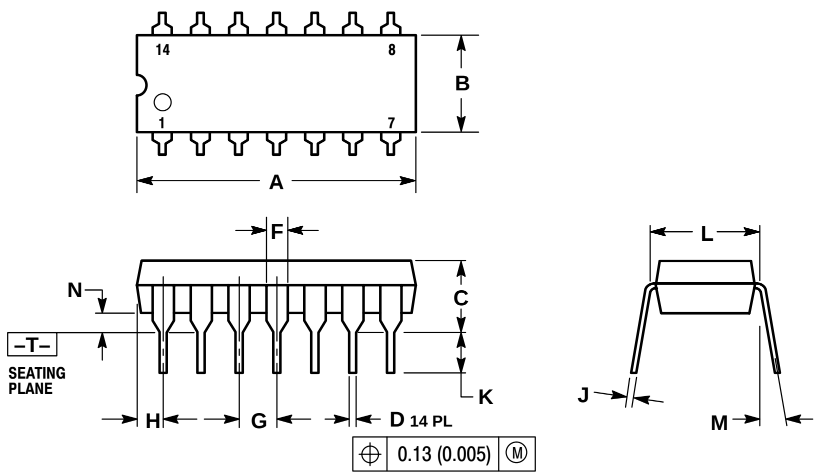


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0°	8°	0°	8°
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

PACKAGE DIMENSIONS

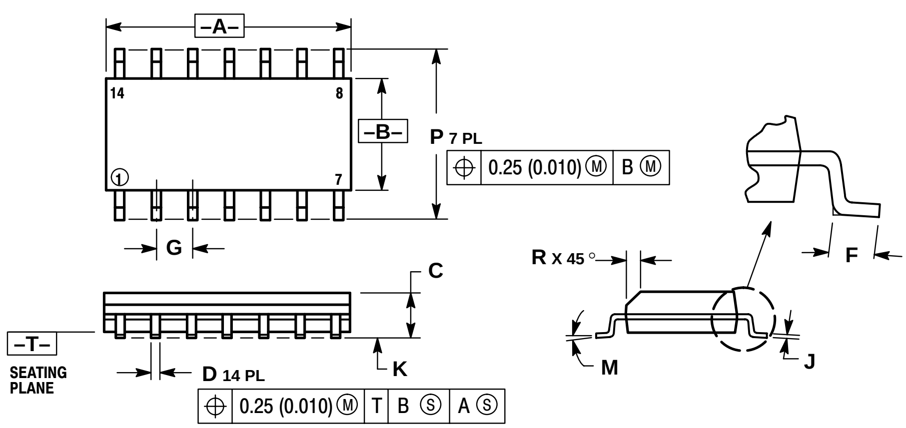
PDIP–14
P SUFFIX
CASE 646–06
ISSUE M



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIMENSION B DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.715	0.770	18.16	18.80
B	0.240	0.260	6.10	6.60
C	0.145	0.185	3.69	4.69
D	0.015	0.021	0.38	0.53
F	0.040	0.070	1.02	1.78
G	0.100 BSC		2.54 BSC	
H	0.052	0.095	1.32	2.41
J	0.008	0.015	0.20	0.38
K	0.115	0.135	2.92	3.43
L	0.290	0.310	7.37	7.87
M	---	10°	---	10°
N	0.015	0.039	0.38	1.01

SO–14
D SUFFIX
CASE 751A–03
ISSUE F

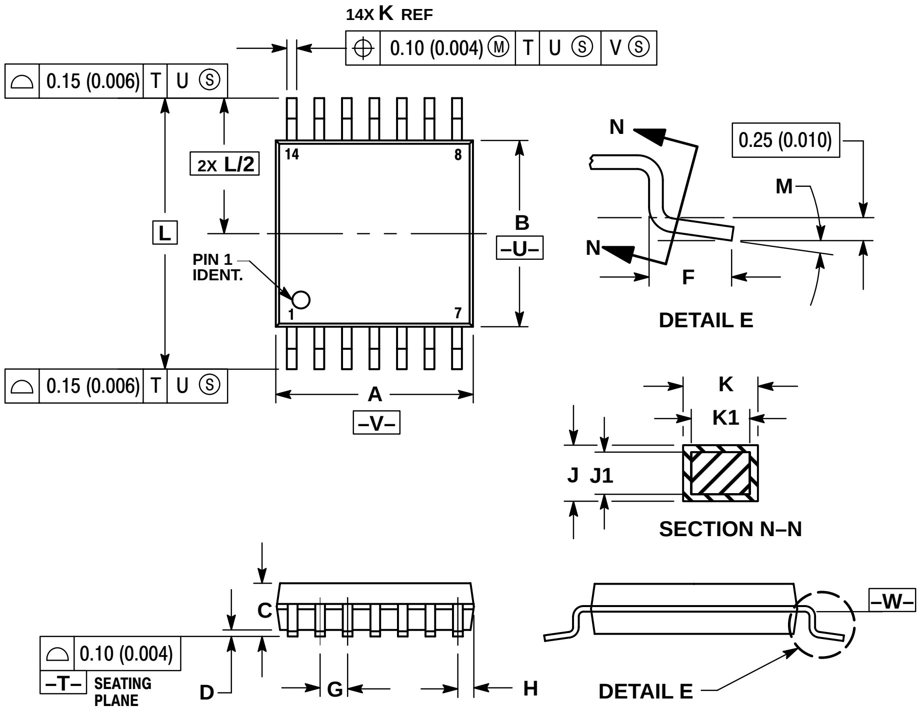


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	8.55	8.75	0.337	0.344
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.19	0.25	0.008	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.228	0.244
R	0.25	0.50	0.010	0.019

PACKAGE DIMENSIONS

TSSOP–14
DTB SUFFIX
CASE 948G–01
ISSUE O



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. DIMENSION K DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE K DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
7. DIMENSION A AND B ARE TO BE DETERMINED AT DATUM PLANE –W–.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	4.90	5.10	0.193	0.200
B	4.30	4.50	0.169	0.177
C	---	1.20	---	0.047
D	0.05	0.15	0.002	0.006
F	0.50	0.75	0.020	0.030
G	0.65 BSC		0.026 BSC	
H	0.50	0.60	0.020	0.024
J	0.09	0.20	0.004	0.008
J1	0.09	0.16	0.004	0.006
K	0.19	0.30	0.007	0.012
K1	0.19	0.25	0.007	0.010
L	6.40 BSC		0.252 BSC	
M	0°	8°	0°	8°

Notes

Notes

PUBLICATION ORDERING INFORMATION

Literature Fulfillment:
Literature Distribution Center for ON Semiconductor
P.O. Box 5163, Denver, Colorado 80217 USA
Phone: 303–675–2175 or 800–344–3860 Toll Free USA/Canada
Fax: 303–675–2176 or 800–344–3867 Toll Free USA/Canada
Email: ONlit@hibbertco.com

N. American Technical Support: 800–282–9855 Toll Free USA/Canada

JAPAN: ON Semiconductor, Japan Customer Focus Center
4–32–1 Nishi–Gotanda, Shinagawa–ku, Tokyo, Japan 141–0031
Phone: 81–3–5740–2700
Email: r14525@onsemi.com

ON Semiconductor Website: http://onsemi.com

For additional information, please contact your local Sales Representative.

Dankoff Solar Slowpump™

1300
1400
2500
2600
Series

Use solar-electric power to provide 200–2,600 Gallons per Day (750–10,000 ltrs.) from shallow water sources. Slowpump can push water as high as 450 vertical feet (137m).

Solar Slowpump was the world's first commercially available low power solar pump. It was developed by Windy Dankoff in 1983, in response to those who said "that's impossible". Thousands of Slowpumps have been installed worldwide by ranchers, homeowners, missionaries, health workers, government agencies, etc. Some of our oldest Slowpumps are still in daily service.

Slowpump is not submersible, but can draw water from shallow wells, springs, cisterns, tanks, ponds, rivers, and streams, and push it as high as 450 vertical feet and through miles (kilometers) of pipeline. Slow pumping minimizes the size and cost of the solar array, wire and piping.

Slowpump is less expensive than submersible DC pumps, and made in a much wider range of sizes. Wearing parts typically last 5 to 10 years. Overall life expectancy is 15 to 20 years.

1300 and 2600 Series Solar Slowpumps

Construction & Features

- Rotary vane mechanism (positive displacement) made of forged brass, carbon-graphite and stainless steel
- NSF® approved for drinking water
- Handles sea water, dissolved minerals
- Survives most freezes
- Permanent magnet, DC motor
- AC models use a low-surge PM motor that greatly reduces starting surges, inverter and wire size requirements
- Installation and Service Manual is highly detailed and illustrated

"The Slowpump #2507-24V is supplying water for a work camp on the outer island of Onotoa. It's supplying water for 60 people. The well is one half mile [800m] away from the camp."

B.C., Ministry of Works and Energy,
Kiribati, South Pacific

"I have been very happy with the 1308 Solar Slowpump!... We are using it in a 5 meter deep hand dug well in a valley, and pumping 200 meters distant and 50 meters vertically."

Dr. D.L., World Missions,
Cameroon, W. Africa

"These pumps work great.... Even during low light levels when the motor is turning slowly, a small amount of water can be pumped.... The manual is easy to read. Windy's troubleshooting section is excellent.... Not only have these pumps stood the test of time, but small changes have made them even better."

B. Schultze
product review in *Home Power Magazine* #42

"Over the last five years, we've found the Slowpump to perform impressively. We've also been very happy with Dankoff Solar's friendly service and great attitude."

JT, Nemia Valley, BC, Canada

Solar Slowpump™ Performance Chart

1300
1400
2500
2600
Series

Dankoff Solar Slowpump™

1300 & 2500 Series 1/4 HP • PV or Battery 12, 24V • 115Vac

Total Lift		Pump # 1322		1310		1308		1304		1303		2505		2507	
Feet	Meters	GPM	Watts	GPM	Watts	GPM	Watts	GPM	Watts	GPM	Watts	GPM	Watts	GPM	Watts
20	6	0.51	27	0.92	29	1.25	30	1.75	37	2.50	48	3.25	52	4.00	57
40	12	0.51	32	0.92	41	1.25	48	1.75	53	2.50	60	3.23	69	3.95	78
60	18	0.51	36	0.89	46	1.20	54	1.68	64	2.40	78	3.15	90	3.90	102
80	24	0.49	40	0.88	51	1.20	60	1.64	73	2.30	93	3.10	106	3.90	120
100	30	0.49	45	0.88	57	1.20	66	1.64	82	2.30	105	3.08	124	3.85	144
120	36	0.48	50	0.88	61	1.20	70	1.62	90	2.25	121	3.02	142	3.80	165
140	42	0.47	56	0.88	66	1.20	75	1.60	100	2.20	138	2.92	166	3.65	195
160	48	0.47	62	0.87	74	1.20	84	1.60	112	2.20	153	2.85	187		
180	54	0.47	66	0.86	82	1.18	93	1.57	122	2.15	165	2.75	205		
200	60	0.45	74	0.85	89	1.16	101	1.56	133	2.15	180				
240	72	0.44	90	0.83	105	1.14	117	1.54	152	2.15	204				
280	84	0.41	102	0.81	120	1.12	135	1.51	175						
320	96	0.41	120	0.79	138	1.10	153	1.48	196						
360	108	0.41	134	0.76	154	1.05	171								
400	120	0.40	150	0.73	176	1.00	198								
440	132	0.39	168	0.70	202										

performance at 15 or 30V (PV-Direct voltage)
For battery, subtract 20% from Flow & Watts

24V pump may be run at 12 volts to yield 1/2 flow at 1/2 watts.
Actual performance may vary ±10% from specifications.

LPM = GPM X 3.8

1400 & 2600 Series 1/2 HP • Battery 24V, 48V • PV-Direct 36V • 115Vac

Pump# →		1408		1404		1403		2605		2607	
Feet	Meters	GPM	Watts	GPM	Watts	GPM	Watts	GPM	Watts	GPM	Watts
160	48									4.30	283
180	54							3.35	280	4.25	305
200	60							3.33	296	4.20	338
240	72					2.55	266	3.30	331	4.05	396
280	84					2.50	302	3.25	373	4.00	444
320	96			1.66	255	2.50	338	3.20	410		
360	108			1.62	280	2.50	374	3.16	450		
400	120			1.64	312	2.50	406				
440	132	1.10	269	1.66	342	2.50	451				

Max Voltage: 29V or 58V on Battery Models

Order pumps using these item numbers

Pump #	12V	24V	36VPV or 48VBatt
1322	22207	22208	
1310	22205	22206	
1308	22203	22204	
1304	22201	22202	
1303	22209	22210	
2505	22211	22212	
2507	22213	22214	
1408		22220	22221
1404		22222	22223
1403		22224	22225
2605		22226	22227
2607		22228	22229

Voltage option 115Vac—for any above, ADD Item 22219

Suction Capacity

- 20 vertical feet (6 m) at sea level– subtract 1 ft. for every 1000 ft. altitude (1 m for every 1000 m). Pump should be placed as low as possible.

Filtration Requirement

- This pump CANNOT tolerate dirt. Water MUST be filtered clear. If water is very dirty, improve the source or consider a different pump.

PV-Direct (non-battery) Requirements

- The rated power of the PV array must exceed pump watts by 20% or more.
- A Linear Current Booster (controller) is required to start and run in low light
- Solar Tracker (optional) will increase daily yield (40-55% in summer)

Accessories

- **#20242 Intake Strainer/Foot Valve:** Monel metal screen, stops coarse debris
- **#20235 Inline Filter:** (10") Uses standard filter cartridges
- **#20237 Intake Filter/Foot Valve:** (30") Replaces Intake Strainer and Inline Filter with a single unit, may be lowered into a shallow well or stream
- **Spare Filter Cartridges:** (5 or 10 micron spun fiber)
  #20236 10" 2–pack
  #20238 30" 3–pack
- **Dry Run Switch:** Prevents pump damage if source runs dry
  #20240 for 1300/1400 Series
  #20241 for 2500/2600 Series
- **#20308 Close Elbows** for use in 6-10" well casings (150-250 cm)
- **Linear Current Booster** (LCB) required for PV-Direct: Specify voltage and current (amps = watts from chart divided by volts)

Fittings

- 1300/1400 Series: 1/2" female
- 2500/2600 Series: 3/4" male

Dimensions (1300/2500 Series)

- 5.7 x 15.5" (14 x 39 cm)
- Weight 16 lbs (7 kg)

Warranty

1 year against defects in materials and workmanship

Available From:

version 4/2000

Flowlight Booster Pump®

and

Solar Slowpump™

Installation & Service Manual

<u>IMPROPER INSTALLATION WILL DAMAGE YOUR PUMP AND VOID YOUR WARRANTY</u>

This manual is based on 20 years of experience with over 5000 pumps sold. We are pleased to observe how *few* problems arise when our pumps are *properly installed and maintained.*

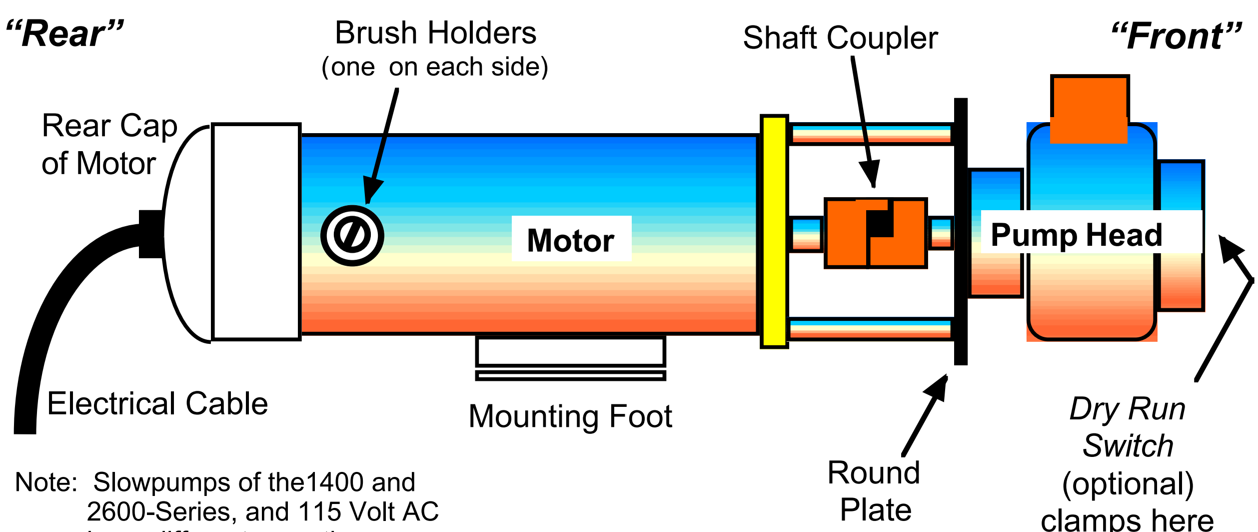
Please read and save this manual!

RECORD your MODEL # ______ - ___ SERIAL # _______

Verify your purchase: Please check Specification Sheet at the end of this manual, to verify that the pump you received is the best model for your application. If it is not, please contact your dealer or the factory for correction BEFORE installing your pump.

This manual covers two similar product lines:

- **Solar Slowpump** for water lift, powered by battery or solar-direct power, and
- **Flowlight Booster Pump** for water pressurizing, powered by battery system only.



Note: Slowpumps of the1400 and 2600-Series, and 115 Volt AC have different mounting structure.

INDEX IS INSIDE BACK COVER

BASIC CONSTRAINTS

I. PUMP MUST NOT BE SUBMERSED
II. WATER MUST BE FILTERED ABSOLUTELY CLEAN
III. PUMP MUST NOT RUN DRY

I. NON-SUBMERSIBLE PUMPS

Your pump must NOT be submerged in water, or rained or dripped on. If it is installed outdoors, supply some weather protection, such as a sheet-metal shield or even a dog house – something to keep it dry and also to protect it from the sun’s heat.

II. FILTRATION REQUIREMENT

Your pump is a PRECISION MACHINE. Traces of sand, clay, rust or other solids will cause rapid wear or immediate damage, just as they would in your automobile engine. If your water is CRYSTAL-CLEAR <u>ALL</u> THE TIME, our Fine Intake Strainer will provide sufficient protection. If you have an intake strainer already, it is probably not fine enough -- openings must be no more than several hairs wide, or additional filtration is required. Since water conditions are subject to change, it is good insurance to use a filter regardless. Many dealers refuse to sell our pumps without a filter since it minimizes call-backs.

Our 30-INCH INTAKE FILTER/FOOT VALVE is necessary for pumps lowered into wells. Otherwise our INLINE FILTER is best, installed close to the pump's intake. If filters are expected to clog often, maintainance may be minimized by plumbing two or more filters in parallel. The INLINE FILTER has a clear bowl so its condition may be observed. KEEP SPARE CARTRIDGES HANDY!

FILTER CARTRIDGES are available from your dealer or the factory. 9 7/8-inch cartridges for the INLINE filter may also be obtained from local water system suppliers. The 5 or 10-micron "spun polypropylene" type is best. Paper filters have less capacity. The kind that look like string has more restance to flow. Carbon taste and odor cartridges have less capacity for dirt, more resistance to flow, and cost more. Use them only if you have taste and odor problems.

A filter cartridge may look clean and still be clogged, due to fine silt embedded in the fibers. If the pump becomes increasingly noisey over time, it is usually due to a clogging filter cartridge. On the other hand, a cartridge that looks discolored may not be clogged. As long as your pump runs quietly, the filter is OK. Use pump noise to indicate the need to change cartridges.

IRON PIPE OR FITTINGS will introduce abrasive rust particles if installed on the intake side of the pump (they rust, even if galvanized). Pipe that is dirty inside (even new pipe) or has mineral deposits in it will also introduce dirt. Dirt is introduced as pipe joints are assembled, especially in a trench. Therefore, make sure inlet lines and fittings are FLUSHED CLEAN before hooking up to pump.

The INLINE FILTER may have a red push-button valve to release pressure for maintenance. If filter is placed more than a few feet higher than water source (at lowest level) the suction may pull the valve open and introduce air. Prevent this by sealing around the push-button with silicone sealant or epoxy, or replace the button with a nut, tightened down.

III. PUMP MUST NOT RUN DRY

Water is the lubricant for your pump. If it runs completely dry, it will overheat and fail.

DRY RUN SWITCH is an optional accessory to prevent damage from dry run. It is a small device with two wires that attaches to the front of the pump. It senses temperature, and switches the pump off before it gets too hot. If you are pumping from a tank, cistern or any water source that can run low accidentally, a Dry Run Switch should be used. If it saves a failure once in 10 years, it's worthwhile.

WARNING The dry run switch must be clamped tightly to the front (red plate) of the pump. Its round metal surface MUST press firmly against the red plate or it will not function. If you can slip a piece of paper between the switch and the red plate, it is not making sufficient contact. Loosen the clamp and press the brackets further onto the pump so the contact is tight.

OPERATION The red push-button pops out if the pump runs dry. Push it in to reset the switch, after water is restored.

A FLOAT SWITCH placed in the supply tank is an alternative to the Dry Run Switch. The advantage is that it will reset itself when water rises, and will not allow the pump to lose prime. The disadvantage is the need to run a power cable to the switch -- OK if distance is short. Please call your dealer or the factory if you have questions.

WARNING Do NOT use a “LOSS OF PRIME” PRESSURE SWITCH for dry run protection. This is a pressure switch with an automatic shut-off lever. It will NOT function with this type of pump. Your pump will push sufficient air to maintain pressure, holding the switch on.

PLUMBING SYSTEM DESIGN

If you are not experienced in water supply design and installation, you may wish to seek professional assistance. Many people are surprised to find how "complex" water system design can be.

See diagrams on p. 20, for typical groundwater installations.

MINIMIZE SUCTION LIFT to just a few feet, if possible. The practical suction limit for any pump is 20 vertical feet at sea level (subtract 1 ft. for every 1000 ft. of elevation). The more you minimize suction lift, the more reliable and quiet your pump will be. Just be sure the motor will not be submerged if the water level rises, or it will be ruined. Your pump may be placed DOWNHILL from your water source, if feasible.

YOUR INTAKE PIPE may run any reasonable horizontal distance, although it is BEST TO KEEP IT SHORT. (We know of installations where the pump is placed 200 feet from the water source, using 1 1/2" pipe.) USE LARGE PIPE for the intake (1 to 1 1/2" for larger Slowpumps or Booster Pump).

Slope the intake line from the water source UP toward the pump. AVOID HUMPS in the intake line. They trap air pockets which can block the flow. AVOID LEAKS IN SUCTION LINE. They are hard to locate and will cause constant problems.

INTAKE PIPE MUST BE SIZED GENEROUSLY to allow no more than a slight pressure drop at peak flow rate, or pump will be noisey and will wear rapidly. USE PIPE REDUCER FITTINGS to adapt your pump's inlet or outlet to larger pipe size where necessary. Excessive pipe sizing will do no harm!

INTAKE MUST NOT BE RESTRICTED by undersized pipe, excessive suction lift, or a CLOGGED FILTER. Excessive suction at the pump intake causes CAVITATION (formation and implosion of vapor bubbles). This causes very loud buzzing noise and RAPID PUMP WEAR. A slight buzzing noise is acceptable, if it cannot be avoided.

DO NOT USE THIN-WALL HOSE or soft tubing on the pump's intake. It may collapse under suction and restrict the flow. Do not use polyethylene pipe (black flexible) for the suction either. It is prone to slight leakage at the fittings.

INLINE FILTER should be mounted **HORIZONTALLY and as low as possible**. This prevents any air trapped in it from blocking the water flow. Be sure to leave some space below it for a pan, to catch water when replacing the filter cartridge.

FOOT VALVE is a check valve installed at the water intake. It is required in any case where the pump is located higher than the low-water level in the source. We recommend a high quality spring-loaded type to avoid loss of prime. A check valve allows water to flow one way and not the other. Be sure to install it the right way! Our 30" Intake Filter or Fine Intake Strainer Foot Valve accessory is recommended. These prevent debris from catching in the foot valve and causing loss of prime.

REMOVE FOAM PLUGS BEFORE CONNECTING PIPES. New pumps are packed with foam plugs to prevent contamination.

PRIMING YOUR PUMP: Priming a pump means filling its intake and suction line completely with water. This must be done if the pump is mounted higher than the water source. A removable plug or a valve must be installed at the highest point is in the suction plumbing. Prime the pump and intake line by pouring water into the opening until it is completely full. Your foot valve prevents loss of prime by not allowing water to flow back into the water source.

Your pump will create enough vacuum to SELF-PRIME to around 10 feet (less at high elevations), but only when it is in new condition and wet inside. A priming plug is always recommended if the pump is to be located higher than the water source. (EXCEPTION -- see "Installation in Deep Well Casings"). You may use a good quality ball valve instead of a plug, if frequent priming is expected.

A CHECK VALVE AT THE PUMP OUTLET is required if there is more than a 30 foot lift above the pump, or in any pressurizing system. This allows the pump to start easier. It also prevents back-flow when changing filter cartridges.

PIPE UNIONS: If you run rigid piping (copper or PVC) directly to the pump, unions are required. Unions make pump replacement easy, without the need to cut and re-solder or re-glue the pipe. "Copper Flex Connectors" commonly used for water heaters may be used instead. However: Do NOT use them for the larger *Slowpumps* (2507, 2607) or Booster *Pump*. They are too restrictive.

MOUNTING YOUR PUMP

Locate your pump in a cool place. Do not allow direct exposure to sunshine during operation, or the motor may overheat. Allow free flow of air around the motor for cooling. SHELTER IT FROM RAIN AND SUN, or it will be a mess in a few years.

The pump may be mounted horizontally or vertically. If vertically, FACE THE PUMP HEAD DOWNWARD. RIGID MOUNTING IS NOT required in most installations. In a non-battery system, starting is gradual and the pump does not jerk with the start. In a battery system, it will jerk slightly, but simply mounting it to a small wooden board is sufficient to stabilize it. The pump may be hung vertically on a rope. Observe the pump and see that it is not likely to overstress or loosen pipes as it starts. DO NOT mount the pump directly to a wall or wood floor in your home. It will increase the noise.

CHANGING PUMP HEAD POSITION: If you wish to face the pump's fittings sideways or downward, you may rotate pump head to a different position by removing the four bolts that secure the pump to the motor. If your pump looks like the picture on P.1, do this: Remove the four hex-head bolts from the round plate, then rotate pump head to new position. REALIGN THE PUMP AND MOTOR SHAFTS, or the coupler will bind and wear. This is simple. When you remove the round plate, notice that the bolt holes are oversized for alignment adjustment. Reposition as desired, but leave the bolts loose. BEFORE installing the pump, drop a teaspoon of water into the inlet and run the pump (on 12 volts is OK for the 24v pumps). Slide the plate around so it settles into the position where there is NO VIBRATION, then tighten the bolts firmly.

HANDLE YOUR PUMP CAREFULLY! Never hammer on it, clamp it in a vice or drop it. Pump-motor alignment is critical. DO NOT DISTURB THE ALLEN-HEAD BOLTS holding the mounting plate to the motor UNLESS you wish to rotate the pump head to a different position.

The shaft coupler between the motor and pump should turn easily using two fingers. Sometimes after a period of dry storage, the pump will stick. If you can't turn the coupler, put a bit of water in the pump intake and turn the coupler with pliers to "crack" it loose. Do this by turning it BACKWARDS. If it sticks again, see “Troubleshooting”.

IF YOU ARE NOT EXPERIENCED WITH WATER SUPPLY INSTALLATION, PLEASE CONSULT LOCAL SOURCES regarding:

(1) Freeze protection
(2) Choice and sizing of pipe
(3) Plumbing design in general.

INSTALLATION IN A DRILLED WELL CASING

INSIDE A 6-INCH WELL CASING, SPECIAL ELBOWS ADAPTERS are required. The elbows fit 1/2" polyethylene (black flex) pipe. MEASURE CAREFULLY to determine the length of pipe you need. SUBTRACT 1.5% TO ALLOW FOR PIPE AND ROPE STRETCH.

Assemble according to diagram. A priming plug is not needed. Before lowering the pump, place the intake into a bucket of clean water and run the pump until water exits. Now it is

primed. A "pitless adapter" may be optimum for freeze protection. Check with your local well supplier for details.

POLYETHYLENE PIPE comes in rolls, and is inexpensive and quite freeze-tolerant. Use with plastic adapters and secure with ALL-STAINLESS hose clamps (obtain such clamps from a pipe supplier rather than automotive supplier). If pipe does not stretch tightly over fittings, warm it with a torch or hot water then tighten clamps firmly with a wrench. Use two clamps at each joint. Keep extra clamps handy in case you strip one.

ELECTRICAL WIRING

WIRE SIZING: DON'T CHEAT YOURSELF with undersized wire! Your pump is wired with a short length of #14 or #12 cable. This size is sufficient for short lengths only. Splice it to a larger size of wire if your wire run is longer than 15 feet. Consult a low voltage wire size chart or call your dealer or the factory for recommendations. Excessive voltage drop will slow the pump down, but if it is unavoidable, don’t worry. It will NOT cause any harm to the motor.

BLACK WIRE = POSITIVE (+)   WHITE WIRE = NEGATIVE (-)   GREEN WIRE = GROUND
1400 & 2600-Series Slowpumps: Red = Positive   Black = Negative

Reverse polarity will cause reverse rotation. This will not cause damage if done for a short time. Reverse the wires if necessary so pump turns CLOCKWISE looking at the red face of the pump.

FUSE OR CIRCUIT BREAKER PROTECTION

FAILURE TO INSTALL A FUSE OR BREAKER equal to or less than the motor's Max Amps rating WILL VOID YOUR WARRANTY.

If water flow becomes blocked, or if the pump jams or freezes and cannot turn freely, the motor will draw excessive current. A fuse or circuit breaker will then break the circuit. Without such a "safety valve", a minor fault can burn your motor and wiring.

Install a fuse or breaker with an AMP RATING close to the "MAX AMPS" rating of your motor, OR LESS (but not more higher). If a Linear Current Booster is being used (for array-direct Slowpumps) install the fuse between the booster and the pump. Use the rating recommended for the booster or for the pump, WHICHEVER IS LESS. This fuse will protect the booster as well as the motor and wiring from overload.

FUSES: Use a “time-delay” type. The 3" paper cartridge type is good, and may be installed into a raintight disconnect switch available at any electric supplier. An automotive in-line fuse holder is fine for 12 or 24V systems. Automotive blade fuses (type ATC) are prefered over glass fuses. They have sufficient time-delay. (Time-delay glass fuses are available from ELECTRONIC suppliers only, not automotive.) Use good quality fuse holders, protected from weather. Keep spare fuses handy. Never substitute a larger fuse!

CIRCUIT BREAKERS: Most AC breakers cannot be used for low voltage DC circuits. We recommend only the SQUARE-D® QO or QB-series which been rated safe up to 48 volts DC. A 10 amp size is available, but not in most stores. It may be ordered from your PV dealer or from an electric supplier.

Install the fuse or breaker at the power source, to protect the wiring as well as the motor. If the circuit is protected by a breaker, then any additional fuse may be installed at the motor.

THERMAL OVERLOAD

If your pump resembles the illustration on P.1, a THERMAL SWITCH is mounted on the rear of the motor (inside the white cap) to shut off the motor if it approaches an overheat condition. If this happens, it will turn back on after a cooling period of about 20 minutes. If overheating occurs during normal operation of the pump, it may be because it is working beyond it's capacity. See Troubleshooting.

The Flowlight Booster Pump, Standard Model may overheat if it is running for more than 20 minutes at a pressure exceeding 50 PSI. It will cool and reset automatically.

GROUNDING and LIGHTNING PROTECTION:

A long wire run may act like an antenna, receiving induced surges of high voltage when lightning is present. Proper grounding will greatly reduce risk of lightning damage to your power system.

A proper ground system consists of a minimum of one 8 ft. copper-plated ground rod driven into the ground, preferably in a moist spot close to the PV array. Or, if you have a steel well casing, drill and tap a bolt hold to make good contact to it.

In a dry, lightning-prone location, use more than one ground rod at least 10 ft. apart. Bury bare copper wire between them. Use min. #8 ground wire (larger for distances exceeding 20 ft.). In a rocky location, where ground rods can't be driven, bury (as much as feasible) 150 feet (total) of bare copper wire, radiating out in two or more directions from the PV array. Try to contact moist earth as much as possible. Use only the copper or bronze electrical connectors designed for grounding application, and BE SURE ALL CONNECTIONS ARE TIGHT.

Connect your ground system to the METALLIC FRAME of your PV array via min. #8 copper wire. Also ground metallic support structures and electrical enclosures. For non-battery pumps, we have observed the least lightning damage where only the mechanical structure is grounded -- NOT an electrical conductor. This may vary from electrical codes. Call the manufacturer of your controller, if you have questions.

WATER LEVEL & FLOW CONTROL

FLOAT SWITCHES/WATER LEVEL SENSORS: These are devices that sense high or low water level and switch your pump on and off. Ask your dealer or factory about these. Most switches rated for 15 AMPS at 230 VAC are fine for your DC pump.

FLOAT CONTROL IN WATER SOURCE may be used if dropping water level is causing dry run or excessive suction (noise due to cavitation).

FLOAT CONTROL IN STORAGE TANK may be used to turn pump off when tank fills. This eliminates tank overflow and reduces pump wear and filter changing.

REMOTE FLOAT CONTROL when tank is a LONG DISTANCE from pump may be done in three ways:

(1) Small wire buried from tank/float switch to pump actuates a relay at the pump.

(2) Very small wire from sensor in tank actuates "Water Level Sensor" option in your pump controller (LCB). This is for non-battery systems only.

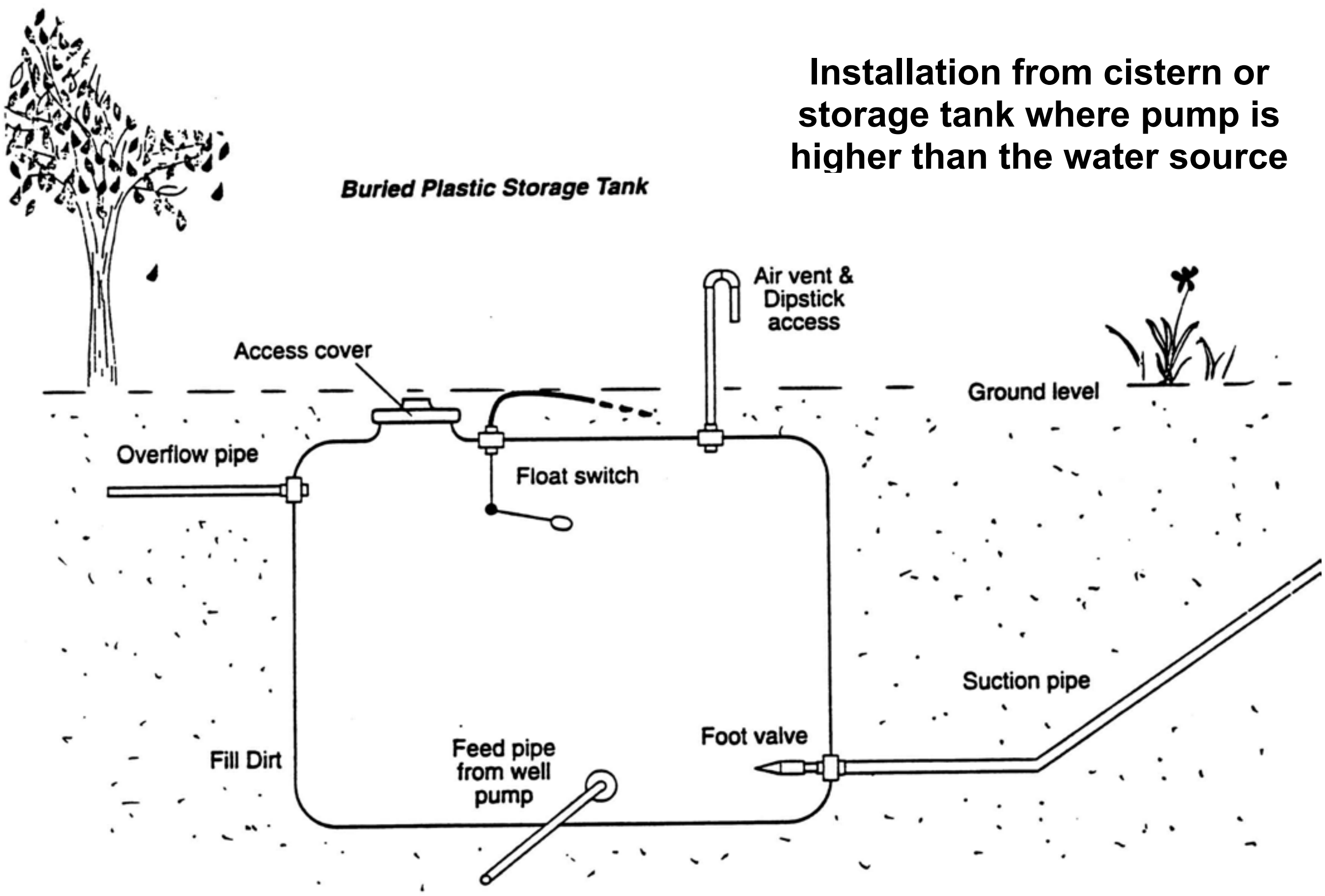
(3) Float valve in tank restricts flow. Pressure builds up and actuates pressure switch at pump. Small captive-air pressure tank is necessary at pump to prevent "switch chatter". Contact your dealer or the factory for further advice.
FLOW RESTRICTION MUST NOT BE USED as a method to reduce your pump's flow rate. It may result in excessive pressure build-up and current draw.

Flowlight ®Booster Pump Installation
For Pressurizing Systems

A PRESSURE TANK IS REQUIRED with a Booster Pump system. PRESSURE TANKS are available from local water supply dealers. Use the largest tank that you are willing to buy. 40 gallon size is typical -- it allows you about 12 gallons of water between pump cycles. Those 12 gallons may be drawn at a higher flow rate than the pump produces. A large pressure tank will minimize on/off cycling of the pump. In a typical household of more than four people, a tank of at least 60 gallons is recommended. The bigger the better! More than one tank may be connected. They need not be the same size.

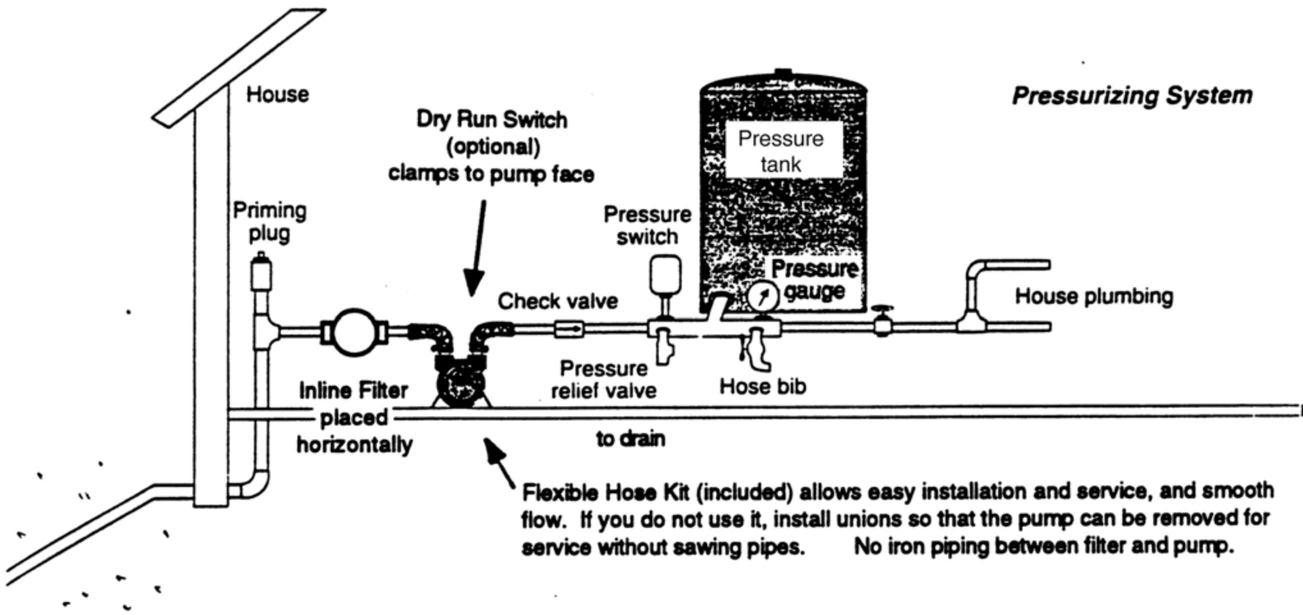
A PRE-CHARGED "CAPTIVE AIR" TANK is recommended. Cheaper "galvanized tanks" require periodic recharging, store less water between cycles, and don't last as long. PROPER PRE-CHARGE IS ESSENTIAL. Follow the instructions that come with your pressure tank – With presure discharged from the tank, adjust pre-charge to 2-3 PSI below cut-in pressure. This will assure that you get the best performance from your system.

Installation from cistern or storage tank where pump is higher than the water source



NOTE: It is preferable to place the pump LOWER than the water level in the tank. This illustrates an alternative, not an ideal. Note the upward rise of the suction pipe, the high position of the priming plug, and the horizontal position of the filter. These measures help prevent air entrapment that restricts flow and causes pump noise.

Follow your pressure switch instructions for wiring. Use the flexible hose that comes with your Booster Pump (cut it into two sections). Our *Easy Installation Kit* contains the tee fitting at the tank, a DC-rated pressure switch, and all of the small parts shown between the pump and the house plumbing. **See PRESSURE SWITCH DIAGRAM on PAGE 20**



Typical *Flowlight Booster Pump* installation

Illustration by Home Power Magazine

PRESSURE SWITCH ADJUSTMENT: Switch settings determine the pressure range of your system. To conserve energy, set the pressure as LOW as feasible. This will also prevent the motor from overheating if you run it for long periods -- sprinkling, for example. Low pressure (even 15-20 PSI) may deliver excellent water flow IF your plumbing and hoses are sized larger than minimum. If not yet plumbed, use at least one size larger pipe than conventional, and avoid restrictive connections such as 3/8" tubing often used to feed sinks.

Adjustment: Start with the standard setting (usually 30/50 PSI). Reduce the pressure according to your requirements, if you wish. It is wise to measure the current used by your pump (with an amp meter in series with the line, your system metering). Current draw will rise in direct proportion to outlet pressure. Pressure should NOT be set beyond 50 PSI MAXIMUM (65 PSI with 2910 Model) or loss of efficiency and motor over-heating will result. IMPORTANT: After any change to your cut-in pressure, you need to readjust the pressure tank pre-charge.

If you are raising water vertically AND pressurizing, note the relationship: 2.31 ft. = 1 PSI. Example: A pump that lifts 23 vertical feet and pressurizes to 30 PSI must pump a total of 40 PSI. Total lift = vertical distance from water surface to pressure tank.

WARNING: INSTALL THE PRESSURE RELIEF VALVE INCLUDED WITH YOUR PUMP! Flowlight Booster Pumps are supplied with a 75 PSI Pressure Relief Valve as a safety feature. If your pressure switch fails, EXCESSIVE PRESSURE may cause your tank or piping to burst and flood your home. (A properly sized fuse or circuit breaker should shut pump off before relief valve opens BUT many breakers are not accurate, and the proper fuse may not always be present.)

INSTALL THE PRESSURE RELIEF VALVE near your pressure tank (at the "Accessory Tee" shown in diagram). Run a pipe or hose from its outlet to a drain or drain pipe or to the outdoors where water can drain away safely.

A GATE VALVE and DRAIN VALVE are recommended (see diagram) for convenience during system shut-down. The drain valve is simply a garden hose outlet which allows easy draining of the system. It also allows water delivery by hose while water is shut off to the house during installation or repairs to plumbing.

EASY INSTALLATION KIT IS AVAILABLE!

If you have not yet purchased the small parts you need to install your Booster Pump, you can save time and confusion by purchasing our convenient *Easy Installation Kit*. Pipe components are brass to resist corrosion. The kit includes pressure switch, pressure gauge, tank tee, shutoff (ball) valve and hose bib (drain valve) plus the necessary pipe nipples. Order Dankoff Solar Item #20200

VENTILATION SLOTS are located on bottom of motor for cooling (Standard Model Booster Pump only). If you are concerned with insects building nests inside your motor, glue some screen over the slots. Silicone sealant works best for this.

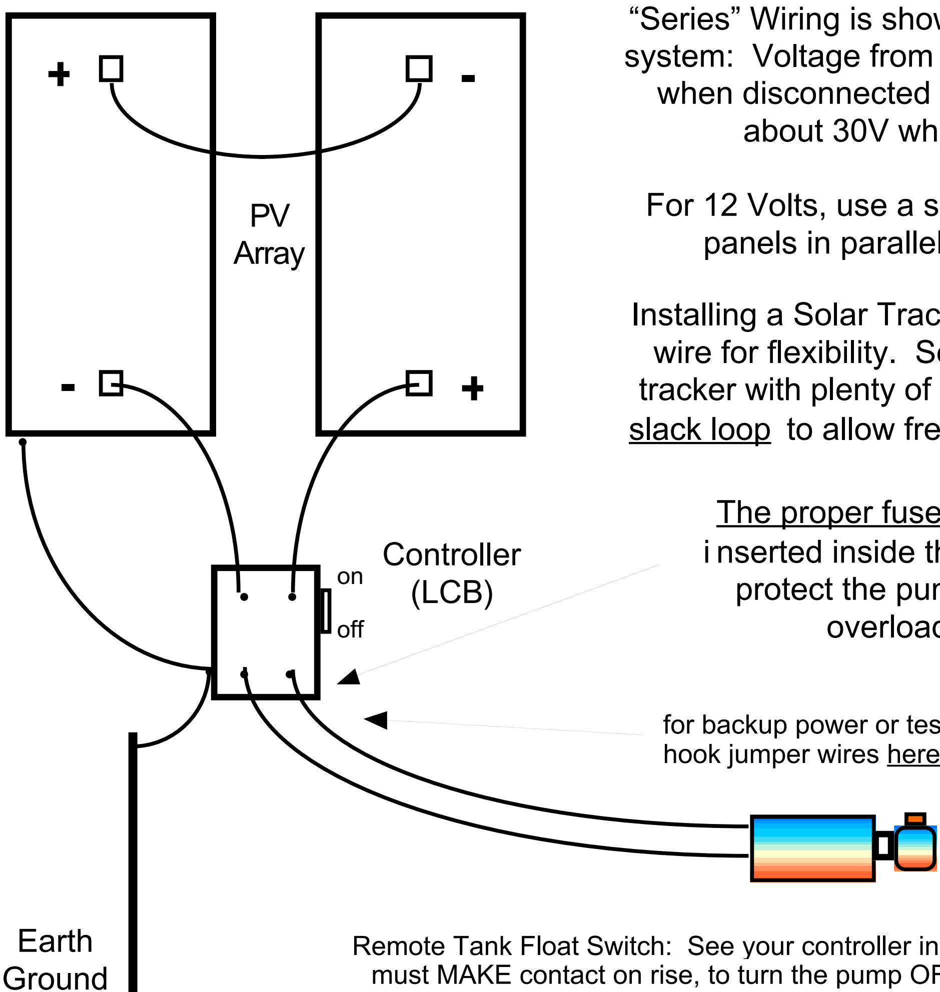
FLOWLIGHT BOOSTER PUMP requires a BATTERY SYSTEM, NOT A PV ARRAY-DIRECT installation. PV ARRAY voltage may exceed 15V and overspeed the pump.

SOLAR SLOWPUMP — POWER CONTROL for ARRAY-DIRECT (NON-BATTERY) OPERATION

When working against a constant head (vertical lift) *Solar Slowpump* requires nearly constant current, regardless of the voltage/speed. When low light conditions are present, the PV array cannot supply full current. The voltage will drop to nearly zero, and the pump will “stall” (like a truck trying to start in 4th gear). The remedy is either to add a PUMP CONTROLLER, also called LINEAR CURRENT BOOSTER (LCB) to your system. This device will match the power source to the load by transforming the voltage down while increasing the current delivered to the motor (like an automatic transmission). If you are not using a controller in your non-battery system, contact your dealer. It will greatly improve low-light performance.

System Wiring for Typical *Slowpump* Installation

-- *Non-battery System* --



“Series” Wiring is shown, for *nominal* 24V system: Voltage from panels will read 40V when disconnected (open circuit), and about 30V while pumping.

For 12 Volts, use a single panel, or wire panels in parallel (+ to +, - to -).

Installing a Solar Tracker? Use stranded wire for flexibility. Secure the wires to tracker with plenty of tape. <u>Make a long slack loop</u> to allow free motion of tracker.

<u>The proper fuse</u> must be inserted inside the LCB to protect the pump from overload.

for backup power or testing using a battery, hook jumper wires <u>here</u> , <u>not</u> to controller input.

Remote Tank Float Switch: See your controller instructions. Float switch must MAKE contact on rise, to turn the pump OFF. This is opposite of normal action, so your float switch may be labeled “pump down to empty”.

WATER USAGE

WATER CONSERVATION = ENERGY CONSERVATION
+ LESS FILTER MAINTENANCE

TOILETS: A 1.6-gallon flush toilet may reduce total domestic water consumption by 50% compared with typical 4-5 gallon toilets. They are now standard in U.S.A.

IRRIGATION SYSTEMS: Many drip, trickle or flood irrigation systems will function on LOW PRESSURE. It is wasteful of energy to supply pressurized water where it is not required. You may wish to arrange separate gravity flow from your water source or storage tank, if possible. Or, if a small amount of lift/pressure is required, consider a low-pressure DC pump such as a marine bilge or circulator pump.

LOW FLOW SHOWER HEADS are recommended IF you are running 30-50 PSI pressure range. At lower pressures, they may not provide adequate flow.

FREEZE PROTECTION

If freezing of your outlet pipe is to be expected, you may avoid the frequent necessity of replacing fuses or resetting your breaker by installing an ADJUSTABLE PRESSURE RELIEF VALVE at the pump outlet. This will allow water to flow back into the well when outlet pipe is blocked. Order the valve from your dealer or any electric or plumbing supplier (Grainger's part number 1X624 or equivalent, about $15). To adjust, be sure water has reached the highest point in your system. Loosen the valve til it leaks water, then tighten it gradually JUST PAST the point where it stops. Be sure water will not drip onto the motor/pump.

To PREVENT freezing of exposed pipes (*Slowpump* system) you might consider the primitive method of drilling a small "weep hole" in the outlet pipe, below ground level. The pipe will drain when pumping stops but a small amount of water will be wasted during pumping. Set the outlet pipe to spill into the top of the tank so that the tank will not drain, or install a check valve and "vacuum breaker" to allow pipe to drain.

Water WILL drain back through the pump if allowed to, but it will do so slowly. If this is desired, do not use any check valves or foot valve. Pump must have suction draw of no more than a few feet, however. If pump drainage is required, position pump vertically (head downward) or horizontally with intake and outlet facing downward (see "Changing Pump Head Position", p.5).

Take every precaution to PREVENT pump freezing. The forged brass pump head will survive most light freezes, but a hard freeze may damage it. If you insulate your pump for freeze protection, keep the motor exposed so it won't overheat.

MAINTENANCE

INTERNAL INTAKE SCREEN: The pump has an internal metal intake screen. It's purpose is to catch solids accidently introduced during installation or filter servicing, dirt stuck inside your intake pipe before installation, or mineral deposits that may accumulate and flake off of the intake piping.
1300-SERIES *"SLOWPUMP"* has an angled extension with a large brass nut on the end. Remove the nut to inspect and empty screen.
2500-SERIES *SLOWPUMPS* & *"FLOWLIGHT BOOSTER PUMP"* have a strainer pushed into the intake fitting.

EXTERNAL FILTRATION IS STILL REQUIRED! If you notice signs of intake blockage, inspect your screen. If solids keep accumulating, improve your filtration. See Page 2 for details about filters and cartridges.

PUMP HEAD: Except for the internal screen, your pump head is maintenance-free. DO NOT remove its front plate or otherwise tamper with it unless you are intending to get it rebuilt. The pump head is NOT USER-SERVICEABLE. It is easy to dissemble, but difficult to reassemble without special tools.

WATER FILTER:
The best way to determine when a cartridge is becoming clogged is to listen for an increasingly loud buzzing noise (cavitation). It is difficult to determine the condition by the appearance of the cartridge. KEEP SPARE CARTRIDGES! You can buy cartridges locally, but the best ones are thick-body polypropylene fiber construction (not the type that looks like twisted string or paper). We recommend 10-micron cartridges (pack of two: Dankoff Solar Item# 20236). Do not use a carbon filter for this purpose.

***30" INTAKE FILTER*, WARNING:** Cartridges vary slightly in outside diameter. If replacement fits loosely into end caps, wrap ends with cloth or tape to make a snug fit. If cartridge is too large to fit, peel away some fibers using a knife. End caps MUST fit snugly or dirt will enter! Pack of 3 cartridges: Dankoff Solar Item #20237.

MOTOR BRUSHES: After a year or two, inspect your motor brushes and measure their length (remove one or both of the black plastic screw heads near the rear of the motor). Motor brushes on most models measure 3/4 inch long, not including the rounded end. If you have a 1/2 HP model (1400 or 2600 series, or any motor larger than 5" diameter) they begin life measuring about 1 1/4"). After they show some wear, you may calculate how many more years they have left before they are too short. After inspecting a brush, replace it in the EXACT SAME POSITION and tighten the plastic screw GENTLY. Most brushes last at least 5 YEARS of daily running. Brush wear will not effect motor performance until contact is suddenly lost.

MOTOR BRUSHES for 12V pumps: Dankoff Solar Item # 20301
MOTOR BRUSHES for 24V pumps: Dankoff Solar Item # 20302

For 1400 and 2600-series pumps (large blue motor) and for AC models, please ask your Dankoff dealer.

TROUBLESHOOTING

BEFORE YOU CALL FOR HELP,
TRY TO LOCATE YOUR PROBLEM HERE:

Please note the terms "Front" and "Rear" -- See P. 1 illustration

PUMP WILL NOT FIT INTO YOUR 6" DRILLED WELL CASING: Close Elbow fittings are required (Dankoff Solar Item #20308).

PUMP DOESN'T TURN ON -- NO POWER: (1) CHECK DRY RUN SWITCH on front of pump, if present. Press red button to reset. Correct the cause of dry run. (2) CHECK FUSE or BREAKER and any control or wiring devices in line. (3) MOTOR STARTS WHEN YOU HIT IT: Sticking brushes -- "Motor Brush Problems" (4) Remove rear cover of motor to check connections there. Check for voltage present at motor. If voltage is present, see next entry. (5) CHECK THERMAL OVERLOAD SWITCH on rear of motor. Bypass it by holding a piece of wire across its terminals. If motor runs (and is not hot) replace thermal switch. DRY RUN SWITCH may be tested the same way.

PUMP SPINS BUT DOESN'T PUMP WATER: (1) CHECK DIRECTION of rotation. If not clockwise (viewed from brass front-end) reverse polarity. (2) CHECK PRIME: Open priming plug or valve (see instructions). Pour water in. LOSS OF PRIME/INTAKE PIPE LEAKAGE: CHECK ALL FITTINGS -- a pinhole leak in suction pipe will cause loss. FOOT VALVE may leak. Inspect, pressure-test, clean or replace. Debris may be stuck in foot valve causing leak if not protected by fine screen or intake filter. REGARDING POLYTHYLENE PIPE FITTINGS: If pipe does not stretch tightly over fittings, it may leak. Gently heat with torch or hot water and retighten hose clamp WITH WRENCH. Replace stripped clamps. Use ALL-STAINLESS clamps.

NOISY PUMP:
NOISE = CAVITATION = RAPID PUMP WEAR
FIX THE PROBLEM!

STEADY BUZZING SOUND Indicates EXCESSIVE SUCTION due to any combination of (1) HIGH SUCTION LIFT -- mount pump as low as possible, (2) UNDERSIZED SUCTION PIPE, (3) CLOGGED FILTER -- NOTE: Fiber filter cartridges may be clogged and LOOK CLEAN (fine silt is hidden within the fibers). (4) CLOGGED INTERNAL INTAKE SCREEN. See next two entries. (5) SOFT, FLEXIBLE HOSE used on intake line may be crushed or kinked by suction -- replace with more rigid pipe material.

UNSTEADY BUZZING SOUND Indicates LEAK IN SUCTION LINE allowing AIR to enter. (1) Check for bubbles in in-line (transparent) filter or air in outlet water. (2) See LOSS OF PRIME in above entry. (3) If you have IN-LINE FILTER with red Pressure Relief Valve (red button) on top, and it is mounted several feet above water source, air may be drawing in around the valve. SEAL AROUND THE VALVE with silicone sealant or epoxy glue OR unscrew the red button and replace it with a nut, tightened. (4) If no source of air leakage is present, water may have high concentration of DISSOLVED GASSES which release as bubbles in suction pipe. Reduce suction lift if possible. Install air chamber in intake line, with valve on top. Pour water in to replace air when problem reappears. (5) Turn filter to a horizontal position. This allows bubbles

to get out of the way of flow. Do NOT turn it upside-down, or dirt may fall in when filter is changed.

NOISE AND VIBRATION IN PIPES (pressure gauge vibrates extremely): One of four vanes in the pump is broken. Pump head must be rebuilt -- See Rebuild/Exchange Service. There should be almost no vibration of pressure gauge needle.

FILTER CLOGS FREQUENTLY: (1) INTAKE TOO CLOSE to bottom of well, stream, tank etc. Raise it as high as feasible to reduce intake of dirt. (2) IMPROVE THE DEVELOPMENT of the water source -- channel water into a settling tank, clean tank periodically. (3) Install a larger filter, or plumb two filters parallel to each other.

CLOGGED INTAKE SCREEN: Safety screen is located at the pump intake. Remove large nut (1300-series) or intake fitting (2500-series or Booster Pump) to inspect and clean screen. (1) IF YOU DON'T HAVE A CARTRIDGE-TYPE FILTER, INSTALL ONE NOW! (2) If screen is clogged with fibers from filter cartridge, use higher quality cartridges. (3) If screen is clogged with rust deposits, replace iron pipe or fittings with plastic, copper or brass. (4) If mineral or corrosion deposits are clogging screen, install filter as close as possible to pump intake. Ask local water professionals what type of pipe is least susceptible to mineral accumulation and corrosion in your area.

FILTER IS CLOGGED AND YOU DON'T HAVE REPLACEMENT: (1) IN-LINE FILTER: Purchase common "Rust and Sediment" fiber-wound cartridge at local hardware store or pump/well supplier. (2) 30" INTAKE FILTER: Obtain spares from your dealer, factory or industrial suppliers. In emergency, purchase 3 ordinary 10" fiber filters (not paper) from local source. Glue them end-to-end with epoxy and install. (3) TRY BACK-WASHING filter by blasting it with pressure from the inside. For 30" intake filter, remove check valve and attach garden hose adapter. Back-washing is effective on coarse, sandy material but is NOT effective with clay, rust, very fine or sticky deposits.

PURCHASE SPARE FILTERS. NEVER RUN PUMP WITHOUT A FILTER!

LOW FLOW RATE -- PUMP TURNS FAST, DRAWS LOW CURRENT: Pump is worn out from dirt, rust or other abrasive particles in water, or from cavitation, from running dry, or just from age. REPLACE PUMP HEAD. See "Rebuild/Exchange Service".

***BOOSTER PUMP* TAKES LONG TIME TO REACH CUT-OFF PRESSURE:** (1) If pump spins fast, see above entry. (2) If pump rotation slows way down as pressure builds, wire is too small. Consult low voltage wire size chart or ask your dealer for correct wire size.

LOW FLOW RATE -- PUMP TURNS SLOW, DRAWS HIGH CURRENT (may run hot, may blow fuses): Pump is hard to turn due to: (1) EXCESSIVE VERTICAL LIFT, beyond system's capacity: Trade pump head for lower volume model, or increase size of solar array if it will not overpower the motor -- see Specifications Chart. (2) MISALIGNMENT: Pump plate was removed from motor and not readjusted after assembly. See "CHANGING PUMP HEAD POSITION", p.5. Check rubber shaft coupler for damage. (3) MINERAL DEPOSITS: Turn shaft with two fingers. Will be hard to turn. Use vinegar, or whatever solution works to dissolve the mineral deposits in your plumbing. Remove pipes from pump and allow solution to circulate through pump by turning it backwards. If this doesn't work, or if pump has been damaged, replace or rebuild.

PUMP CYCLES ON AND OFF ABOUT EVERY 20 MINUTES: MOTOR IS OVERHEATING. Thermal switch on back of motor is working. (1) HIGH CURRENT DRAW: See above. (2) NO VENTILATION: Motor must have FREE AIR FLOW to prevent overheating. Do not wrap with insulation. (4) Motor is exposed to sun or other heat source -- keep it cool. (5) BAD THERMAL SWITCH: Motor should shut off at approximately 140 degrees F. If motor smells or is too hot to hold your hand on for 3 seconds, replace thermal switch and check for overheat damage. If motor is not getting so hot (you can hold your hand on it for 5 seconds) replace thermal switch.

NOTE ON *BOOSTER PUMP*: STANDARD MODEL may overheat if run continuously (periods over 20 minutes) at pressures exceeding 50 PSI. This may happen while running irrigation. Observe pressure gauge and open valve(s) for higher flow so that pressure drops below 50 PSI, or reduce your pressure switch setting. The thermal switch protects the motor from damage.

***BOOSTER PUMP* CYCLES ON AND OFF EVERY FEW SECONDS (PRESSURIZING SYSTEM):** PRESSURE TANK MUST be used with system. Pre-charge tank via air fitting to 2 PSI less than cut-in pressure (that's 28 PSI air in a 30-50 system). Turn power off and release water pressure before setting pre-charge. Modern "captive air" tank will not need pre-charging again. GALVANIZED TANK (without air bladder) MUST BE RECHARGED with air about once per year as air dissolves into water. Use tire pump or compressor.

***BOOSTER PUMP* TURNS ON PERIODICALLY WHEN NO WATER IS BEING USED.** (1) Water is leaking somewhere after the check valve (check valve must be installed at pump outlet). (2) Check valve leaks internally. Foot valve, if present, also leaks.

LOW FLOW RATE -- PUMP TURNS SLOW, MOTOR COOL: (1) Voltage at motor measures lower than voltage at source: WIRE IS UNDERSIZED. Consult wire size chart or ask your dealer. (2) See next entry.

***SLOWPUMP* RUNS TOO SLOW OR STALLS IN LOW LIGHT (Array-Direct, Non-Battery System):** (1) Solar array or wire is undersized. (2) Linear current booster or similar matching devices needed to prevent stalling when array current is less than pump requires. Contact dealer or factory. (3) Current booster not "tuned" properly (if it has an adjustment). Set screwdriver adjustment for peak performance in LOW LIGHT conditions. See current booster instructions. (4) Pump may be drawing too much current -- Test: Connect pump to battery(s) of proper voltage. Measure current draw (amps) and flow rate. Check against chart (Watts = Volts X Amps). See "Low Flow Rate/Slow/High Current" above, if not close to specifications.

PUMP WON'T TURN, shaft coupler can't be turned by hand. Should blow fuse or breaker: (1) After a period of disuse or storage, parts may lock up. Grab shaft coupler lightly with pliers and try turning it backwards. (2) Debris jammed in pump. Disconnect plumbing, pour water into outlet, and run pump IN REVERSE (by reversing polarity). Watch for debris exiting inlet. Check performance -- damage is likely. (3) See "Pump Frozen".

PUMP JAMS, MAKES CRUNCHING NOISES, black material in outlet: Internal parts are broken, either by debris in pump, severe freezing, external shock or just bad luck. See "Rebuild/Exchange Service".

WATER DAMAGE: MOTOR SUBMERGED OR DRIPPED ON. Inspect brushes and commutator. If in very poor condition, motor may be beyond repair. Contact factory. If motor was not run wet for very long, it may need only new bearings, available from factory or from any

motor repair shop or bearing supplier. Rough commutator must be turned (resurfaced) on a lathe. This may be done by a machine shop or electric motor shop. CORRECT THE CAUSE of damage. If your water level is too unstable, contact your dealer or factory about a submersible pump.

RUSTY BEARINGS: (1) PUMP HEAD: Steel ball bearing is visible at pump head shaft. Rust caused by water drip or submersion. Pump head must be rebuilt to replace the bearing (see Rebuild/Exchange). (2) MOTOR: Replace with DOUBLE SEALED "R8" bearing (front) and "R6" (rear). These are common bearings available from automotive or electric motor suppliers, or factory. Any mechanic can do this. (A puller tool or a press is needed for removal.)

PUMP FROZEN BY LOW TEMPERATURE: (It should blow fuse or breaker.) Allow it to thaw. Observe/test performance. If damaged, replace or rebuild. Check all plumbing for damage and leaks and protect from future freezing.

RUBBER SHAFT COUPLER FAILURE: MISALIGNMENT between pump and motor shaft due to removal of pump plate from motor and reassembly without readjustment. See "CHANGING PUMP HEAD POSITION" on p.5. Replace rubber "spider". Inspect metal coupler halves for damage and replace if worn. These are common parts available from any electric motor shop, machine shop, or heating/air conditioning supply, or from factory. Coupler parts will last "forever" if alignment is correct.

MOTOR BRUSH PROBLEMS: Motor brushes are carbon rods that make electrical contact with the spinning copper "commutator" on the motor shaft. The two brushes are accessible by the plastic screws near the rear of motor. They MUST slide in and out very easily -- a spring pushes them in as they wear. Brushes must be at least 3/8" long (longer on motor larger than 5” diameter). They generally last about 5 years, unless motor has been wet inside (see "WATER DAMAGE"). Retighten plastic screws gently!

(1) WORN BRUSHES: Call dealer or factory for replacements.

(2) STICKING BRUSHES: Inspect inside each brush holder with flashlight. Clean if corroded or dirty. If brushes still don't slide in/out without friction, sand down two of the long sides of brush VERY slightly.

(3) BRUSH SPRINGS WEAK, wire looks overheated: Motor overheated (severe overload, lack of fuse protection). Replace motor and correct the cause.

(4) BROKEN BRUSH HOLDER: Repair with epoxy, or replace (contact factory). Glue it to motor shell with EPOXY PUTTY, carefully mixed. To insure proper position, remove rear plate of motor to see that brush sets into perfect position as glue sets. Glue must be hard and strong.

(5) COMMUTATOR PROBLEMS may be caused by poor brush contact, overheating or water damage: Com is visible thru brush holders or Booster Pump cooling slots. The wearing surface should be smooth, with a uniform brown color. If it looks good, DO NOT sand it or do anything to it. Commutator damage may require resurfacing on a lathe. A local electric motor repair shop or automotive electric shop can perform these repairs.

FACTORY REPAIRS

WHEN CALLING FACTORY OR DEALER FOR HELP,
PLEASE tell us your MODEL and SERIAL NUMBERS !

Most failures involve the pump head, not the motor. This is the brass part that the pipes connect to. The pump head may be replaced with simple hand tools (a 7/16" wrench and a 1/8" Allen wrench/hex key).

YOUR PUMP HEAD IS NOT USER-SERVICEABLE. It is delicate and difficult to re-assemble. Disassembly of your pump head will void your warranty. Individual parts are not available. If the pump head is faulty, it must be replaced with a new one.

WARRANTY CLAIMS must include receipt to prove date of purchase.

TO SHIP PUMP TO FACTORY FOR REPAIR:
Please call us before shipping anything.

(505) 473-3800   FAX (505) 473-3830   Email: pumps@dankoffsolar.com

PLEASE tell us your MODEL & SERIAL NUMBERS

****

WARRANTY

****

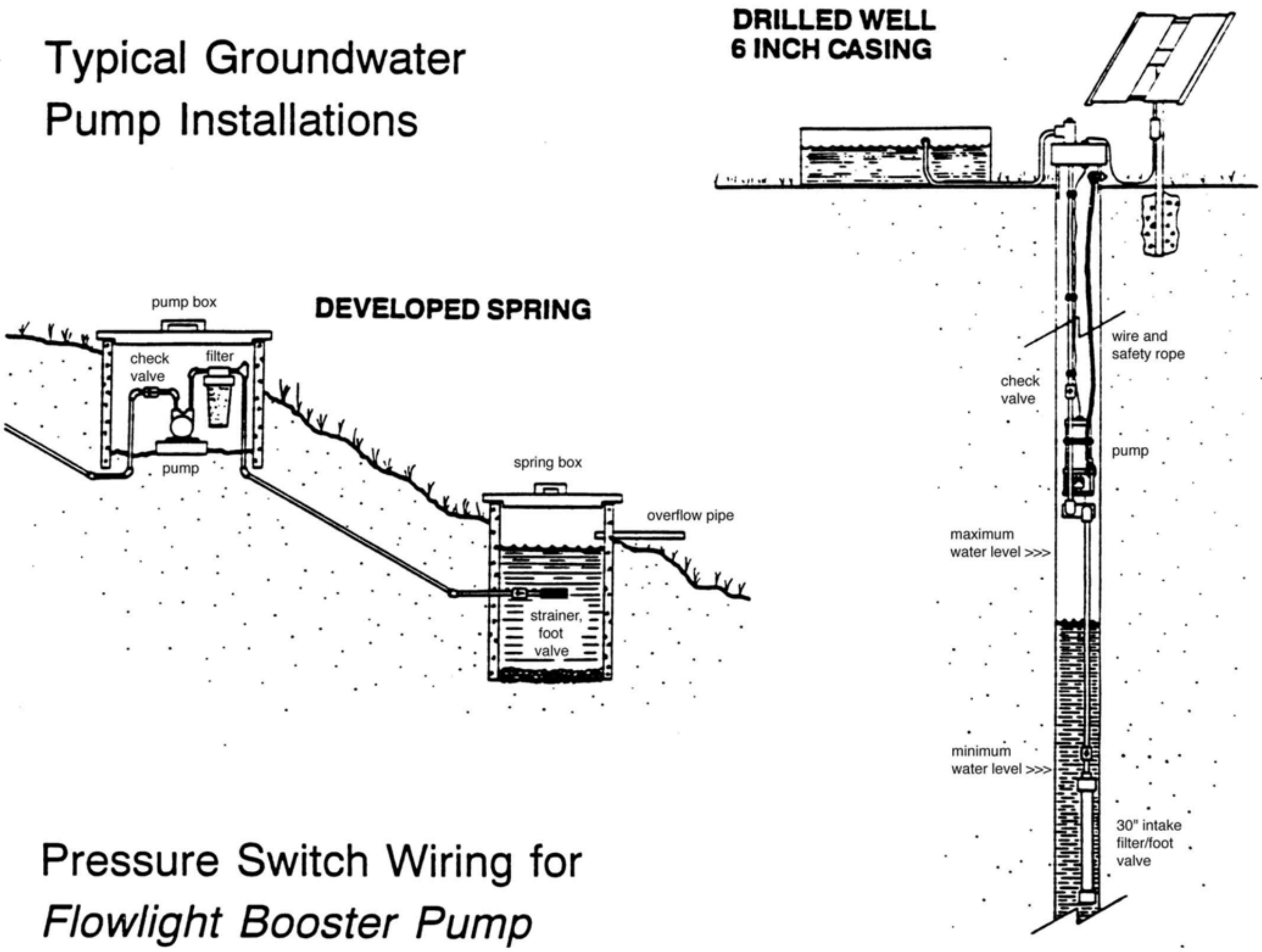
Your pump is warranted to be free from defects in material and workmanship for ONE (1) YEAR from date of purchase.

Failure to provide correct installation, operation, or care for the product, in accordance with instructions, will void the warranty.

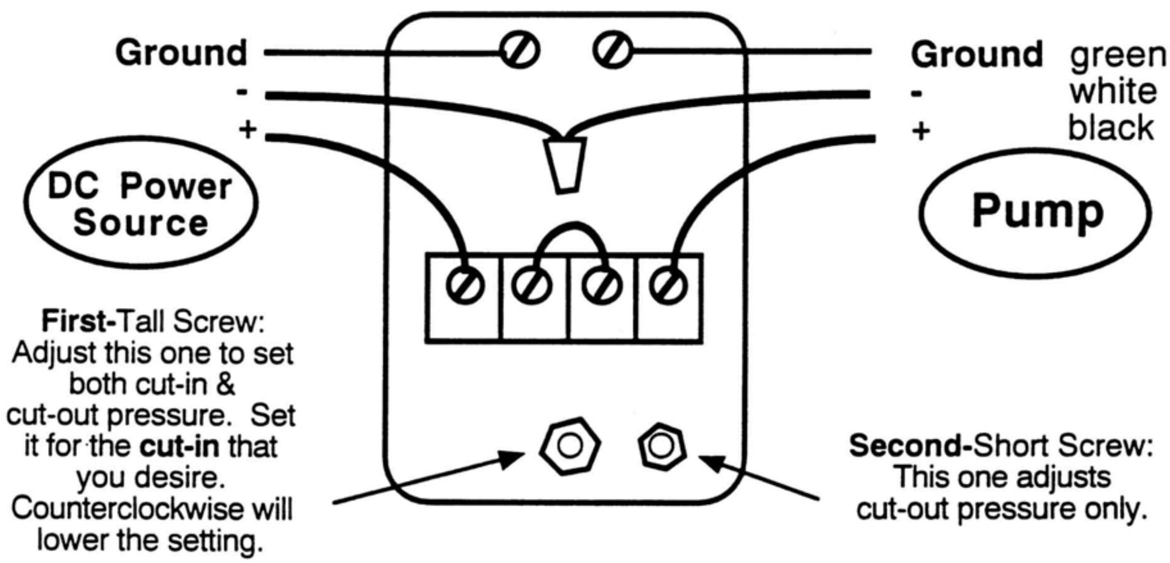
Product liability, except where mandated by law, is limited to repair or replacement, at the manufacturer's discretion. No specific claim of merchantability shall be assumed or implied beyond what is printed on the manufacturer's printed literature. No liability shall exist from circumstances arising from the inability to use the product, or its inappropriateness for any specific purpose. It is the user's responsibility to determine the suitability of the product for any particular use.

In all cases, it shall be the responsibility of the customer to insure a safe installation in compliance with local, state and national electrical codes.

Typical Groundwater Pump Installations



Pressure Switch Wiring for *Flowlight Booster Pump*



Explanation: The National Electrical Code® specifies that switches not disconnect the "grounded conductor", which is the negative. So, we are switching only the positive. Using both sets of contacts as shown (in series) will extinguish the arc (spark) that forms when the contacts break. This greatly increases switch reliability.

Other solar and DC water pumps

by Dankoff Solar Products

SUBMERSIBLE PUMPS FOR SURFACE AND DEEP WATER LIFT AND PRESSURIZING

ETAPUMP® SOLAR SUBMERSIBLE
32 GPM at 25 FEET
1.7 GPM at 650 FEET
High-tech, maintenance-free

SURFACE PUMPS FOR LIFT AND PRESSURIZING

SOLAR FORCE™ PISTON PUMP
5-9 GPM to 230 FEET or to 100 PSI
Extremely rugged and dirt-tolerant

SUNCENTRIC™ CENTRIFUGAL
5-70 GPM to 90 FEET
Also for circulation for swimming pools, pond management, solar heating, and more

SOLARAM™ SURFACE PUMP
3-9 GPM to 960 FEET

Ask your Dankoff dealer or go to www.dankoffsolar.com

INDEX

WARNINGS TO INSTALLER

1. This pump pulls water in by suction. The suction pipe must offer a very free flow, like a drain pipe in reverse. The pump will be very noisy if intake is restricted or blocked by air pockets. *See Page 3*

2. This pump tolerates NO solid debris. A disposable-cartridge filter is required at the intake. NEVER run the pump without a filter. *See Page 2*

3. Low voltage systems require larger wire than 115V. *See Page 6*

4. Do not omit the intake screen. After the first test run, check the screen and remove any plumbing debris.

5. This manual contains maintenance information, and is the property of the pump owner. Please give it to the owner when you are finished!

Thank You!

Notes to Installer:

This pump pulls water in by suction. The inlet plumbing must offer a very free flow, like a drain pipe in reverse. The pump will be very noisy if intake is restricted or blocked by air pockets or being undersized. See Page 3

NOISE = CAVITATION = RAPID PUMP WEAR
FIX THE PROBLEM!!! See Page 14

This pump tolerates NO solid debris.
A disposable cartridge filter is required at the intake.
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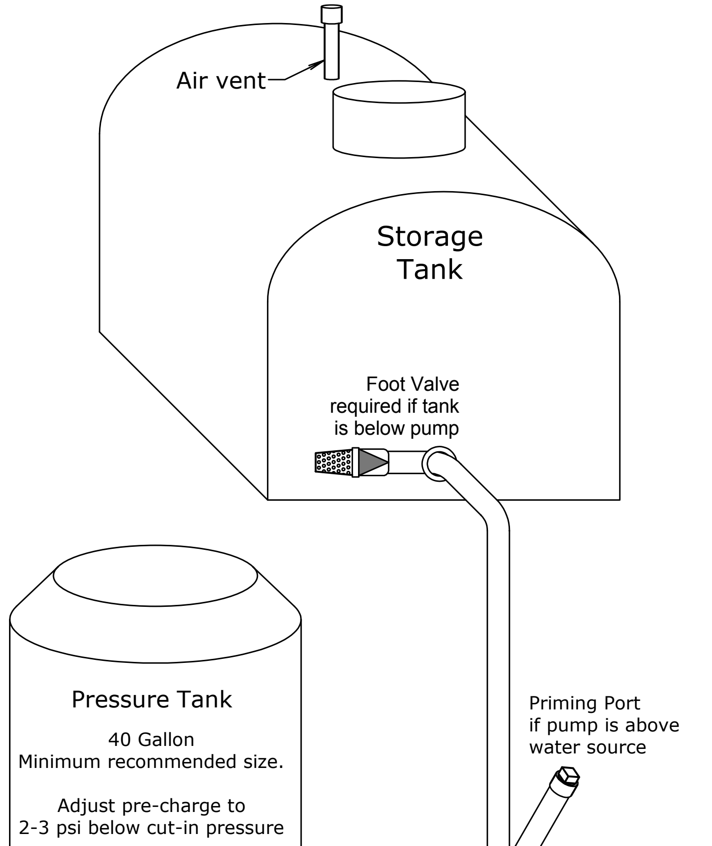
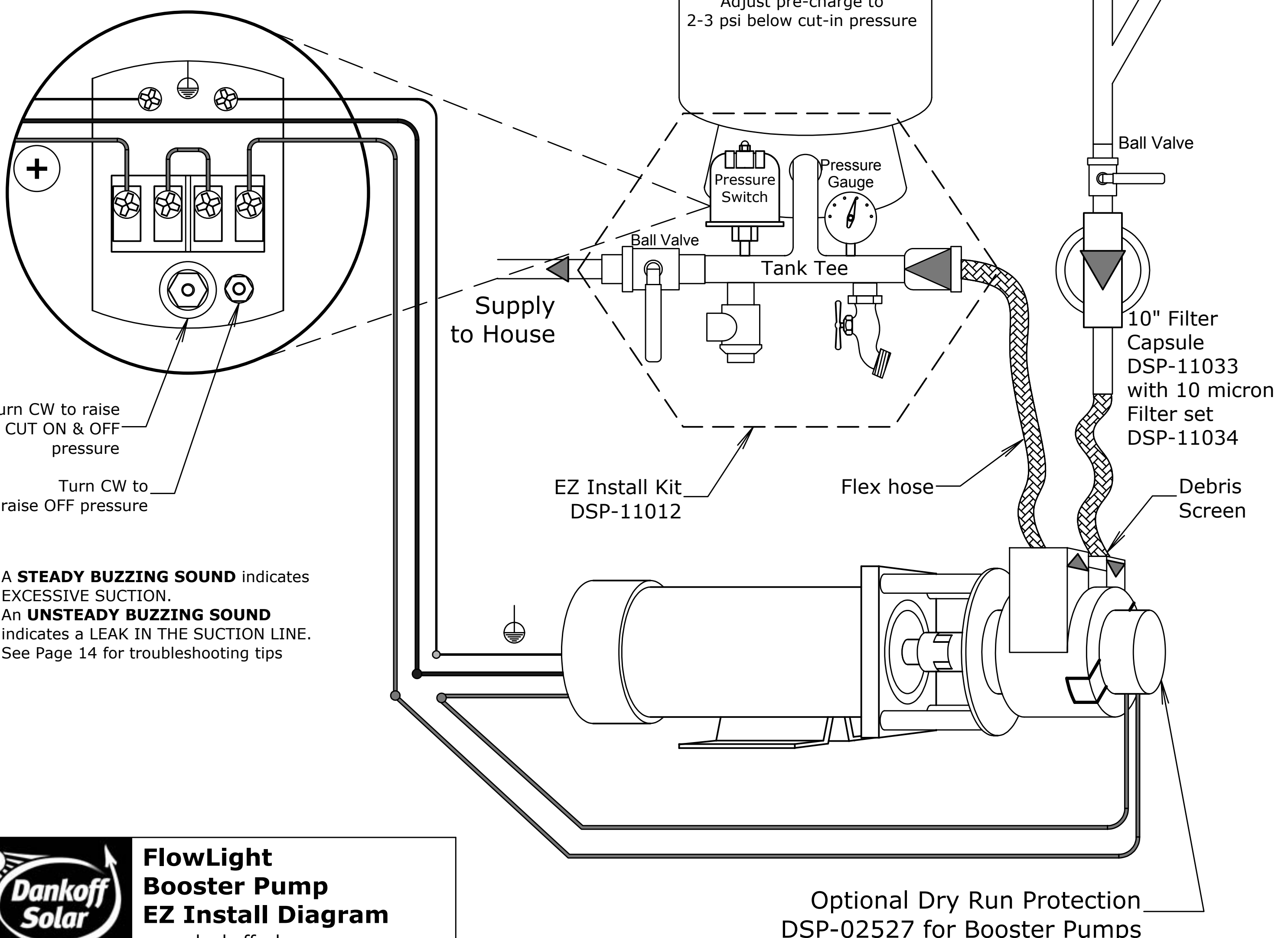
Low voltage systems require larger wire than 115v.
See Dankoff Universal Wire Sizing Chart for assistance.

Failure to install a fuse or breaker equal or less than the motor's Max Amp rating will void your warranty.

The manual contains important maintenance information, and is the property of the pump owner. Please give it to them when you are finished!





A **STEADY BUZZING SOUND** indicates EXCESSIVE SUCTION.
An **UNSTEADY BUZZING SOUND** indicates a LEAK IN THE SUCTION LINE.
See Page 14 for troubleshooting tips

Dankoff Solar	**FlowLight Booster Pump EZ Install Diagram** www.dankoffsolar.com	
2/2005	R 1.1	

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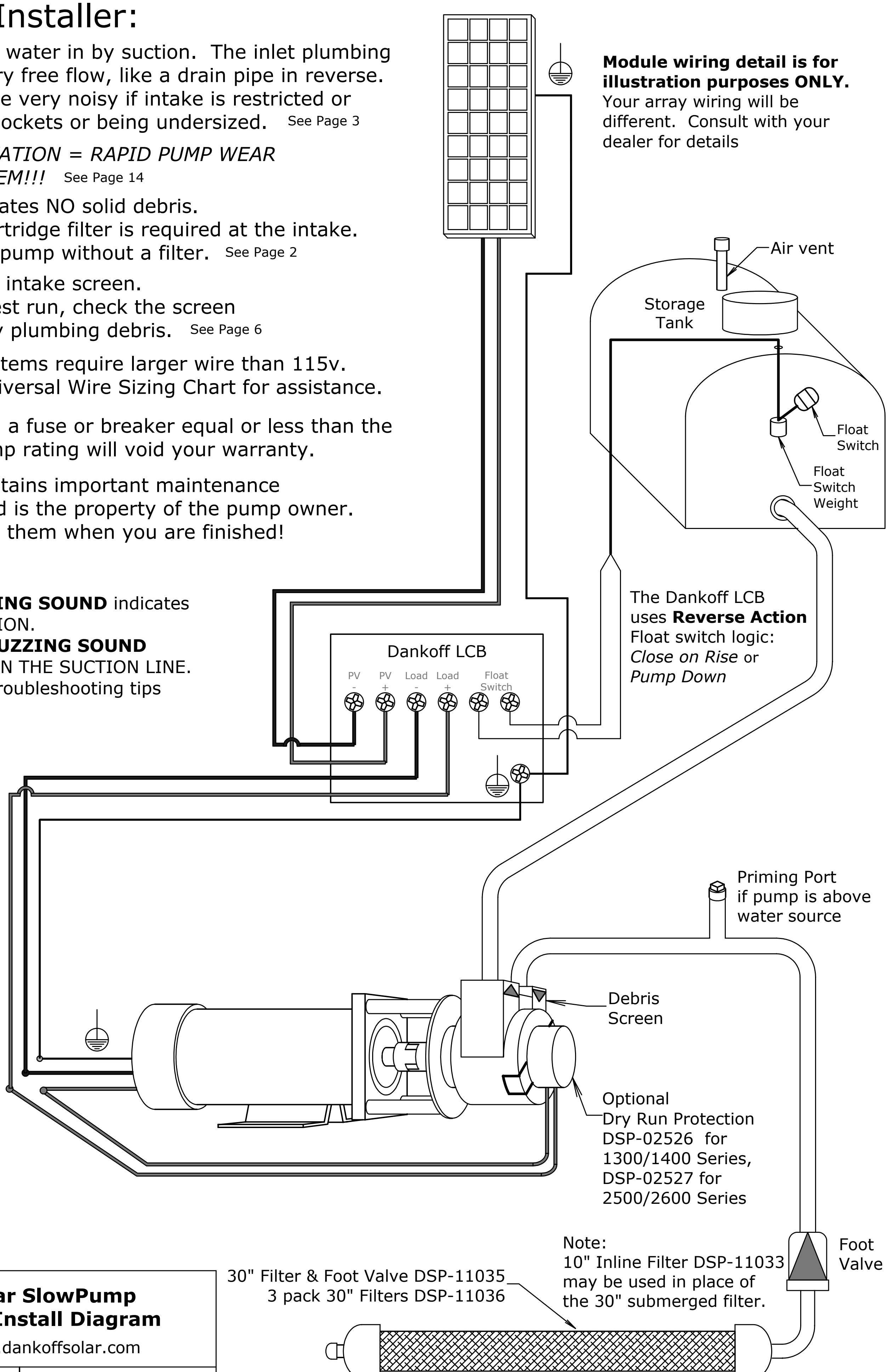


Solar SlowPump
EZ Install Diagram
www.dankoffsolar.com

2/2005 | R 1.1 |

Appendix E:

QFD

Gantt Chart

Management Plan

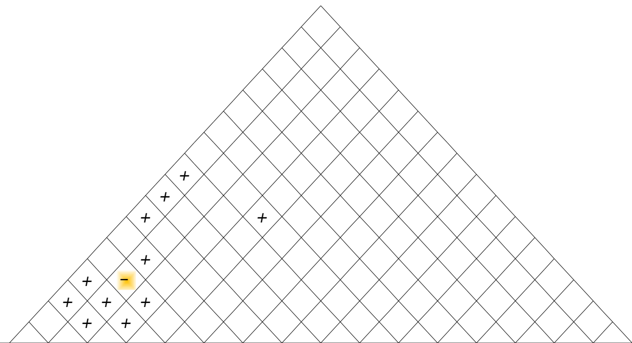
QFD

QFD: House of Quality
Project: ABC Wind Turbine Project
Revision: B
Date: 2-28-2012

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

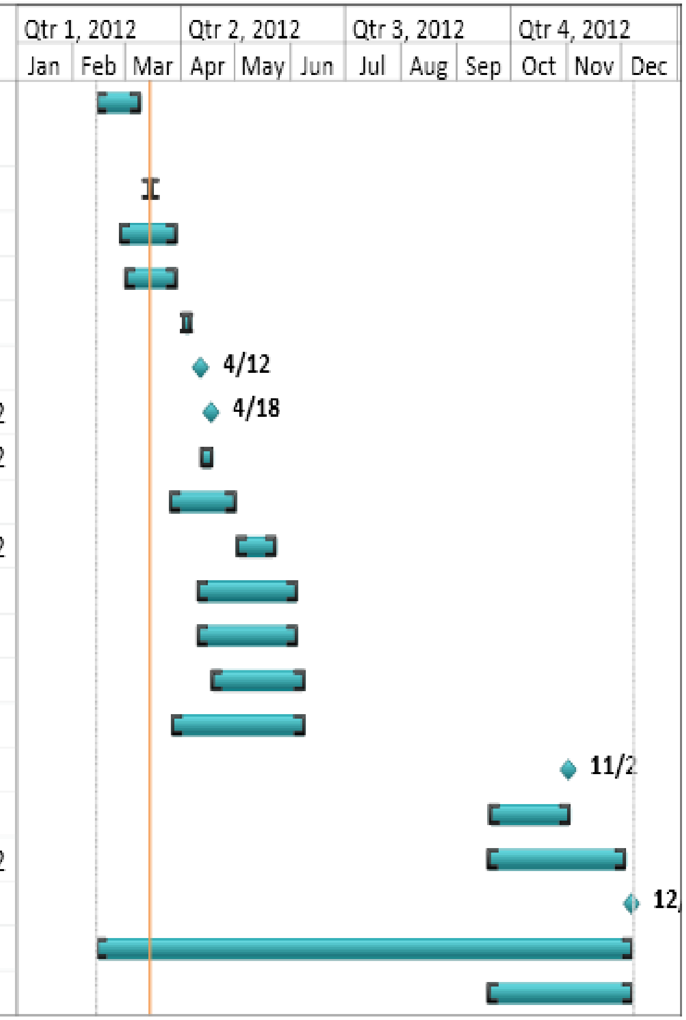


Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) / Functional Requirements	System efficiency (%)	Flow rate (gpm)	Pump power input (W)	Pump Voltage supply (V)	Pump output pressure (psi)	Battery Capacity (V, Amp-hrs)	Durability of pump (hrs)	Durability of Batterys (# of charge cycles)	Water Storage (Gallons)	Controllers or circuits with wide range of voltage tolerance	Housing Unit						ABC Wind	Bergey Wind Power	Alt E Store	Egyptian Solar Energy Society	Row #
					Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16					
					Direction of Improvement	▲	▼	◇																		
1		16%	9	3	terface properly with existing syste	○									○							5	5	4		1
2		16%	9	5	upply water to existing pipe networ		○	●	●	●	▽	○		●								5	3	5	3	2
3		9%	5	3	Near-continuous running of pump	○			▽		●	●		●								5	5	3	3	3
4		10%	6	3	Toggle abilitly between pump and resistive heating										○							5	4	4	1	4
5		16%	9	9	System that can handle variability from generator						●		●		○							5	3	3	1	5
6		12%	7	9	Safe system setup										●	●						5	5	5	4	6
7		10%	6	3	Low Cost						○	○	○									5	3	4	3	7
8		9%	5	9	Resistance to element exposure							●	●			●						5	5	2	2	8
9		3%	2	3	Easy/ Simple Maintence							○	○			○						5	5	5	5	9
10																										10

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Target	50%	2.50 gpm @ 12 hours a day	Max 700W	24 V	50 psi	24 V, 120 Amp-hours	10000 hrs runtime	2000 cycles	500 gallons	0 to 500 Volts	5'x5'x5'					
Max Relationship	5	5	5	5	5	5	5	5	5	5	5					
Technical Importance Rating	4	2	4	5	4	4	5	5	4	5	4					
Relative Weight	8%	5%	12%	10%	8%	10%	15%	12%	5%	13%	2%					
Weight Chart																
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Gantt Chart

ID	Task Mode	Task Name	Duration	Start	Finish
2		Specifying a Pump w/ Supporting Calculations	19 days	Tue 2/14/12	Fri 3/9/12
3		Conceptual Design Report	3 days	Wed 3/14/12	Fri 3/16/12
9		Specify Regulators and Controllers	24 days	Mon 2/27/12	Thu 3/29/12
10		Specify Charger (if needed)	21 days	Thu 3/1/12	Thu 3/29/12
4		Meet with Lemieux and Lazanoff	5 days	Mon 4/2/12	Fri 4/6/12
5		Critical Design Review	0 days	Thu 4/12/12	Thu 4/12/12
7		Finalize Design	0 days	Wed 4/18/12	Wed 4/18/12
6		Make Revisions to Design	5 days	Thu 4/12/12	Wed 4/18/12
13		Final Design Report	27 days	Mon 3/26/12	Tue 5/1/12
17		Project Update Report to Sponser	16 days	Wed 5/2/12	Wed 5/23/12
11		Order Regulators and Controllers	40 days	Tue 4/10/12	Mon 6/4/12
12		Order Charger (if needed)	40 days	Tue 4/10/12	Mon 6/4/12
8		Order Pump and Supporting Equipment	38 days	Wed 4/18/12	Fri 6/8/12
14		Devolop Testing Procedures	54 days	Tue 3/27/12	Fri 6/8/12
16		Finish Testing	0 days	Fri 11/2/12	Fri 11/2/12
15		Begin Testing	33 days	Wed 9/19/12	Fri 11/2/12
19		Implementing System	55 days	Tue 9/18/12	Mon 12/3/12
20		Senior Project Showcase	0 days	Fri 12/7/12	Fri 12/7/12
1		Background Research	214 days	Tue 2/14/12	Fri 12/7/12
18		Final Project Report	59 days	Tue 9/18/12	Fri 12/7/12



Management Plan

Basic Rules

*All team members will participate in the generation of Ideas and Designs
*All major design changes and purchases must be approved by the whole team and customer
*After all major design/analysis, the team members work shall be made available to all other teammates
*All questions and what-ifs are always welcome, any criticism must be followed up with a plausible solution

Aaron:

Strength: Fluids, Thermodynamics, Matlab, SolidWorks, has previous experience with pumps
Weakness: Vibrations, Mechanical system design, and Controls

Brian:

Strength: Mechatroncis, Controls, Matlab, Simulink, previous experience with machining and welding
Weakness: Thermodynamics, Fluids, and SolidWorks

Cesar:

Strength: Mechanical System Design, Matlab, ESS, SolidWorks, Thermodynamics, Fluids
Weakness: Controls, and welding

Based on the given weaknesses and strengths provided above work will be divided up as follows:

Fluids:

Primary: Aaron, Cesar
Secondary: Brian

Thermodynamics:

Primary: Cesar, Aaron
Secondary: Brian

Controls:

Primary: Brian
Secondary: Cesar, Aaron

Fabrication:

Primary: Brian
Secondary: Aaron, Cesar

Solid Modeling:

Primary: Cesar, Aaron
Secondary: Brian

Matlab:

Primary: Aaron, Brian, Cesar