

**Final Design Report:
Allergen Mixing Assistant (AMA) Micro-Refrigeration
Redesigning**

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References

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* Following references are attached before the appendices

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Abstract

Allergen Mixing Assistant (AMA) by Xtract Solutions is a device designed to more “effectively refrigerate, organize, and mix allergenic extracts”. Although Xtract Solutions intended the product to be fully automated, the company has decided against its automation and declared its current design as a minimum viable product whose components are too expensive, difficult to source and complex. Therefore, Cal Poly AMA design team - Mitchell Parks and Minwoo Suh - has decided to replace these expensive components with much more economical alternatives as shown below:

Stirling cooler	→	Thermoelectric (Peltier) cooler
Custom Arduino Controller Card	→	TEC Thermostat ***
Original Housing with Wasted Space *	→	New Housing **

The cost analysis of the new design quotes the Allergen Mixing Assistant at \$730, albeit minus the labor cost and manufacturing time, much more economical than the previous design where the Stirling Cooler alone was quoted at \$830. Beyond its cost-effectiveness, the new Allergen Mixing Assistant has been improved from its previous design in following categories: 1, more effective cooling; and 2, better packaging - its overall physical dimensions have been reduced. Testing proved that a larger focus on heat rejection is needed to maintain the desired set temperature. Due to insufficient heat dissipation our new unit is unable to run for extended periods of time, but will be a viable option if a larger heat sink can be obtained.

For more information:

* See Figure 1 of the report

** See Appendix B of the report

*** See Appendix C&D of the report

1. Introduction

Allergen Mixing Assistant (AMA) by Xtract Solutions

Xtract Solutions is an engineering firm located near Portland, Oregon that focuses primarily on providing products (“physical and data management”) for immunotherapy clinics. The Allergen Mixing Assistant (AMA) by Xtract Solutions is a device that was designed to help nurses better administer allergenic solutions to patients with known allergic reaction so that they, the patients, can develop immunity to these allergens. Engineers from Xtract Solutions originally developed AMA’s current design (See Figure 2) with the intention of having the device fully automated to “more effectively refrigerate, organize, and mix allergenic extracts” on its own to assist the nurses. Since then, Xtract Solutions decided against having the AMA fully automated and its design right now is seen as a minimum viable product whose components are too expensive, difficult to source and complex. Additionally, there is a lot of unused space underneath the AMA’s allergen storage head and engineers from Xtract Solutions wish to eliminate this unused space while maintaining the ease of access.

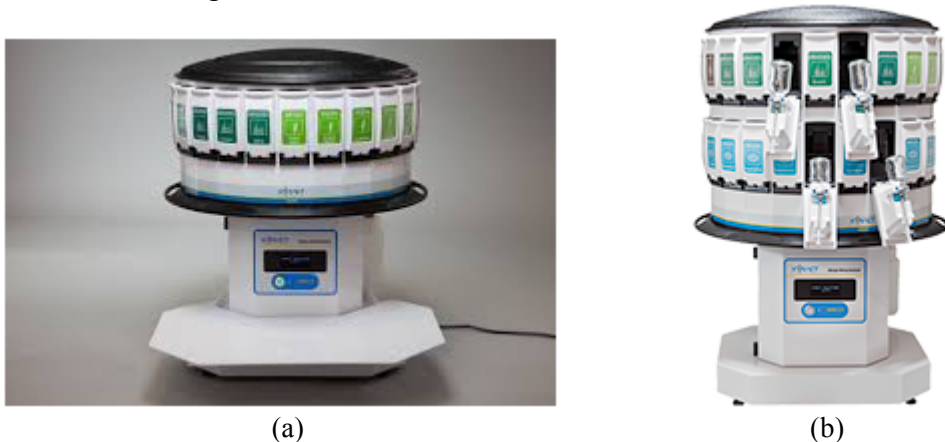


Figure 1. Current Allergen Mixing Assistant design with a single-tier head (a) and a two-tier head (b).

The Problem

Components of AMA’s current design includes a Stirling cooler sourced from Japan and custom Arduino card. The problems with these components are:

1. The cooler has a long lead time.
2. The custom Arduino card that would have allowed a user-interface for the AMA’s automation process is now seen as too complex for what Xtract Solutions want the AMA unit to accomplish.
3. The components are very expensive
4. The dimensions of Stirling cooler drives the current metal housing design which creates undesired, unused space underneath the AMA’s allergen storage head.

The main stakeholders for this project are:

1. The sponsors themselves who may improve their business through the AMA redesign
2. The nurses and other medical employees that will be using the AMA
3. The patients who will be administered the allergens being serviced by the AMA

The Objective

This project redesigned the AMA by finding and incorporating alternative components so that its new design will be more cost efficient and less complex than the current one. The Stirling cooler is replaced with domestic thermo-electric (Peltier) coolers so that it will be cheaper, easier to source and help eliminate the unused space under the AMA storage head. The custom Arduino card is replaced with a simpler temperature control system. The sheet metal housing for the new components has been redone to fit in these new components and bring the allergen storage head will be as low to the benchtop as possible, eliminating the unused space under the head in the original design. Using less sheet metal to fabricate the new housing will also reduce the cost of production for the new AMA design.

To come up with the new AMA design we've identified following customer requirements (Table 1) and engineering specifications (Table 2), in order to effectively address the problems in the current AMA design.

Table 1. The Customer/System Requirements for the New AMA Design

New AMA Design Criteria Considerations	
1.	Needs to incorporate a rotated system
2.	Maintain existing superstructure (needs to incorporate the AMA head)
3.	Maintain the capability to hold the 10ml, 30ml, and 50ml vials from all major extract manufacturers
4.	Reduce or utilize unnecessary spaces
5.	Improve the ease of access regarding placement of the vials relative to mixing space
6.	Reduce the height of the design
7.	Reduce the current cost of the cooling and control system to below \$2000 (ideally keeping the refrigeration and sheet metal costs below \$1500)
8.	Simplify the complexity of the current control system
9.	Reduce the necessity of utilizing custom components
10.	Maintain the minimal leakage of the current design
11.	Maintain the vials at the coldest possible temperature range above freezing temperature
12.	Keep noise emissions relatively low
13.	Meet electromagnetic emissivity standards (IEC 6061)
14.	Product will reject heat at a relatively manageable/reasonable level as to not disturb comfort of user or be detrimental to the surrounding area
15.	Keep the color-coded design

Table 2. The engineering specifications for the new AMA design

Spec. #	Parameter Description	Requirement or Target	Tolerance	Risk*	Compliance*
1	Weight**	45 lbs	± 5 lbs	L	T, I
2	Size**	Minimum Height = 6"	+18"/-0"	M	T, I
3	Sound Emission	40 dB	± 10 dB	M	T, I
4	Cooling Time	1.5 hrs	±0.5hrs	H	A, T
5	Desired Temperature	5 °C	± 3°C	H	T, I
6	Heat Rejection	$\Delta T < 3 \text{ }^\circ\text{C}$	± 1°C	M	T, I
7	Power Input	120 V _{AC} to 12, 18, 24 V _{DC}	-----	L	S
8	Power Output	> 40 Watts (of cooling)	-----	H	A, T, S, I

* The risk level associated with each engineering specifications or targets are identified as either High (H), Medium (M) and Low (L) and the compliance methods, or how each design requirements are to be met are classified as either through Analysis (A), Test (T), Similarity to Existing designs (S), and Inspection (I).

** The total weight and the size of the new AMA unit must be designed so that the product can be hand carried. Additionally, only the size of the actual refrigerating unit is subject to change. Its dimension must be so that its width and length does not exceed past the space underneath the 24" diameter head, although the resulting height underneath the head may vary from 6" - 24".

2. Background

Existing Products

To be clear, in terms of storage, refrigeration is not the only method of storing allergens for a long term. For instance, some allergens can be kept at room temperature or some pharmaceutical companies even freeze their allergens until they are ready for use/distribution. For allergen types that requires refrigeration, however, many clinics and hospitals such as Cedars-Sinai Medical Center in Los Angeles, California Pacific Medical Center in San Francisco, and University of Washington Medical Center in Seattle, usually store them in simple refrigerators of varying sizes (from industrial scale to mini fridge). Size of these units are based on the scale of their allergy and immunology department and the volume of patients that they service. While these simple refrigerators provide a sure way for medical staffs to store these allergens for long term, the vials may easily get misplaced, disorganized without proper method of labeling and storing.

Current State of the Art

In comparison to these contemporary allergen refrigerating units, the AMA, in its current design and the new design, will be the only device in market that allows both proper storage and organization to facilitate allergen preparation process. This will in turn help medical staffs provide better services to patients under-going immunotherapy to particular allergens. The product's brochure as published by Xtract Solutions can be seen in Reference [1].

Applicable Standards

The new AMA design will follow all the applicable codes and standards to ensure the safety of its users and environments. For instance, the metal housing for AMA's new interior components will be grounded so that no electric current runs through it and pose a potential electric shock harm to the clinic staff using it. The fan in the AMA unit also runs at relatively comfortable sound level of ~30 dB (IEC 60601). Once prototyped, the product will be tested so that the heat rejection and/or cold air distribution will not change the ambient temperature such that the medical staffs, the environments (medical labs or the storage space) and the device itself aren't adversely affected.

The following list is the ways the new AMA unit will be tested:

- Current test: This test will be done to verify that no current runs through the metal housing. After properly connecting an ammeter to the metal housing, the ammeter should read ~0 amp, an indication that no current is running through the housing.
- AMA unit temperature test: This test will be done so that the AMA unit's internal components are not being overheated. Overheating the electrical interior components can potentially jeopardize its operation. Temperature readings (through a thermometer or a

thermocouple DAQ) of each electrical components will be compared to its published optimal operational temperature so that AMA unit itself will not break.

- Ambient temperature test: This test will be done so that there are not any adverse temperatures surrounding the AMA unit. Although the main concern for this test is to ensure that the heat rejection from the thermo-electric/Peltier cooler can't adversely affect the user, this test will also check for any cold air leakage from the refrigeration space. Other considerations that will be accounted for in the results include the effects if multiple AMA units are placed adjacent to each other.
- Humidity test: This test will be done so that any liquid condensate (water vapor) formed due to the cold cycle of the Peltier cooler is at reasonable level and away from the electrical components.
- Sound test: This test will take the decibel reading of the internal and external sound emissions to ensure that proper soundproofing keeps the unit within the desired target range.

3. Design Development

Conceptual Designs

After multiple brainstorming sessions involving various methods such as SCAMPER, brainwriting, flowcharts, we have narrowed down to following 7 feasible cooler options that we decided to look further into before choosing our final AMA design. The descriptions, the pros and cons we decided to weight for each of the each potential solution are as follows:

Concept 1 – Forced air convection with Peltier coolers utilizing current AMA redirect cone

This concept utilizes the current head configuration to distribute the cooling to the vials using forced air convection which is redirected by the current cone. The Stirling cooler is replaced by thermo-electric (Peltier) coolers, fastened between two CPU coolers. The hot side of the Peltier cooler draws the heat through a heat sink and fan, which blows the air into the heavily insulated body. This hot air is then vented out into the surroundings. The cold side distributes the cold air through the same process into the head.

Table 3. The Pros and Cons for Concept 1

Pros	Cons
<ul style="list-style-type: none"> • No modification needed for head • Uses all off the shelf components for cooling portion • Can easily be sized up (bigger or more Peltier coolers) • Cooling unit uses cheap parts (Peltier cooler, power source and CPU cooler) • Easy to manufacture 	<ul style="list-style-type: none"> • Requires thick insulation • Thermal leakage may become a problem • May be hard to include height adjustability • Heat in the insulated body may cause performance issues with electrical or control systems, if placed there • Noise from fans may be an issue

Concept 2 – Forced air convection with Peltier coolers in individualized compartments

This concept reduces the cooling space by dividing the 48 vials into smaller compartments. Peltier coolers push cold air outward into the compartments, and direct the hot air inward towards the center of the head. A deflector plate is fastened to the cold side to direct the flow over the vials.

Table 4. The Pros and Cons for Concept 2

Pros	Cons
<ul style="list-style-type: none"> ● Peltier cooler is closer to vials ● Potential for height adjustability ● Larger space for heat to encompass (less heat rejection) ● Can easily be sized up (bigger or more peltier coolers) ● Cooling unit uses cheap parts (Peltier cooler, power source and CPU cooler) 	<ul style="list-style-type: none"> ● Requires thick insulation ● Thermal leakage may become a problem ● Potential for large pressure gradient dependent on number of coolers or fan placement ● Diverter plate will decrease fan speed ● Eliminates current AMA redirect cone, therefore we may need to redesign the top without the cone

Concept 3 – Liquid cooled CPU cooler attached with Peltier cooler

Instead of using forced air convection to cool the vials, coils are used to localize the cooling. Liquid is cooled through an aluminum block attached to the cold side of the Peltier cooler and pumped throughout the head, in between the vials.

Table 5. The Pros and Cons for Concept 3

Pros	Cons
<ul style="list-style-type: none"> ● Localizes the cooling to be near the vials ● Reduces number of fans (noise emissions) ● Better heat dissipation than air 	<ul style="list-style-type: none"> ● Requires complex piping ● Must incorporate a pump and liquid reservoir ● Condensation of pipes may cause electrical failure ● Pricier than air cooled Peltier systems

Concept 4 - Forced air convection with vapor-compression utilizing current AMA redirect (cone)

This concept is similar to the *Concept 1* in that it, too, utilizes the cone inside the storage head to redirect cold air flow and distribute cooling to the vials via forced air convection. Unlike *Concept 1*, however, it'll be run under standard vapor-compression cycle where air is blown past cooling coils to deliver cooling up into the head space.

Table 6. The Pros and Cons for Concept 4

Pros	Cons
<ul style="list-style-type: none"> ● No modification needed for head ● Uses many off the shelf components for easy manufacturing ● Can be sized up (more cooling coils, different working fluids) 	<ul style="list-style-type: none"> ● Requires insulation for components ● Condensates on the coils may be a problem ● Ruptures in pipes and/or in the compressor can result in catastrophic damage. ● The metal coils can be heavy

<ul style="list-style-type: none"> • Cooling unit is cheaper than the original Stirling Cooler unit 	
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Concept 5 - Forced air convection with vapor-compression and helical coils in the head interior
This concept will also deliver cooling via vapor-compression refrigeration cycle. Unlike Concept 4, this will place the helical cooling coils inside the head space with the intention to either place the fans inside the coils to blow the air out or outside the coils to “suck” the air through by creating pressure difference.

Table 7. The Pros and Cons for Concept 5

Pros	Cons
<ul style="list-style-type: none"> • No modification needed for head • Uses many off the shelf components for easy manufacturing • Can be sized up (more cooling coils, different working fluids) • Cooling unit is cheaper than the original Stirling Cooler unit 	<ul style="list-style-type: none"> • Requires insulation for components • Condensates on the coils may be a problem • Ruptures in pipes and/or in the compressor can result in catastrophic damage. • The metal coils can be heavy • May be difficult to size up • Fan placement may be difficult in the head space

Concept 6 - Forced air convection with Stirling cooler

The problem they have with current Stirling cooler is that the one included in the design is rather big spatially, expensive and difficult to source since it’s from Japan. Nevertheless, there are reasons why the engineers from Xtract Solutions included in the original design. They are virtually silent and can achieve very low temperature which can make cooling very efficient in comparison to Rankine cycle systems. Therefore one possible solution we’ve considered is replacing the current Stirling cooler with a smaller domestic Stirling cooler that will require very minimum redesigning.

Table 8. The Pros and Cons for Concept 6

Pros	Cons
<ul style="list-style-type: none"> • Minimum redesigning required (only resizing the shell and fans) 	<ul style="list-style-type: none"> • Finding the correct cooling capacity and fitting it into the shell may be more complex than expected. (if we keep sizing coolers until we reach current cooler size then, we’ve not solved the problem)

Concept 7 - Forced air convection with Peltier cooler and coils

This concept will also deliver cooling via vapor-compression refrigeration cycle but the heat added in and taken out via compressor and expansion valve, respectively will be replaced by the hot and cold side of the Peltier cooler. This concept also plans to use the original head design to redirect cold air flow and distribute cooling to the vials via forced air convection. As with other vapor-compression cycle systems however, it will use a pump in order to make sure that the

working fluid in this system stays flowing throughout, preventing local freezing and clogging in the coils.

Table 9. The Pros and Cons for Concept 7

Pros	Cons
<ul style="list-style-type: none"> ● No modification needed for head ● Uses many off the shelf components for easy manufacturing 	<ul style="list-style-type: none"> ● Requires insulation for components ● Condensates on the coils may be a problem ● Ruptures in pipes and/or in the compressor can result in catastrophic damage. ● The metal coils can be heavy ● May be difficult to size up ● Requires thick insulation ● Thermal leakage may become a problem

Beyond what are tabulated, the following cooler types were also researched but ultimately excluded from feasible conceptual drawings/ideas since their disadvantages outweighed their advantages and did not meet the required specifications. See Table 10 below for the details.

Table 10. Other cooler types researched and the disadvantages of each type that made it difficult to develop into feasible concepts.

Liquid nitrogen cooling	More practical for industrial scale applications because of the needed size requirements
Joule-Thomson coolers	Unable to find readily available coolers and components
Thermoacoustic coolers	Produces a maximum cooling around $\frac{2}{3}$ ambient temperature (not enough cooling) with potential for large sound emissions
Magnetic cooling	Requires a custom configuration
Ice	Lack of convenience and cooling power

Additionally, the lack of readily available off-the-shelf components using these cooling methods means that any designs using these coolers will incorporate many custom parts which is opposite of what we're trying to achieve: to simplify the design and reduce the cost of production.

Concept Selection

When selecting our lead concept, we heavily weighted our decision based off of the three driving factors of cost, simplifying the design, and reducing the use of custom components. Although many of the cooling systems could meet the desired cooling load, these three certain aspects helped narrow our design.

A decision matrix (shown in Appendix A) was used to compare the more viable options to the current design, based off of our system requirements. Each criteria was given a weight based off of level of importance to Xtract Solutions and the customer needs. The results showed that the two thermo-electric coolers using forced air convection were highly ranked along with swapping the current Stirling cooler for a cheaper and better sized Stirling cooler.

Vapor-compression systems became a very viable option because of their proven applications, yet are not optimized according to our driving factors of system complexity and use of off the shelf-parts. These systems are readily available for miniature applications similar to the AMA refrigeration design, but also pose some areas of concern. High pressure in a vapor compression

system could lead to blown pipes and potential for leakage. Dependent on the refrigerant, this may be cause harmful effects to those around the device. Utilizing metals for the coils, the weight of the system becomes a concern along with the complexity of the piping. The overall system involving a compressor, condenser, evaporator, adiabatic expansion valve and fan generally over complicates what is necessary to cool the space, especially if custom piping is needed.

Thermo-electric coolers met all driving factors while supplying ample cooling loads. Our lead concept satisfies the system requirements shown below.

Table 11. How the selected concept satisfies each system requirement

System Requirements	Solution
<ul style="list-style-type: none"> ● Needs to incorporate a rotated system ● Maintain existing superstructure (needs to incorporate the AMA head) ● Keep the color-coded design ● Maintain the capability to hold the 10ml, 30ml, and 50ml vials from all major extract manufacturers ● Maintain the minimal leakage of the current design 	<p>With our chosen concept design, little to no modification to the current head is needed, which satisfies the system requirements to the left. The cooling unit will be incorporated into the body of the design and the head will be placed on top of the body (like the current design), in a way to keep the minimal leakage of the current design.</p>
<ul style="list-style-type: none"> ● Reduce or utilize unnecessary spaces ● Improve the ease of access regarding placement of the vials relative to mixing space ● Reduce the height of the design 	<p>Less than ¼” thick and able to fit within a 2” by 2” area, the size of Peltier coolers make them ideal for our application, when trying to minimize the unnecessary space. Our current design allows potential for height adjustability to improve the ease of access.</p>
<ul style="list-style-type: none"> ● Reduce the current cost of the cooling and control system to below \$2000 (ideally keeping the refrigeration and sheet metal costs below \$1500) 	<p>Costs associated are minimal when comparing to the other cooling designs. The coolers themselves are less than \$40 a piece, but become more expensive once heatsinks and fans are added. Collectively, the entire cooler system is still the cheapest option.</p>
<ul style="list-style-type: none"> ● Simplify the complexity of the current control system ● Reduce the necessity of utilizing custom components 	<p>Peltier coolers can be used as a standalone device, although our design utilizes heatsinks and fans. These components come as a kit for standard CPU coolers and require no added custom components.</p>
<ul style="list-style-type: none"> ● Maintain the vials at the coldest possible temperature range above freezing temperature 	<p>Peltier devices provide ample amounts of cooling capacity and allows easy addition of more coolers if required.</p>
<ul style="list-style-type: none"> ● Keep noise emissions relatively low 	<p>Sound proofing will be added in the manufacturing process if necessary.</p>

<ul style="list-style-type: none"> • Meet electromagnetic emissivity standards (IEC 6061) 	Electromagnetic emissivity will be accounted for within our manufacturing considerations.
<ul style="list-style-type: none"> • Product will reject heat at a relatively manageable/reasonable level as to not disturb comfort of user or be detrimental to the surrounding area 	Testing our prototypes will show whether it is best to completely vent out the hot air within the body, or to contain majority of the heat with a heavily insulated body.

Preliminary Analysis

After accessing various files such as test data and SolidWorks models on AMA from Xtract Solution, we have been able to estimate the required cooling load to about 60 Watts. (See Appendix E - Preliminary Analysis). Assumptions that were made to aid the cooling load calculation are: 1, based on Xtract Solutions test data the allergen storage space was cooled faster than the vials and we can assume that this storage space will be cooled eventually as the vials cool from cold air forced convection; 2, this test data also means that rather drawing the cooling from the interior control space, the vials draw the cooling load directly from forced air convection and we can find the cooling load by the amount of cooling required to cool 48 allergen vials. Since allergens are in aqueous solution they were modeled as 50 ml of water and the thermal resistance from the glass vials was neglected to simplify the calculation even further.

4. Final Design

Overall Description

Primary focus of our design involved choosing the most feasible cooler type to deliver the required cooling to meet our engineering specifications. Following major component changes has been made in the new AMA design:

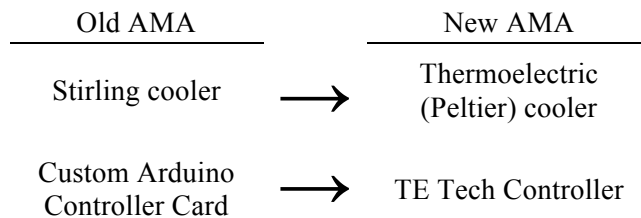


Figure 2. Major components that were changed.

The Stirling cooler, overpriced at nearly \$900 including the electrical components with a long lead time sourced from Japan was replaced by a domestic thermoelectric (Peltier) cooler while the custom Arduino card was replaced by a pre-programmed temperature controller. The temperature controller drew its power from a power supply that converts 120 V_{AC} to 24 V_{DC} and monitored how the cooler can reach the desired set point temperature. The controller reached the desired set point temperature by creating a PID control feedback loop using provided off-the-shelf temperature sensor and controlling the current draw, or the power input, into the Peltier cooler. Fans to both deliver the cooling and the eject the heat drew power directly from the power supply as well with the fan elements and the cooler elements in parallel to each other in terms of the circuit design. These changes - switching from a larger Stirling cooler with a much

more compact Peltier cooler - allowed the reduction of the sheet metal housing's overall dimensions to help change the height of the new AMA unit to be less than 24" off the ground.

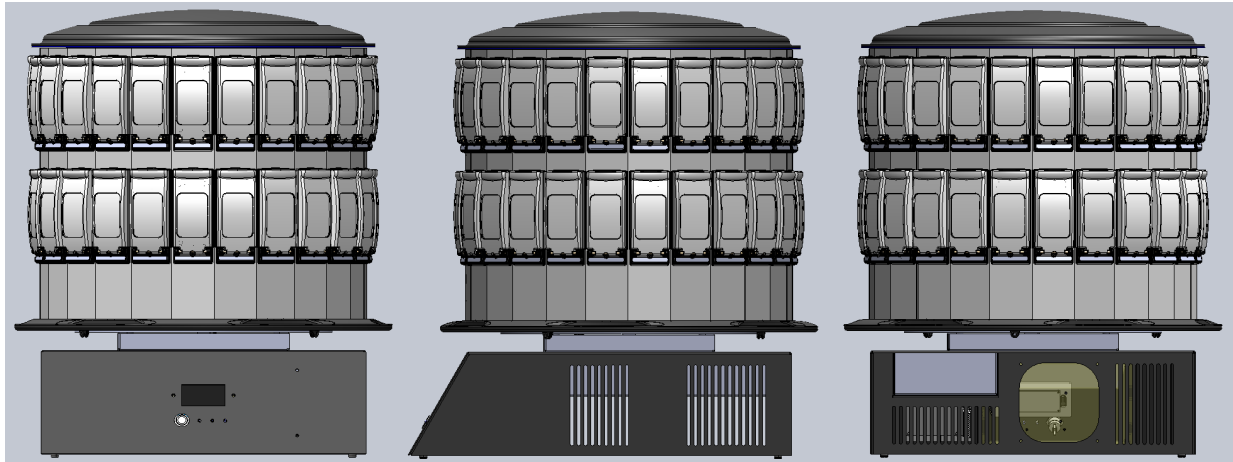


Figure 3. Front, side and back view of the redesigned AMA unit.

Detailed Design Description

With all major electrical interior components such as the thermo-electric cooler, fans, temperature control system and the power supply chosen and sized through initial analysis, we were able find proper fixtures and sheet metal dimensions to locate and house these parts. SolidWorks models have been developed for these fabricated parts, and are assembled to ensure proper fitting of components. Custom fabricated parts involved detailed drawings that are shown in Appendix B along with more model views.

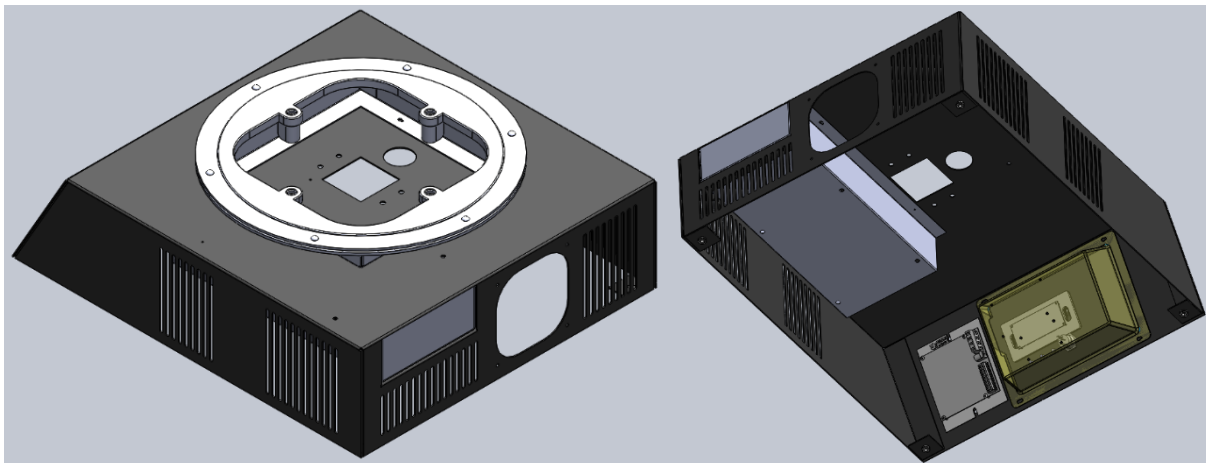


Figure 4. Isometric views of the top and underside of the redesigned AMA unit.

The electrical components will be wired such that there poses no threat to electric shock harm to anyone using the unit. The exact lengths and configuration of the wires will be determined once all parts have been securely fastened to the metal housing. Different colored 12 gauge wires will be used for color coordination to allow easy fastening during installation, maintenance and repairs. The fans and water pump for the CPU coolers were wired using multi-pin connectors.

In the final planned design, we decided to incorporate the same sheet metal fasteners that were used in the original AMA unit. These fasteners, sourced from Penn Engineering, will be press fitted into the design holes to ensure that the parts can easily be slid into place, and secured with screws, nuts or bolts. Screw holes were placed in a way to allow easy access of either a screwdriver, or manually tightening by using your fingers.

Material, Geometry, Component Selection

Note: Reference Appendix B and D as needed for layout drawings and specification data

Material

The sheet metal material used in the new AMA design will be 18/8 stainless steel. Initially, we've considered using aluminum as a possible alternative metal housing material over the 18/8 stainless steel that was used in the original AMA design. Eventually, we've decided to choose the 18/8 stainless steel as the sheet metal material since: 1, heavier sheet metal material will provide more base weight and hence stability; 2, aluminum conducts both electricity and heat much more efficiently than stainless steel and the AMA housing should be more resistant towards both; and lastly, some components in the assembly required welding and since steel will be easier to weld than aluminum, for manufacturing purposes, stainless steel would be more superior sheet metal material.

Geometry

For all geometry, reference Appendix B to see how all components have been located and how the overall assembly meets the customer requirement and engineering specifications to reduce the height of the new AMA assembly.

Although not included in the current layout drawing the final AMA unit will include an air vent to direct heat rejection air out of the AMA unit into the surroundings. Corsair Components has not specified tubing lengths for its Hydro Series H75 Liquid CPU Cooler (CPU cooler chosen to address heat rejection) in order for us to specify the necessary vent lengths and specifications. Therefore as a part of the management plan, once the Hydro Series H75 Liquid CPU Cooler has been delivered, proper vent will be sized so that hot air is directed outside of the AMA unit.

Thermoelectric Cooler

For the main component – the cooling element – we decided to use TE Technology's HP-199-1.4-0.8 Cooler (Appendix D), that can deliver up to 172 Watts of direct conduction cooling and rated at 24 V_{DC} and 11.6 Amps. The cooler has been "oversized" to deliver more cooling than estimated in the preliminary analysis in order to account for all possible unforeseen cooling efficiency losses between different components and possible heat infiltration/leakages from the surroundings. Additionally, delivering more cooling than originally calculated will reduce the cooling time for the vials to reach the desired temperature range of 2 – 8 °C.

Controller Card

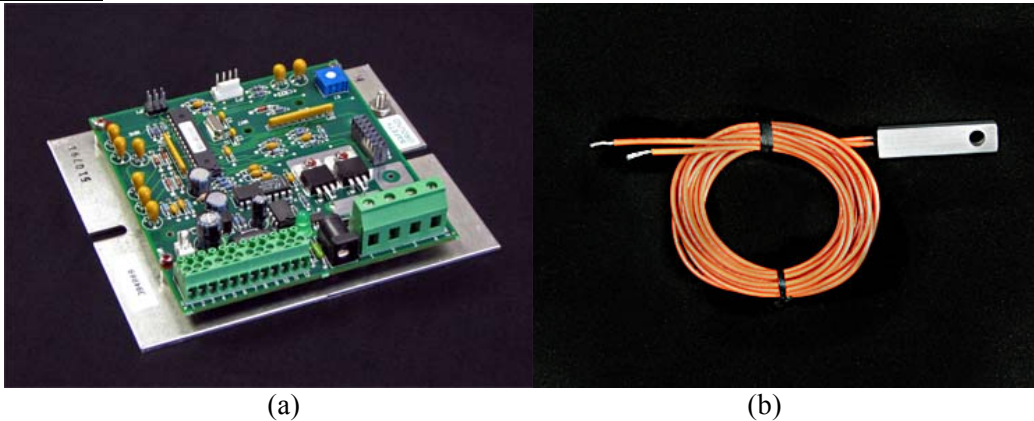


Figure 5. TE Tech TC 48-20 OEM controller (a) and HP-199-1.4-0.8 thermistor (b).

The controller card (part name: TC 48-20 OEM) to operate the AMA unit is from TE Technology, recommended by the company to pair up with the HP-199-1.4-0.8 Cooler for the latter's operation. One of the customer requirement was to simplify the complex, custom Arduino card and TC 48-20 OEM effectively resolves this problem since it is already pre-programmed for temperature control using the TE Technology's HP-199-1.4-0.8 thermoelectric cooler. In addition, the controller card also comes with a thermistor for temperature sensing, and can be wired to the Xiamen Ocular GDM1602K LCD Display that is used in the original AMA design.

Power Supply

The power supply (part name: PS 24-12.5) for the AMA unit's electrical components is also sourced from TE Technology, Inc. The power supply is rated at 24 V_{DC} and 12.5 Amps, sufficient enough to run the HP-199-1.4-0.8 Cooler at maximum capacity. We chose to source as many components from TE Technology, Inc. since the company specializes in thermoelectric cooler and its applications, shipping can be facilitated by using a single source and because these components are compatible with each other. Since the fans for cold air distribution and heat rejection are rated at 12 V_{DC} at <0.5 Amps, we plan to include a circuit (resistors, diodes in parallel to drop/regulate voltages and split currents as needed) within the Power Supply Box assembly (Appendix B) to ensure these fans run at rated operation range.



Figure 6. TE Tech PS 24-12.5 power supply.

Heatsink and Fan Assembly – CPU Coolers

CPU cooler is a heatsink and fan assembly originally designed to provide a way to dissipate heat for a CPU processing chips that, under load, can run up to 70-90 °C during its operation. Since running the CPU processors at high temperature under load is detrimental to the CPU chips’ longevity, it is often recommended to install fan CPU cooler for efficient cooling. In the AMA’s design, we will use the CPU cooler assembly as a “cold sink” for the Peltier element’s cold plate and distribute cold air into the AMA’s headspace to cool down the vials (where as attaching the CPU cooler to the hot plate side of the Peltier element would be similar to conventional method of pairing the CPU cooler to a CPU processors). The justifications for CPU cooler selection were provided by CPU hardware critiques as the manufacturers outsourced their product testing and performance data acquisition to these reviewers.

For the “cold sink” and cold air distribution, the new AMA design will use Cooler Master’s GeminII M4. The reviews from HiTechLegion.com and silentpcreview.com both quote Cooler Master GeminII M4 CPU cooler being able to produce ambient temperature difference of 20 °C. Their test data revealed that when dissipating heat, ambient temperature rose from 20-21 °C to 40-45 °C with the source, the CPU processor, at 60 °C – temperature difference from the original ambient air being $\Delta T_{\text{ambient}} = 40 \text{ }^\circ\text{C}$. If this was dealt in terms of cold sink, Peltier cooler running at $\Delta T_{\text{ambient}}$ range of 40 °C (HP199 running at near -20 °C) will cause ambient air/distributed air change of 20-21 °C. This cold air will in turn, cool down the stored vials



Figure 7. Cooler Master’s GeminII M4

FrostyTech.com also provided following data, which shows the ambient air temperature changes for a constant heat transfer rate (originally at heat input, rather than a cooling input)

Table 12. Heat transfer rate into the GeminII M4 and corresponding air temperature change

Heat Transfer Rate In	Ambient Air Temperature Change
85 W	18.3 °C
125 W	26.5 °C
150 W	29.5 °C

Corsair Hydro Series H75 Liquid CPU cooler has been chosen based on reviews from Hardware Secrets and HardOCP, operating decibel range to meet the IEC 60601 standard, easy installation and its cost effectiveness. H75 Liquid CPU cooler, with its provided mounting brackets, will be fixed onto the sheet metal and locate/mount rest of the thermoelectric cooler assembly (HP 199 and GeminII M4).



Figure 8. Hydro Series H75 Liquid CPU cooler

Fasteners

Fasteners for the AMA unit assembly are based upon original AMA design: a lot of the sheet metal fasteners (SKC-F, PF51, SP-0420) are sourced from PennEngineering®. Other fasteners and threaded parts include UTS #10 Socket Button Head screws, UTS #10 washers, and #10-32 x 3/8" Green Die Finish Grounding Screw by Fastenal® (for fastening unto sheet metal housing for grounding the currents).

Analysis Results

The preliminary analysis and calculation done as part of the preliminary design report (Appendix E) estimated that total amount of cooling for the vials to cool down from 25 °C ambient temperature to the desired temperature of 5 °C in an hour period would be 61.92 Watts.

Cost Breakdown

The cost analysis of the new design quotes the cooling, control and power components of the Allergen Mixing Assistant at \$739, albeit minus the labor cost and manufacturing time, much more economical than the previous design where the Stirling Cooler alone was quoted at \$838 dollars. The cost of the sheet metal has yet to be determined and will require back and forth communication with Rapid Sheet Metal and Eagles Precision to determine a cost estimate. Similar in sheet metal volume, an estimate of the new design can be concluded from the current cost of the sheet metal. The Cal Poly AMA Design team was tasked with keeping the manufacturing cost at \$500 - \$1500 in refrigeration and sheet metal structure range. Our design, will easily meet the sponsor's customer cost requirement. A more detailed cost breakdown is shown in Attachment H.

Safety Considerations

The main safety concern with the new AMA design is the potential exposure to an electric shock. We will perform a current test to verify that no current runs through the metal housing. After properly connecting an ammeter to the metal housing, the ammeter should read ~0 amp, an indication that no current is running through the sheet metal. Vibration from the fans may loosen the nut/bolt that grounds the electrical components. In order to account for that occurrence, we have looked into lock and spring washers that will resist the loosening effect.

Another area for concern arises when the head rotates. While grabbing onto the handle to rotate the head, there is potential for pinching or jamming your fingers on the body. The height of the

bearing box was designed to increase the distance between the head and body as a preventative measure.

A final failure mode may occur if the liquid cooled CPU cooler were to leak. This problem is seen as a high severity problem because of the combination of water with electricity, but a very low probable occurrence. Designed to attach to computers, the liquid cooled CPU coolers have been thoroughly tested and proven to work without failure to the electrical components. Unless a large enough force, or sharp object were to puncture the tubing, this problem is considered a rarity and not an area of concern. All of the electrical components in our design are also situated to the top portion of the underside, and with the help of gravity, should be out of the way if leak were to occur.

Maintenance and Repair Considerations

The AMA unit designed as a standalone unit ideally will not require much maintenance, although periodic checkups of the design are suggested. The following maintenance and repair checkups will ensure proper functioning of the device and will help prevent potential safety concerns from arising.

For maintenance:

- Ensure ground wire screws remain tight
- Observe any detrimental effects of heat to the electrical wiring and sheet metal
- Assure that the TEC is properly fitted to both CPU coolers

For repair:

- Detach head, unplug device from wall, and tilt on side to access underside
- Only apply thermal compound to one side of the TEC to ensure that the entire cooling assembly can be detached from the sheet metal
- If swapping out wires, follow color scheme on wires to allow easy re-attachment

5. Product Realization



Figure 9. The front and rear view of the new AMA design prototype

The Manufacturing Process

Hardware

In order to complete the project deadline of 12/01/2016, majority of its internal components such as the power supply, temperature control, thermoelectric cooler, and CPU coolers were ordered by June of the same year. These purchases, along with all other purchases made during the project, were made by first obtaining the pricing information of the items needed and submitting a pro-card authorization form that lists each item price so that they can be purchased through Cal Poly’s engineering department. The sheet metal housing production began when the school term resumed in late September. Although the initial plan was to consult either Rapid Sheet Metal or Eagles Precision for the sheet metal fabrication, due to longer lead time, the cost estimate for both the raw material and the labor likely to exceed the set budget, only the raw materials were purchased. Table 13 below summarizes the raw materials purchased from McMaster-Carr and how they were used during the manufacturing process.



Figure 10. New AMA side view

Table 13. List of raw materials purchased from McMaster-Carr for housing manufacturing

Line	Item Description	Manufacturing Use
1.	High-Strength 17-4 PH Stainless Steel Sheet 0.063" Thick, 12" x 12" (McMaster Tag: 1773T17)	Body - Top
2.	Multipurpose 304 Stainless Steel Sheet .090" Thick, 36" x 36" (McMaster Tag: 8983K337)	Body - bottom
3.	Rigid HDPE Polyethylene 3/4" Thick, 24" x 24" (McMaster Tag: 8619K484)	Bearing Plate

Due to the larger than 0.060” thickness of the sheet metal, problems arose with finding a laser cutter and sheet metal bender on campus that could handle the thickness. Once obtained, the stainless steel materials for the housing were laser cut through a company in Fresno called Keiser Corporation. Quotes to form the metal from two different companies were assessed, but the cut patterns were bent to shape at Cal Poly’s Aero Hanger in order to keep within our senior project budget. Limitations of the benders at the Cal Poly machine shop forced us to cut off the flanges that held the adjustable legs in order to bend the sheet metal pieces into shape. The HDPE material for a new bearing retention was fabricated using Cal Poly Mustang ‘60’s CNC Machine

with the aid of a shop tech. Outsourcing the raw material preparation to these groups allowed us to minimize the labor cost for the prototyping.



Figure 11. The front view (a) and side view (b) of the new AMA unit's metal housing only.

Electronics and Wiring

While we outsourced majority of the new AMA's housing's manufacturing processes, much of the electrical wiring and testing were done in Cal Poly's Mechatronics Lab where we had access to equipment such as dual power supplies, multimeters, wires and breadboards to help wire all the electrical components.

In order to properly wire the controllers, the thermoelectric coolers, the CPU cooler fans and the pumps from the TE-Tech power supply, PS 24-12.5, we've decided to run the wires in an arrangement similar to one of the suggested wiring diagrams provided below.

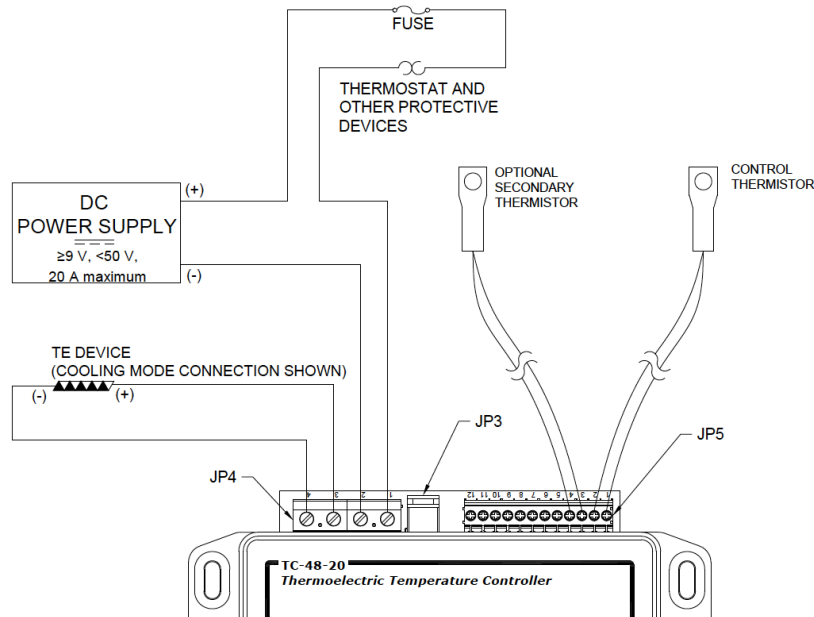


Figure 12. Page 41 from TC-48-20 manual for a sample wiring diagram

This diagram involves running two parallel legs, one powering the controller and the cooler while the other powers the CPU cooler fans and the pumps. Since the new AMA's power supply provides 24 V_{DC} to each of the legs and the fans and pump are rated at 12 V_{DC}, we've decided to use a voltage regulator to curb the 24 V_{DC} to 12 V_{DC} for the leg that contains the fans and the pumps. The part of the circuit that runs to the temperature control and the Peltier cooler did not require such voltage regulator since they were made to tolerate much higher voltage input.



Figure 13. The underside of the new AMA unit prototype housing showing the internal components and the wirings.

Prototype vs. Final Planned Design

The changes that we've made to the planned design from the prototyping are as follows:

Fasteners

Although the original design attempted to incorporate sheet metal fasteners (PEM fasteners) from Penn Engineering, due to the sheet metal requirements such as the thickness, hole dimensions and locations, the final prototyping decided to fasten the assembly together using more generic hardware such as bolts and nuts. Additionally, the scarcity of certain fasteners from local distributors required a bulk order - i.e. minimum order of 1000 units - for the fasteners desired, and ultimately was deemed infeasible to obtain them. As an example, figure shown to the right shows the simpler fasteners being used to secure the controller module to the housing.



Figure 14. The controller module fasteners.

Temperature controller

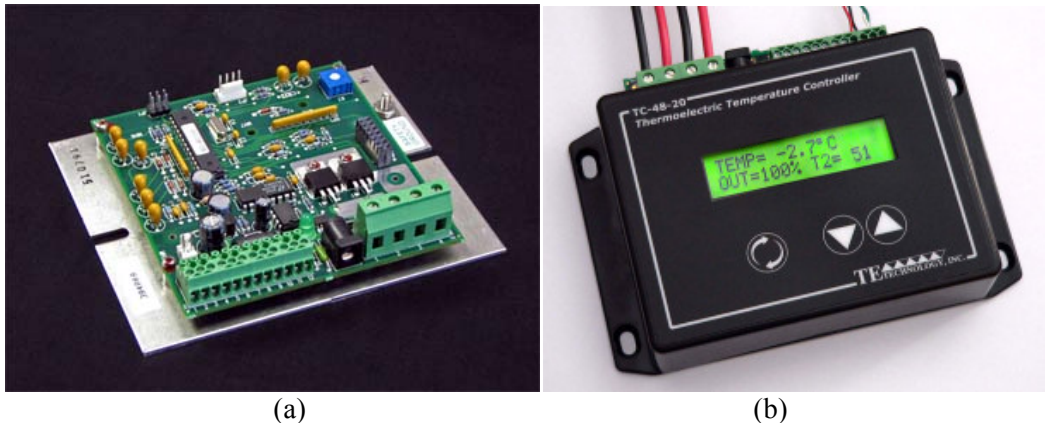


Figure 15. TE Tech TC 48-20 OEM (a) and the TC 48-20 control modules (b).

Initially, the final planned design intended to use TE Tech TC 48-20 OEM as the temperature controller, since it was the most economic control module offered to pair up with the HP-199-1.4-0.8 Peltier cooler operation. Since this control card requires a separate display and key panels for human interaction, we originally decided to wire the Xiamen Ocular GDM1602K LCD Display from the original AMA design to the TC 48-20 OEM control module. However, during a conference meeting, Xtract Solutions recommended an alternative - to use TC 48-20 temperature control as the control module. Upon further consideration, we've realized and agreed that TE Tech TC 48-20 can better meet the customer requirement to simplify any complexity in the previous AMA design since the controller comes ready for human interaction with a display screen (eliminating the need to wire an additional display for the controller module), and with a thermistor for temperature sensing. The TC 48-20 controller interface also allows easy modification to the proportional, integral, and derivative gains, bandwidth, set temperature and alarm settings.

Power Supply

Most Peltier elements commercially found in market intended for cooling purposes are commonly rated at 12 V_{DC} and we hoped by over sizing the Peltier element to a higher rated voltage - 24 V_{DC} to be exact, we would be better able to achieve the required cooling. During our prototyping, however, we've discovered that the original intention to over sizing the cooler had an adverse effect for heat rejection and consequently lower the input voltage to cooler back down to 12 V_{DC}. This change was actually preferably since keeping a 12 V_{DC} in the circuit eliminated the need for a voltage regulator for the fans and the pump for the CPU coolers, reducing the complexity.

Recommendations for Future Manufacturing

The problems that we've encountered during the new Allergen Mixing Assistant's prototyping procedures led to following recommendations to be accounted for future productions.

Sheet Material Thickness

During our consultation with local machinists, we concluded that the optimal sheet metal thickness would be 16 gauge (0.060 inches) since thinner materials would be too weak while thicker materials are difficult to shape the sheet metal housing. The 0.090" thick sheet metal in

our final design also provided majority of the excess weight in our design, and can be drastically reduced with the 16 gauge sheet metal.

Fasteners

We hoped to use the PEM sheet metal fasteners from Penn Engineering to simplify the design but felt that using simpler hardware store fasteners was a much better alternative since PEM fasteners designates sheet metal thicknesses, hole dimensions and locations. Using drills to locate the bolts and nuts to fasten the assembly together was more facile and, as aforementioned, the PEM fasteners are not as readily accessible as a grab-and-go like bolts and nuts and machining the holes to dimensions and locations required more technicality. Although PEM fasteners would allow quicker disassembly and reassembly, we deemed their use to be impractical in our design due to the addition of proper press-fitting and the infrequent disassembly and reassembly needs.

Design a Drain Pan

The final planned design for a new AMA unit did not include a drain pan to collect condensation that forms on the “cold sink” of the Peltier cooler assembly. In order to ensure that the condensate will not flood into any electronics, future production should include a drain pan to place around the cold sink so that there is a proper way to prevent any leakage to electrical equipment. Plenty of space was left within the body that could easily be used to attach the condensation collection vial.

Heat Sink

During our prototyping, we’ve discovered that the Corsair H75 water CPU cooler was not large enough to maintain a steady cooling for the 24 V_{DC} Peltier cooler. We were able to maintain the cold temperature for the Peltier cooler using a much larger heat sink provided at Cal Poly’s Mechatronic lab but since it was only for the testing procedure; in order to package the heat sink module for heat rejection inside the unit, we want to recommend using a similar, but larger Corsair product as shown below.



Figure 16. One recommendation for a great heatsink: Corsair H100i water CPU cooler whose radiator is much larger in size than that of a Corsair H75 cooler

The heat sink used to effectively maintain the set temperature was a large, 1” thick, 24”x24” wide aluminum block adhered to a table. Combination of a similar block with the addition of a CPU cooler will provide even greater heat dissipation.

Power Supply and Peltier Cooler

We intended to oversize the Peltier cooler to require an input voltage of 24 V_{DC} and included TE-Tech PS 24-12.5 power supply module for a 120 V_{AC} to 24 V_{DC} conversion. But since the high voltage rating – or the higher power input – into the Peltier cooler requires greater heat dissipation, we had to size down to 12 V_{DC} during our prototyping. Therefore by sizing back down to a more appropriate size of Peltier cooler whose capacity is rated at 60 Watts of cooling rather than the 172 Watts than originally sized for would solve the heat dissipation issue that we ran into. Majority of Peltier cooler at this capacity level are also rated for a 12 V_{DC} input from the power supply and this will eliminate the need for a voltage regulators for the fans and the pump for the CPU coolers. Placing the Peltier coolers adhered together with thermal compound in series allowed larger cooling to occur.

6. Design Verification

Desired Testing Plan

Since our project is not as analytically strenuous, we planned to focus a large portion on the testing aspect of the design to provide proper functioning and improved cooling results. Conducting these tests would verify the cooling load, electrical components and sound limitations. The primary test involving the temperature measurements is shown below and includes access to our on-campus data acquisition software (PolyDAQ).

Test Equipment

- 2 PolyDAQ (Data acquisition system) stations
- 4 T-type thermocouples (36 gage) with quick connect plugs
- 3 50 ml vials
- Thermometer
- Tape

Assumptions

- Response time of the thermocouple will not factor in
- Water at room temperature will be used to represent the immunotherapy solutions

Procedure

Note: The following procedure includes two PolyDAQ systems, each with two thermocouples attached. The data will be taken simultaneously from both, to allow measurements of four thermocouples, therefore, the procedure shown below will occur for both systems.

1. Connect the two thermocouples to Channels 1 and 2 as referenced in Appendix B of ME 236 Thermal Measurements Course Pack*.
2. Load up the DAQ software program on the desktop of a thermal measurements lab computer. More information regarding the software is referenced in Appendix B of ME 236 Thermal Measurements Course Pack*.
3. Settings of the software will be configured as follows:
Channel A: CH1 Type T TC (50mV)

Channel B: CH2 Type T TC (50mV)
Sample Rate: Largest Sample Rate (ms)
Oversampling: 10 (scans/sample)
Scan Rate: 1 (scans/sec)
Save Data: ON
File Name: C:\usrtmp\filename.txt

Note: Since the response time of the system currently takes 2 hours and the short sample rate is not necessary, we will be manually recording temperature measurements on a minute basis for all four thermocouples until the desired temperature range of 8 degrees Celsius is met. The PolyDAQ system will just be used as a simple way to hook up the thermocouples and a visual display to read off the values.

4. Fill the three 50 ml vials as full as possible with room temperature water. Submerge the ends of two thermocouples in the water of two separate vials and use the vial lids (and potentially tape) as a way to secure the thermocouples, ensuring that the thermocouples do not come in contact with the sides of vials.
5. Place the two vials with thermocouples vertically aligned in the same column (one on the top row and one on the bottom row), with the third vial placed to either side of the top vial.

Note: Three vials are used to replicate the same results taken by Xtract Solutions and are placed in a way to represent a worst case scenario, where the forced convective heat of the top two vials flow over the bottom vial.

6. The third thermocouple will be taped to the heat rejection vent on the back of the unit.
7. The fourth thermocouple will be taped to the counter, 5 feet from the back edge of the unit, with the end of the thermocouple facing upward to capture the surround temperature change.
8. Take the ambient temperature of the room with a standard mercury thermometer to be used as a reference (in degrees Celsius).
9. Record the starting temperatures of each thermocouple.
10. Begin collecting data, recording the temperatures (in degrees Celsius) at minute intervals until all vials are within the 2-8 degree Celsius range.
11. The measured temperatures will then be inputted into excel to conduct calculations (such as time constant characteristics) and create plots of the temperature versus time.
12. If need be, the data file from the PolyDAQ system may be referenced to ensure proper measurement of data.

Testing Procedures Conducted

Using an external power supply, each component was tested individually to ensure proper function. The following cooling characteristics were taken into account:

- Lowest temperature achieved
- Desired set temperature
- Steady state temperature
- Optimal PID setting and bandwidth
- Voltage and current supplied to the components

Complete wiring of the cooling components were configured on a table top. Initial tests included the 24V power supply, using the 24V Peltier cooler and a voltage regulator to step down the voltage from 24V to 12V for the two CPU coolers. Further tests involved the 12V power supply due to the intuition that too much power was being supplied to the Peltier coolers. Two 12V 10A Peltier coolers were bought to replace damaged 24V Peltier coolers from previous testing. The Peltier coolers were tested individually, with and without CPU coolers attached. Placing the two 12V Peltier coolers in series allowed greater cooling load to be achieved.

Arctic silver thermal compound was saved for testing once the components could be fastened to the final formed sheet metal body. Improper adhesion of prior tests may have played a role in insufficient heat dissipation. Unfortunately due to insufficient heat rejection, we were unable to provide the overall end result, showing a graph of temperature at different set points as a function of time as hoped in our desired testing plan.

Testing Results

During the new Allergen Mixing Assistant design's prototyping, it was discovered that the heat rejection did not happen effectively to maintain the cooling requirement. The maximum cooling that was achieved with the given heat sink - the Corsair H75 water CPU cooler - was 12 °C, outside the desired temperature range of 2 - 8 °C.

Multiple Peltier coolers were damaged in the process caused by the excessive heat that would detach the solder wiring into the cooler. Initial assumptions of the problem were directed towards improper settings of the temperature controller and a large portion of the testing was done so by adjusting these settings.

Proportional, integral and derivative gains were altered in order to find the optimal control to maintain the set temperature. Due to the failed rejection of the heat out of the body of the unit, the Peltier cooler would overheat overtime. Adjusting the PID controls helped to mitigate the rise, although overheating of the Peltier cooler still occurred. Overheating would exponentially increase in temperature due to the fact that the thermistor was attached in close proximity to the Peltier cooler. Heat from the hot side was detected by the sensor, which caused an unwanted increase of amperage supplied to the Peltier cooler, in turn amplifying the heat output.

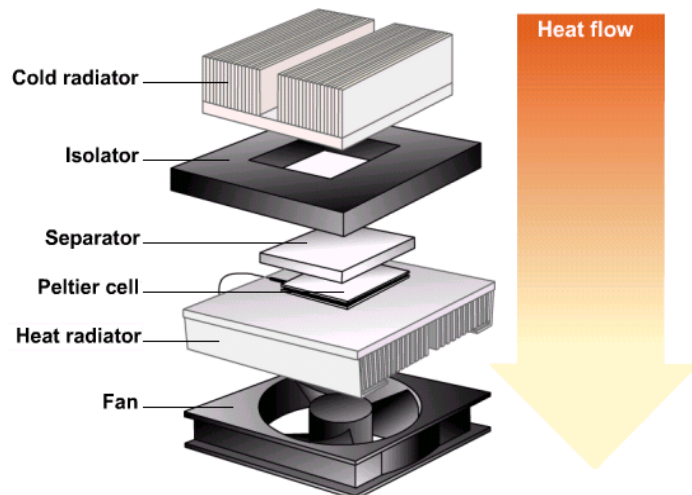


Figure 17. Simple Peltier cell assembly

Several heat sinks were tested for the heat dissipation side of the Peltier cooler. Using the large aluminum block achieved the greatest results, allowing the two 12V Peltier coolers to achieve a

sufficient 5.3 °C. Unlike the prior tests, heat accumulation was nearly mitigated and did not increase exponentially, but was not completely eliminated. For the most part, the temperature oscillated $\pm 0.1^\circ\text{C}$ about the 5.3 °C, changing temperature every 1-2 minutes. A slight increase trend in oscillation temperature started to show after 30 minutes, where the temperatures reached up to 6 °C.

Specification Verification Checklist

Table 14. Achieved engineering specifications for the new AMA design

Spec. #	Parameter Description	Requirement or Target	Tolerance	Achieved
1	Weight**	45 lbs	± 5 lbs	No
2	Size**	Minimum Height = 6"	+18"/-0"	Yes
3	Sound Emission	40 dB	± 10 dB	Yes
4	Cooling Time	1.5 hrs	± 0.5 hrs	No
5	Desired Temperature	5 °C	$\pm 3^\circ\text{C}$	Yes
6	Heat Rejection	$\Delta T < 3^\circ\text{C}$	$\pm 1^\circ\text{C}$	No
7	Power Input	120 V _{AC} to 12, 18, 24 V _{DC}	-----	Yes
8	Power Output	> 40 Watts (of cooling)	-----	Yes

7. Conclusions and Recommendations

In order to reduce the cost and the complexity of the current Allergen Mixing Assistant device from Xtract Solutions, we tried to replace the Stirling cooler with a Peltier cooler, as shown. Unlike the Stirling cooler that is sourced from Japan with a long a lead time and at a steep cost, each components of the Peltier cooler assembly could be sourced easily and domestic in the U.S. During our initial researches, we came across a company called TE Technology, located in Michigan, that specializes in Peltier cooling technology and offers a variety of products that include Peltier coolers, controller modules, heat sinks, etc (they offer finished Peltier assemblies as well). We ultimately decided to source the Peltier cooler, power supply and the control module from TE Technology.

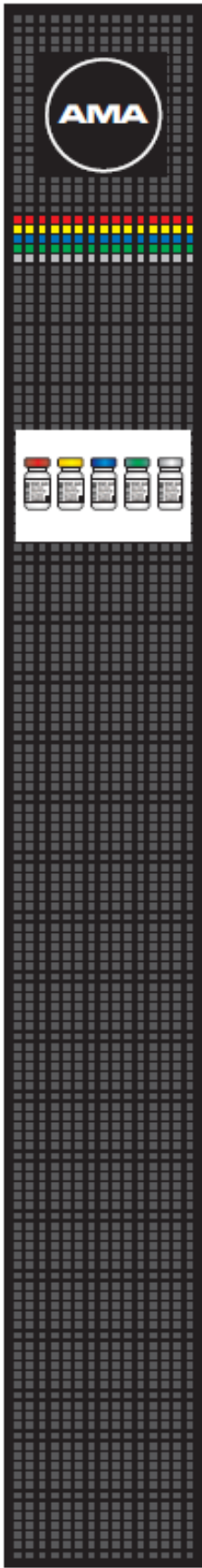
We ran into problem with our heat sink for heat rejection not being able effectively reject the heat, we would require a bigger one as shown in figure 17.



Figure 18. An example of commercially available Peltier assembly. The side facing front shows the smaller cold radiator/sink with fans while the side facing away has much larger heat radiator/sink with fans that can compensate for Peltier cooler's rather low efficiency.

Although we've failed to successfully make a prototype that meets all the engineering specifications to satisfy our customer requirements, we want to recommend Xtract Solutions to consider Peltier coolers as they are a more economical choice and successfully replace the Stirling cooler as a better alternative. The benefits of size, simplicity, cost and cooling power makes the Peltier coolers still a very viable option for the AMA unit if the heat dissipation aspect can be better achieved. Aspects of our design that are readily available and easy to source like the TE Tech components, further simplify the complexity of the current control and electrical portions of the old design. Testing verified the ample cooling capacity of the Peltier coolers and the use of CPU coolers to provide the forced convection cooling.

Overall, my partner and I are forever grateful for the learning experiences provided to us throughout this project. Countless trial and error attributes that have forced adaptation and learning for us. It has showcased the inner workings and processes needed to end up with a physical prototype while expanding our breadth of knowledge, especially with the manufacturing, electrical and control side of our project. Looking at the end result and the details required for each component has given us the practice and understanding of how each portion comes together for an end result and has prepared us to tackle similar projects in the future. It has been a pleasure working with you guys at Xtract Solutions, and we hope our work has supplied you with improvement options for your AMA refrigeration unit.



Allergen Mixing Assistant

The Allergen Mixing Assistant (AMA) provides nurses with a valuable tool to more effectively refrigerate, organize, and mix allergenic extracts. Through a unique combination of technological and ergonomical features the AMA is designed to enhance productivity, reduce error, and improve the quality of life for your mixing staff.



THE AMA 2400
Stores up to 24 vials.



THE AMA 4800
Stores up to 48 vials.



Xtract Work Station (XWS)

This mobile work station ergonomically accommodates all the components of AMA, XPS and can be easily adapted to your clinic's environment.

Features:

- Holds 10, 30, and 50 ml vials from all major extract manufacturers.
- Requires minimal set-up time, training, or maintenance.
- Color-coded, easy to read labeling.
- Holds bottle at appropriate angle with a Syringe Guide for easy draw.
- Stores vials at a consistent and virtually silent 2-8°C displayed on a temperature monitor.

Advanced Cooling Technology Quiet, Efficient, and Stable.

The AMA uses a specialized cooling device to keep your allergens at near constant temperature. Unlike traditional refrigeration on/off cycles, the AMA holds a stable, constant temperature. This cooling approach uses significantly less electricity while being gentle on your Allergens.



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www.xtractsolutions.com

AMA-CX 4800 Thermal Validation Summary

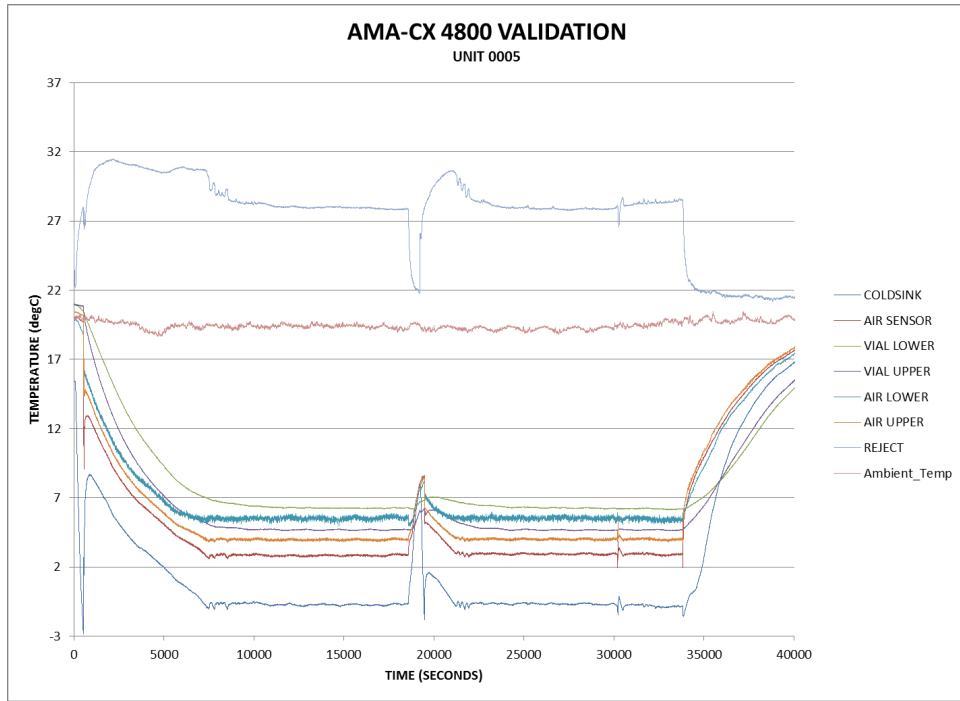
Test Outcome

AMA-CX 4800	
THERMAL PERFORMANCE METRICS	
Time to temperature	
AMA and Vial Start at 20C	
INTERNAL AIR	46 Min
UPPER VIAL	73 Min
LOWER VIAL	99 Min
Steady State Temperature	
Evaluated after 6 hours contious operation	
Upper Vial	4.7 C
Lower Vial	5.7 C
Cold Sink	-0.7 C
Tolerance	+/- 0.5 C
Defrost Cycle	
Occurred ~ 6 hrs after turn-on	
Max Vial Temp	7.0 C
Defrost Time	9.8 Min
Re-Heat (Shutdown)	
Shut Down at steady-state cold conditions	
Time to 8 C	34 Min
Time to 15 C	97 Min

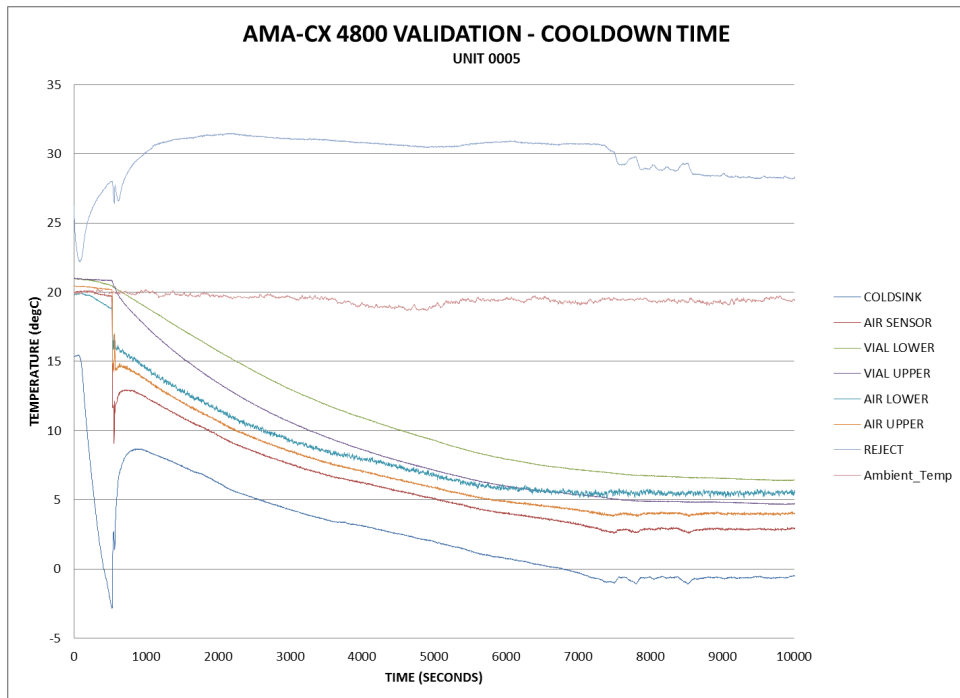
Test Summary

An AMA-CX Base with a “Version 2” 4800 head was instrumented in an office environment regulated to standard clinical conditions (~20°C, RH 30%-60%). The unit was allowed to cool down (including 3 30mL vials) with all contents at room temperature. It entered defrost as scheduled (shown by the temperature spike mid-test) and was shut down after ~11hrs to measure the amount of time it takes for the vials to return to ambient conditions.

The conclusion of this test (in the outcome section above) shows adequate performance to the design specification of vial temperature maintained between 2°C – 8°C.



Time to Temperature

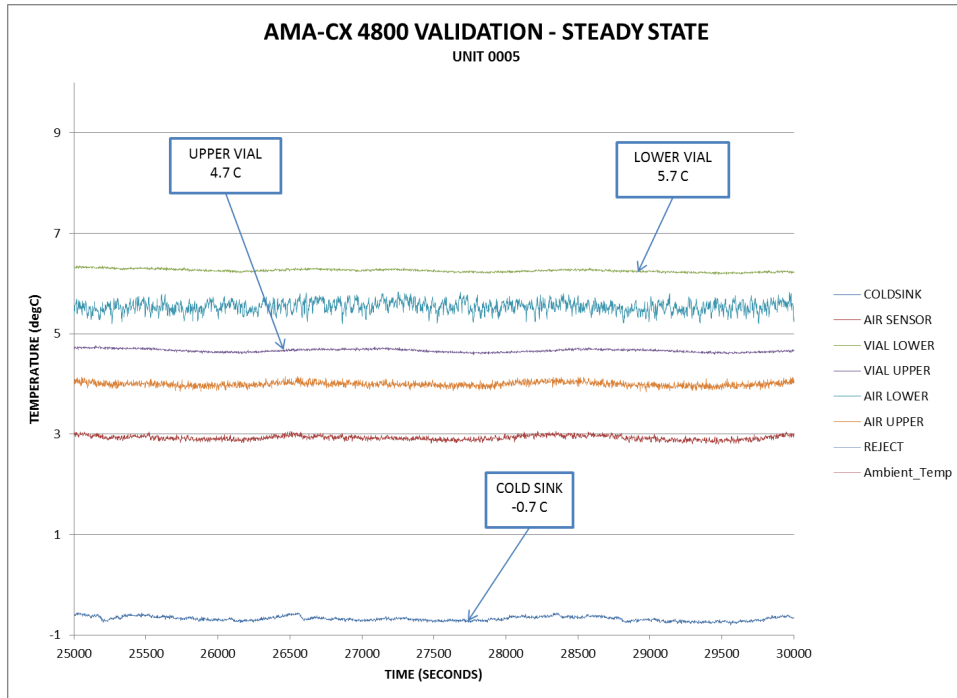


Internal Air: 46 Minutes (2746 sec / 21°C to 8°C)

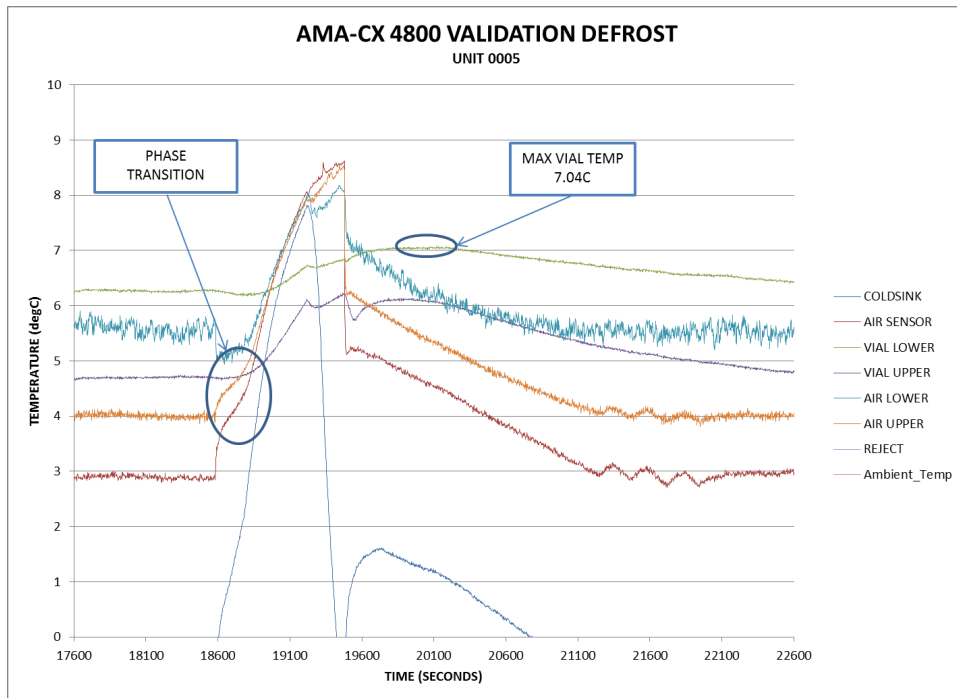
Upper vial: 73 Minutes (4388 sec / 21°C to 8°C)

Lower Vial: 99 Minutes (5956 sec / 21°C to 8°C)

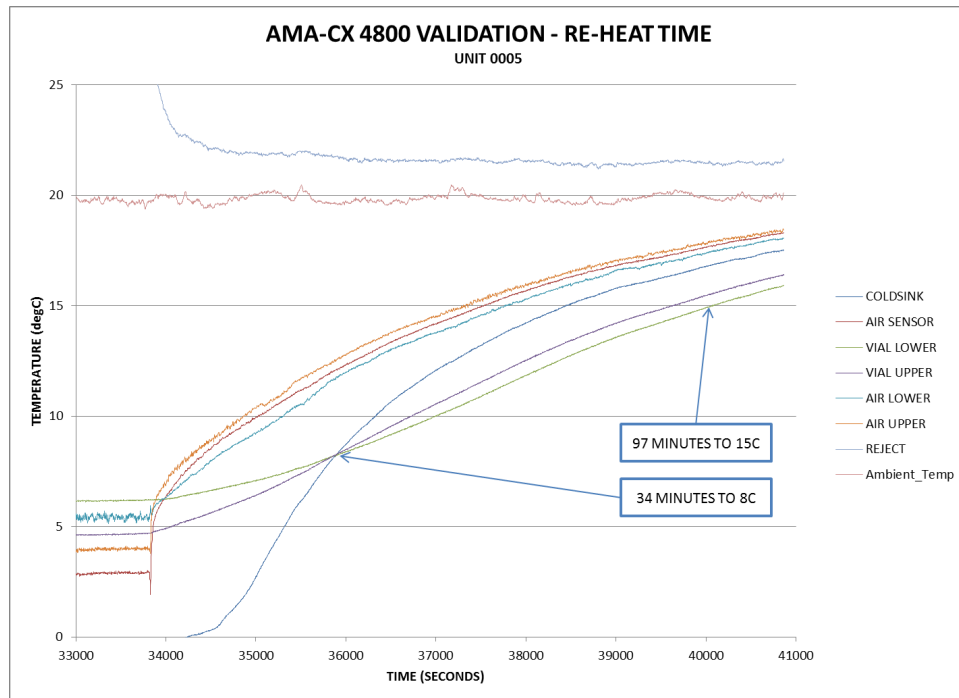
Steady State Stability



Defrost



Post Operation Re-Heat



Shut Down at 33770

Time to 8°C: 34 Minutes (35786sec – 33770sec)

Time to 15°C: 97 Minutes (39582sec – 33770sec)

Appendix A AMA Design Quality Function Deployment (QFD) Diagram

QFD: House of Quality
 Project: Extract Solution's AMA Redesign
 Revision: 2/2/16
 Date: 2/2/16

Row #	WHO: Customers						Maximum Relationship	Column #	1	2	3	4	5	6	7	8		
	Weight Chart	Relative Weight	Extract Solutions	Manufacturer	End User (Clinics/Hospitals)	Sales Team		Direction of Improvement	1	2	3	4	5	6	7	8		
							WHAT: Customer Requirements (explicit & implicit)	HOW: Engineering Specifications	◇	▼	▲		▼	▼	▼	▼		
1		5%	8	2	7	4	9	Remove unnecessary space	●	○						○		
2		6%	8	1	9	8	1	Improve ease of access regarding placement of the vials relative to mixing space		▽								
3		6%	9	2	3	8	3	Maintain existing superstructure (incorporate the AMA head)	○	○			▽	▽	▽	○		
4		5%	5	1	6	6	3	Reduce the height of the design		○								
5		7%	9	1	8	9		Needs to incorporate a rotated system										
6		9%	7	6	8	8	3	Maintain the capability to hold the 10ml, 30ml, and 50ml vials from all major extract manufacturers	○							○		
7		8%	10	4	7	7	3	Reduce cooler and control components to be less than \$2,000 (ideally decreasing the refrigeration and sheetmetal to be less than \$1500)	▽	○	▽					○		
8		5%	10	4	2	2	9	Simplify the complexity of current control system	●	○						●		
9		9%	10	9	2	5	1	Reduce the necessity of utilizing custom components		▽						▽		
10		5%	4	1	8	7	9	Maintain the minimal leakage of the current design	●				●			○		
11		7%	9	1	10	8	9	Maintain the vials at a temperature range of 2-8 degrees Celsius	●		●	○	○			○		
12		8%	8	4	9	8		Keep the color-coded design										
13		6%	6	1	9	8	9	Keep noise emissions relatively low						●				
14		8%	7	6	8	5	9	Meet electromagnetic emissivity standards (IEC 6061)				○				●		
15		8%	6	5	9	6	9	Rejection of heat at a relatively manageable level as to not disturb comfort of user or be detrimental to the surrounding area	○		○		●			●		
HOW MUCH: Target																		
								The temperature of the vials will maintain a 5±C temperature within a ± 0.5 degree tolerance										
								The weight of the overall design will stay within 35 lbs ± 5 lbs										
								The output power shall not exceed 40 W of cooling										
								The power input will not exceed 12 VDC										
								The heat rejection will not increase the ambient temperature by more than 3C within a 5 ft radius										
								Sonic transmission will stay within 40 dB ± 10 dB										
								There will be no housing conductivity										
								The vials will take less than 2 hours to cool down from room temperature to desired temperature (ideally less than 1 hour)										
Max Relationship								9	3	9	3	9	9	9	9	9	9	9
Technical Importance Rating								276.38	100.77	92.093	43.988	139.8	59.509	75.925	241.48			
Relative Weight								27%	10%	9%	4%	14%	6%	7%	23%			
Weight Chart																		

Correlations	
Positive	+
Negative	-
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

Appendix A Pugh Matrices

Key	
+	Improved
-	Worse
o	Neutral
	Dependent on Details

Requirements	Cooler Concepts				
	Current Design	Stirling Cooler	Vapor-Compression	Peltier Cooler	Ice Water
Remove unnecessary space	o	+	+	+	+
Ease of access	o	o	o	o	-
Reduce the height	o	+	+	+	+
Height adjustability potential	-	+	-	+	o
Reduce price	o	o	+	+	+
Simplify the complexity	o	o	-	+	+
Reduce custom components	o	+	-	+	+
Safety	o	o	-	o	-
Cooling speed	o	o			-
Cooling efficiency	o	o	+	-	-
Cooling power	o	o	o	o	-
Noise emissions	o	o		-	+
Electromagnetic emissivity	o	o	o	-	+
Heat rejection	o	o	o	-	+
Weight	o	o	o	+	+
Sum of +	0	4	4	7	9
Sum of -	1	0	4	4	5
Sum of Neutral	14	11	5	3	1
Overall Score	-1	4	0	3	4

Appendix B 3D Models/Layouts

All sheet metal: 18ga stainless steel (18-8)

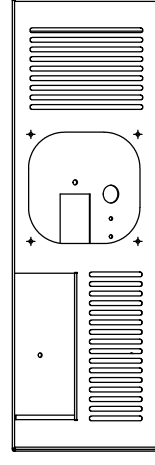
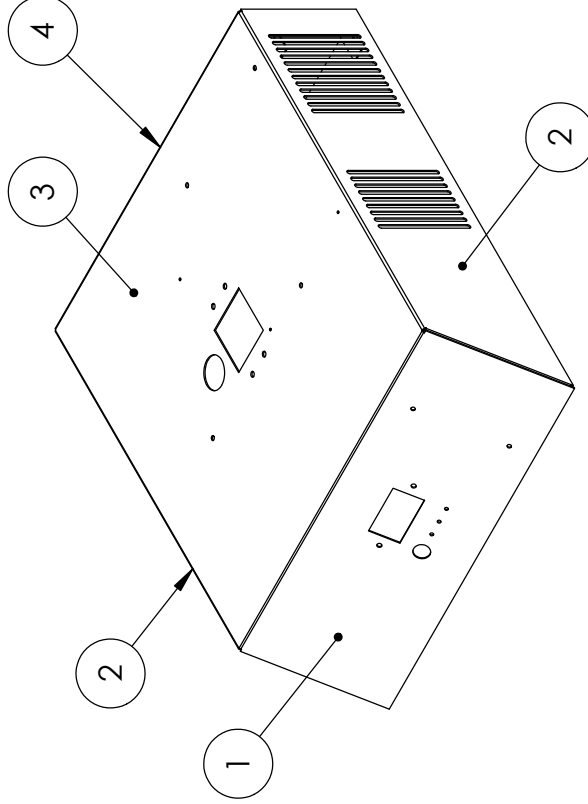
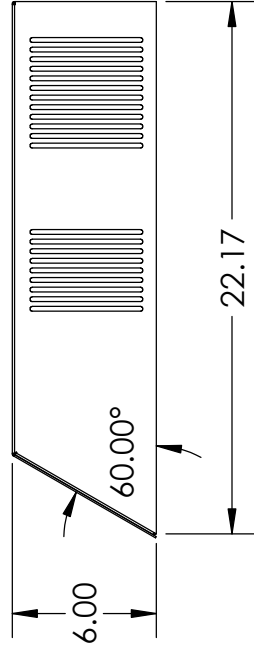
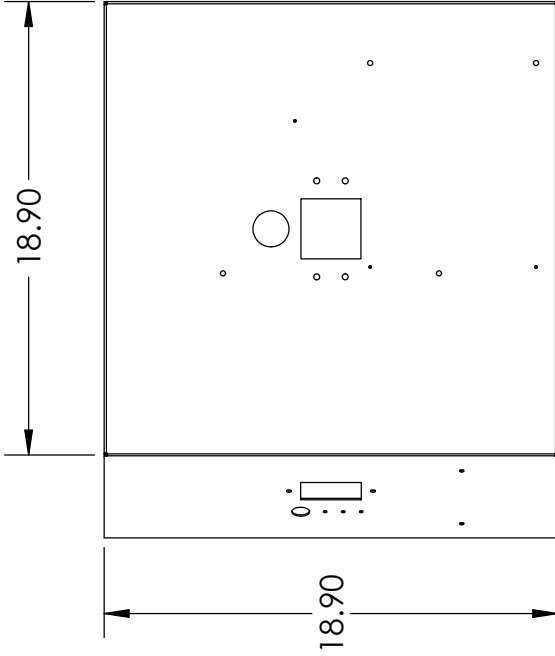
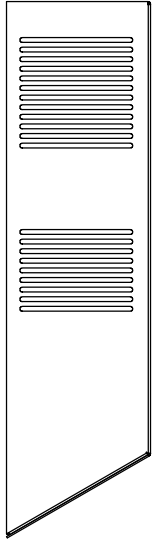
Locate ground screw/nut in all parts

NOTE:

1. Unless otherwise specified, tolerances are:
 - ± .01" for dimensions to 2 places
 - ± .003" for dimensions to 3 places
2. All reference planes have a flatness of .005" unless otherwise specified
3. All planes parallel to the reference plane are parallel to the reference plane by .005".
4. Mask all threads before powder coat
5. Apply masking discs over and round all SKC-F Fasteners (See each layout and/or Appendix C)
6. Following parts not sized in layout drawings since these parts remain unchanged from the original AMA design. Xtract Solutions, to whom this CDR is addressed to, already knows the dimensions and layouts of these parts.

Parts not sized:

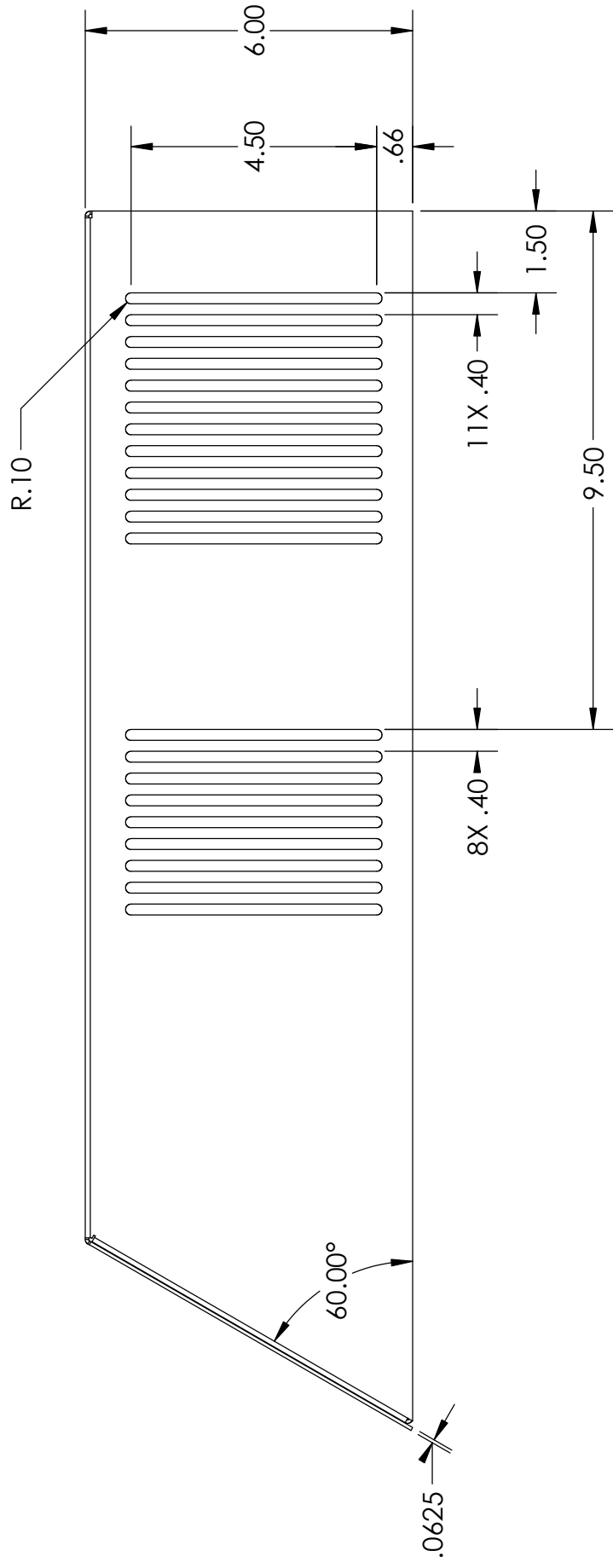
- BEARING BALL
- BEARING
- CENTRAL ENCLOSURE



NOTE:

1. All dimensions are in inches
2. Numerical balloons refer to separate body drawings.

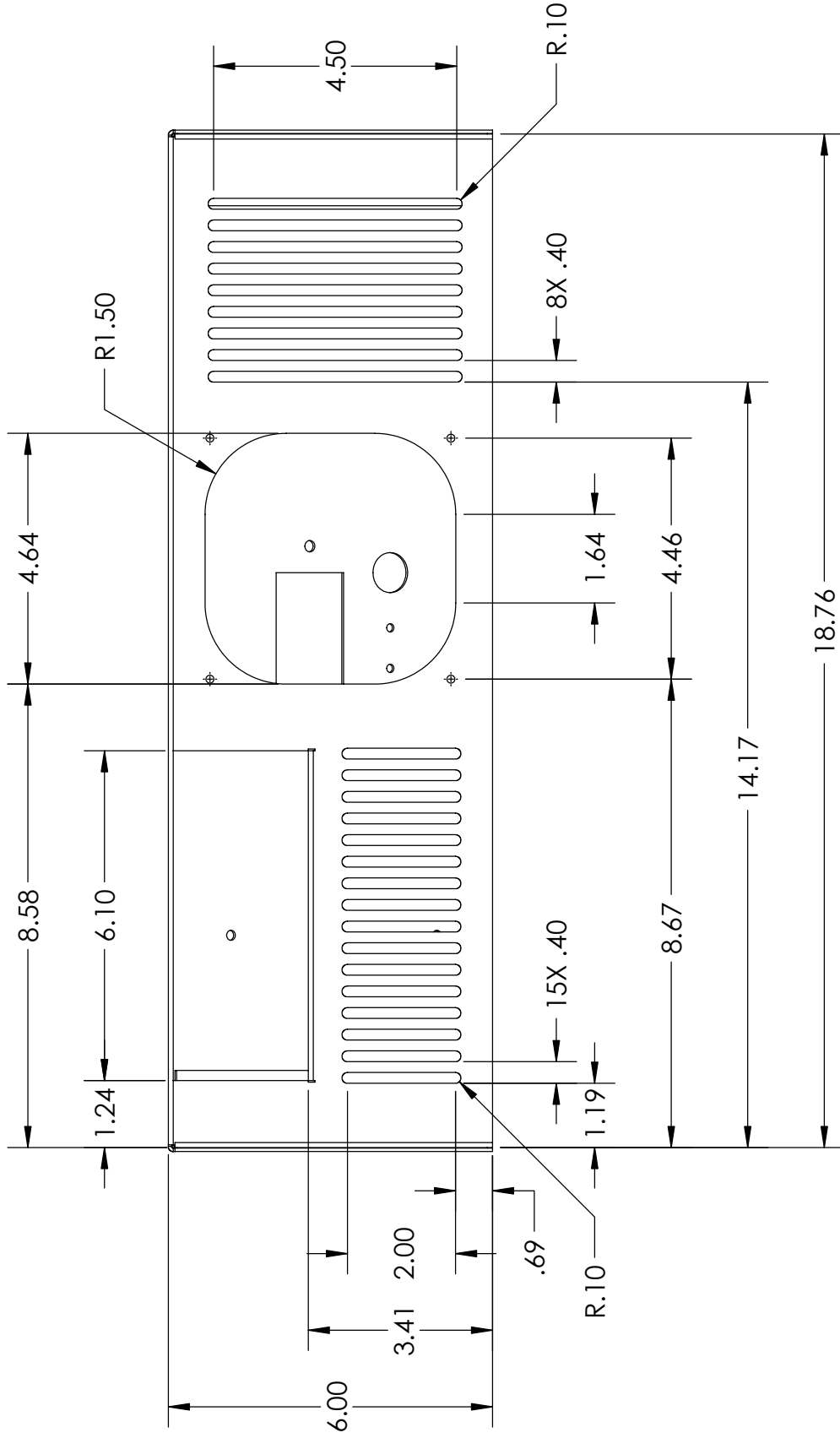
Cal Poly Mechanical Engineering Senior Project: AMA Re-design	Part #: 1	Title: BODY OVERVIEW		By: MITCHELL PARKS, MINWOO SUH
	Dwg. #: 1 of 5	Date:	Scale: 1:8	



NOTE:

1. Vent slots are dimensioned the same and evenly spaced apart.
2. All dimensions are in inches.

Cal Poly Mechanical Engineering Senior Project: AMA Re-design	Part #: 1	Title: BODY SIDE VIEW		By: MITCHELL PARKS, MINWOO SUH
	Dwg. #: 2 of 5	Date:	Scale: 1:3	



NOTE:

1. Vent slots are equally spaced apart.
2. All dimensions in inches.

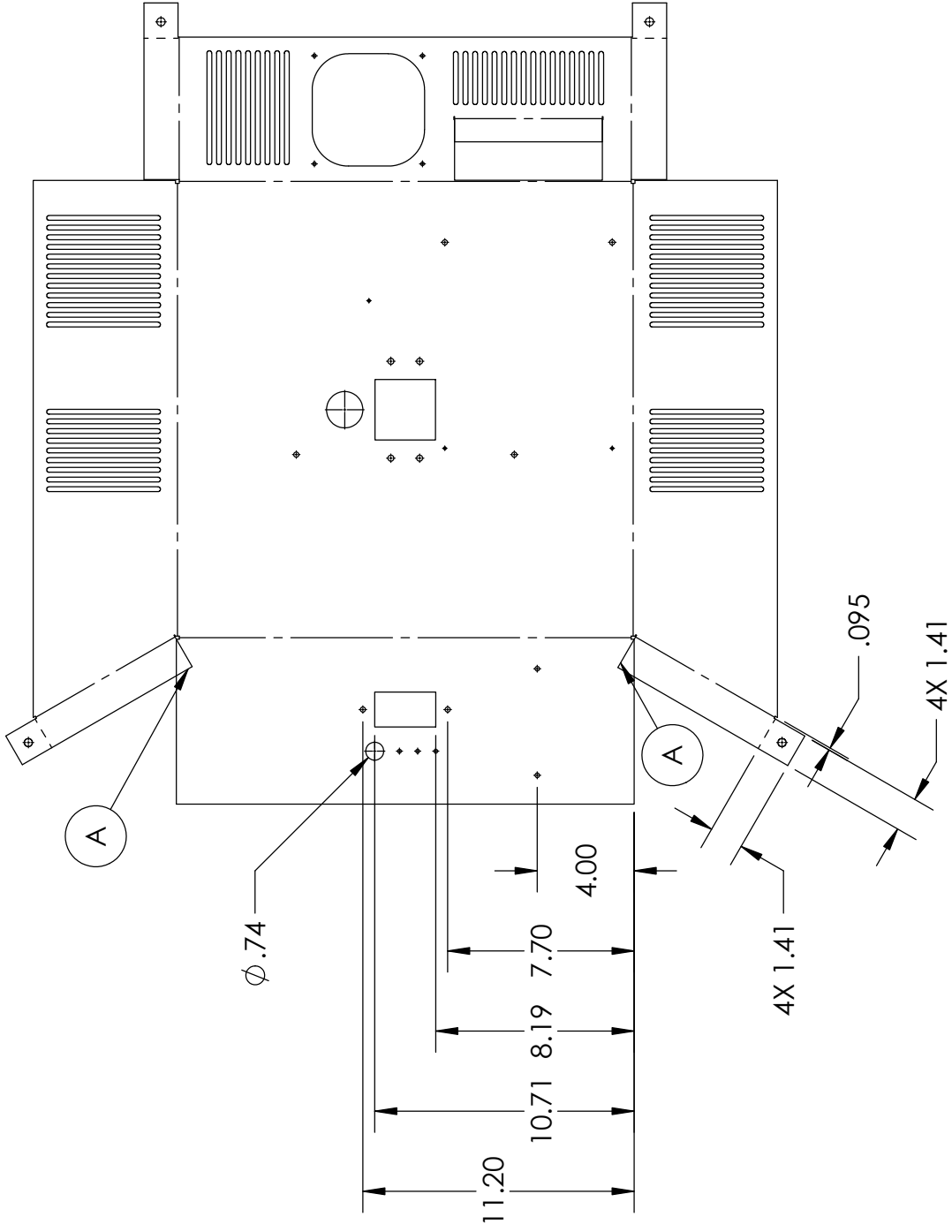
Cal Poly Mechanical Engineering
Senior Project:
AMA Re-design

Part #: 1
Dwg. #: 4 of 5

Title: BODY BACK VIEW
Date:

Scale: 1:4

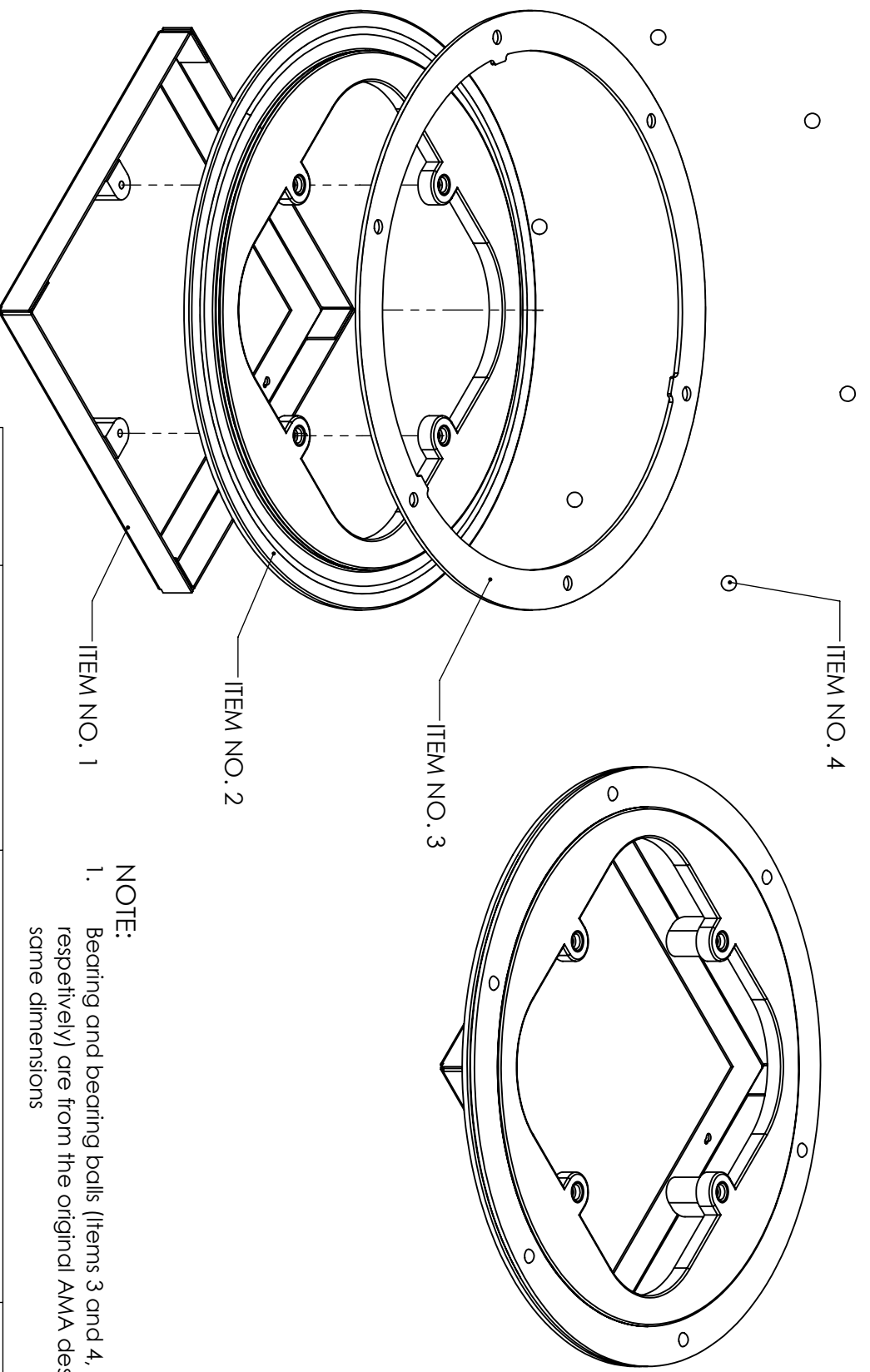
By: MITCHELL PARKS, MINWOO SUH



NOTE:

1. Auto relief cuts at the corners of the folds are subject to change dependent on sheet metal manufacturer recommendations.
2. Balloon A denotes the areas that are not feasible in the design and therefore should be trimmed from the drawing.

Cal Poly Mechanical Engineering Senior Project: AMA Re-design	Part #: 1	Title: BODY FLAT LAYOUT VIEW		By: MITCHELL PARKS, MINWOO SUH
	Dwg. #: 5 of 5	Date:		



NOTE:
 1. Bearing and bearing balls (Items 3 and 4, respectively) are from the original AMA design with same dimensions

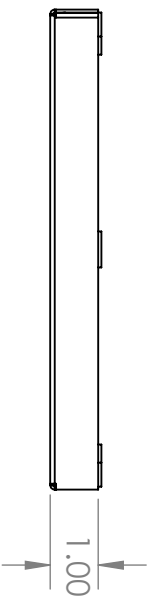
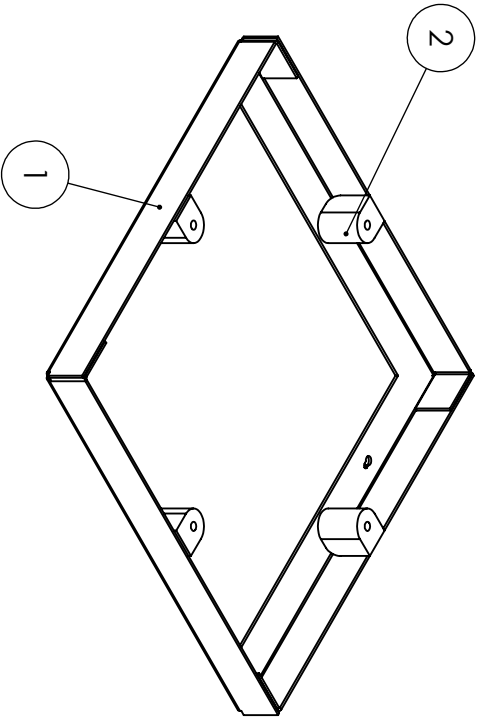
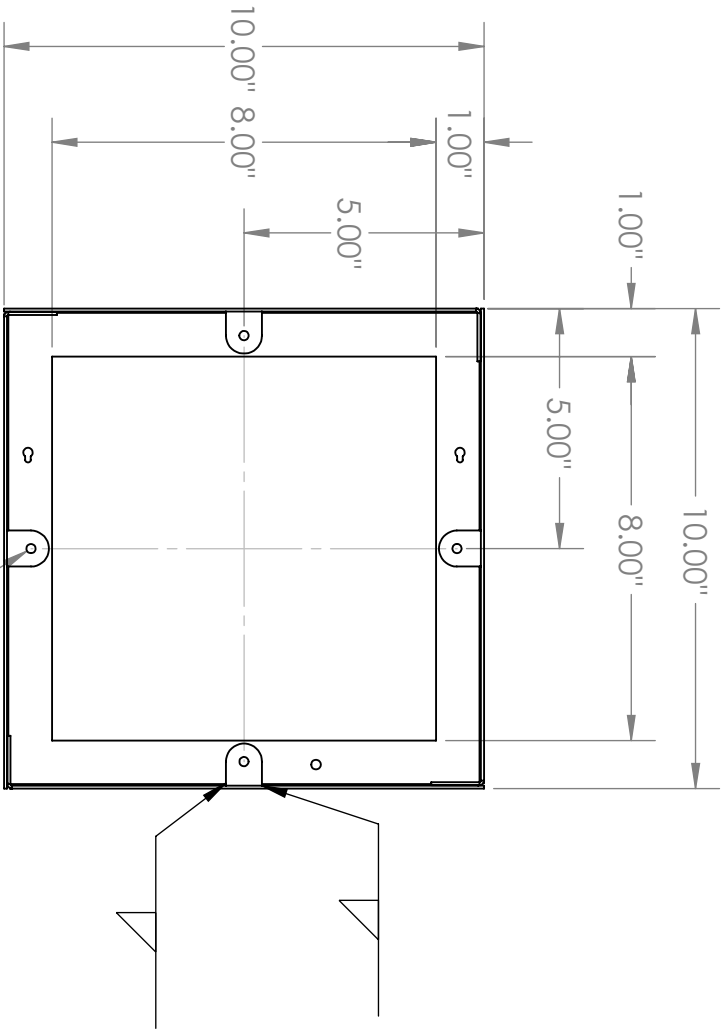
ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	ENCLOSURE BOX	ENCLOSURE BOX	1
2	STATIC PLATE	LOCATEDS BEARING AND BALLS	1
3	BEARING	LAZY SUSAN BEARING	1
4	BEARING BALLS	BEARING BALLS	6

Cal Poly Mechanical Engineering
 Senior Project:
 AMA Re-design

Part #: 2
 Dwg. #: --

Title: ENCLOSURE BOX
 Date: 5/3/2016

Scale: --
 By: MITCHELL PARKS, MINWOO SUH



4x UTS #10 THRU ALL (in ITEM NO. 2)

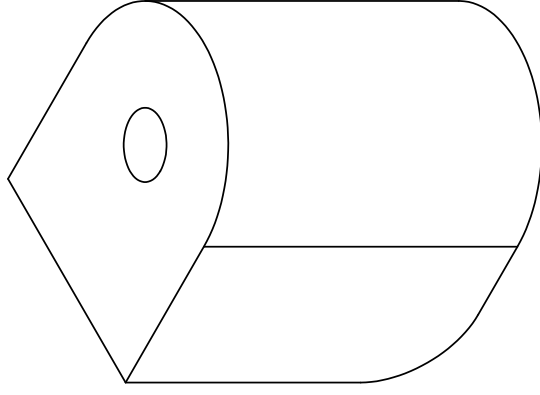
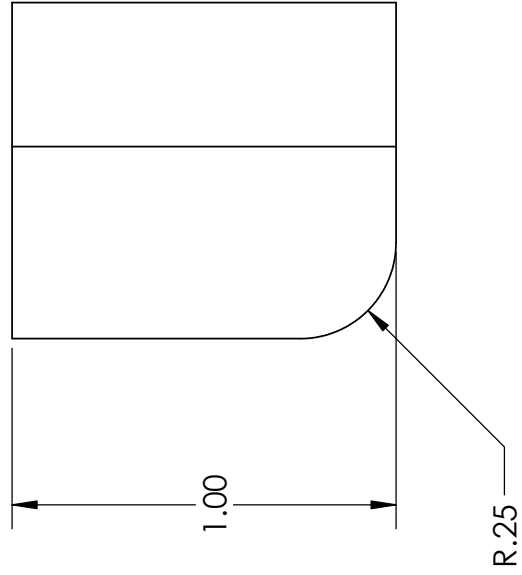
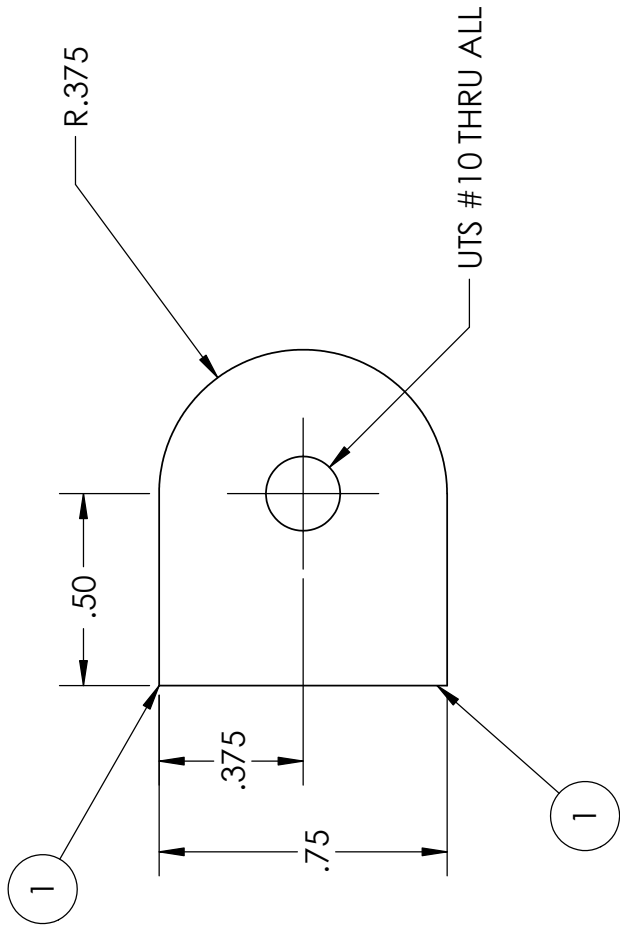
- NOTE:**
- Each of Item No. 2 - THREADS will be fillet welded to Item No. 1 ENCLOSURE BOX to locate UTS #10 HOLE THRU ALL (in Item No. 2) at locations specified.
 - Weld ITEM NO. 2 onto ITEM NO. 1 as shown (to a total of 4).

ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	ENCLOSURE BOX	ENCLOSURE BOX	1
2	THREADS	UTS #10 THREADS	4

Cal Poly Mechanical Engineering
 Senior Project:
 AMA Re-design

Part #: 2
 Title: ENCLOSURE BOX
 By: MITCHELL PARKS, MINWOO SUH

Dwg. #: 1 of 4
 Date: 5/3/2016
 Scale: --



NOTE:

1. Fillet Weld here to Item No. 2

Cal Poly Mechanical Engineering
Senior Project:
AMA Re-design

Part #: 2

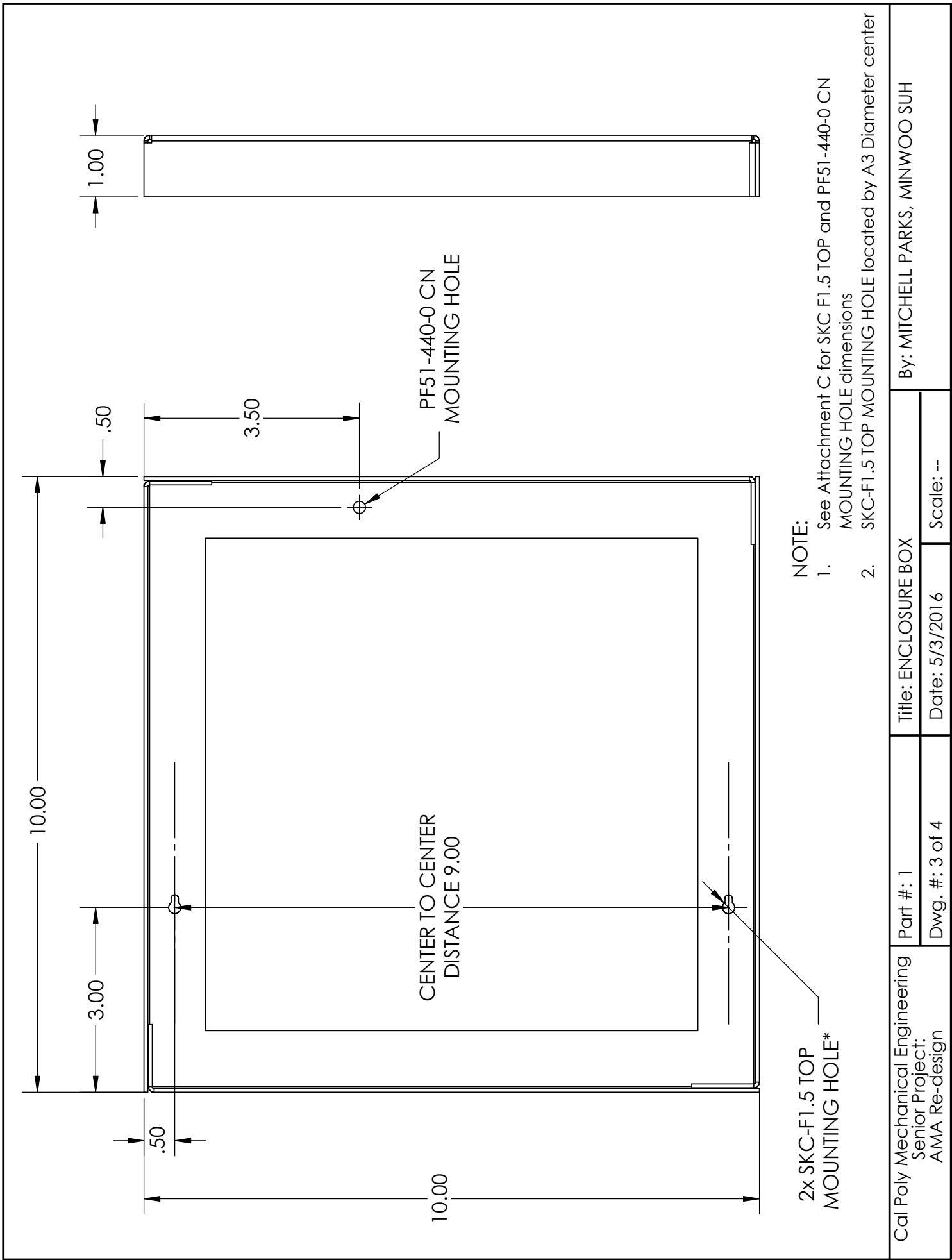
Dwg. #: 2 of 4

Title: THREADS

Date: 5/3/2016

Scale: --

By: MITCHELL PARKS, MINWOO SUH

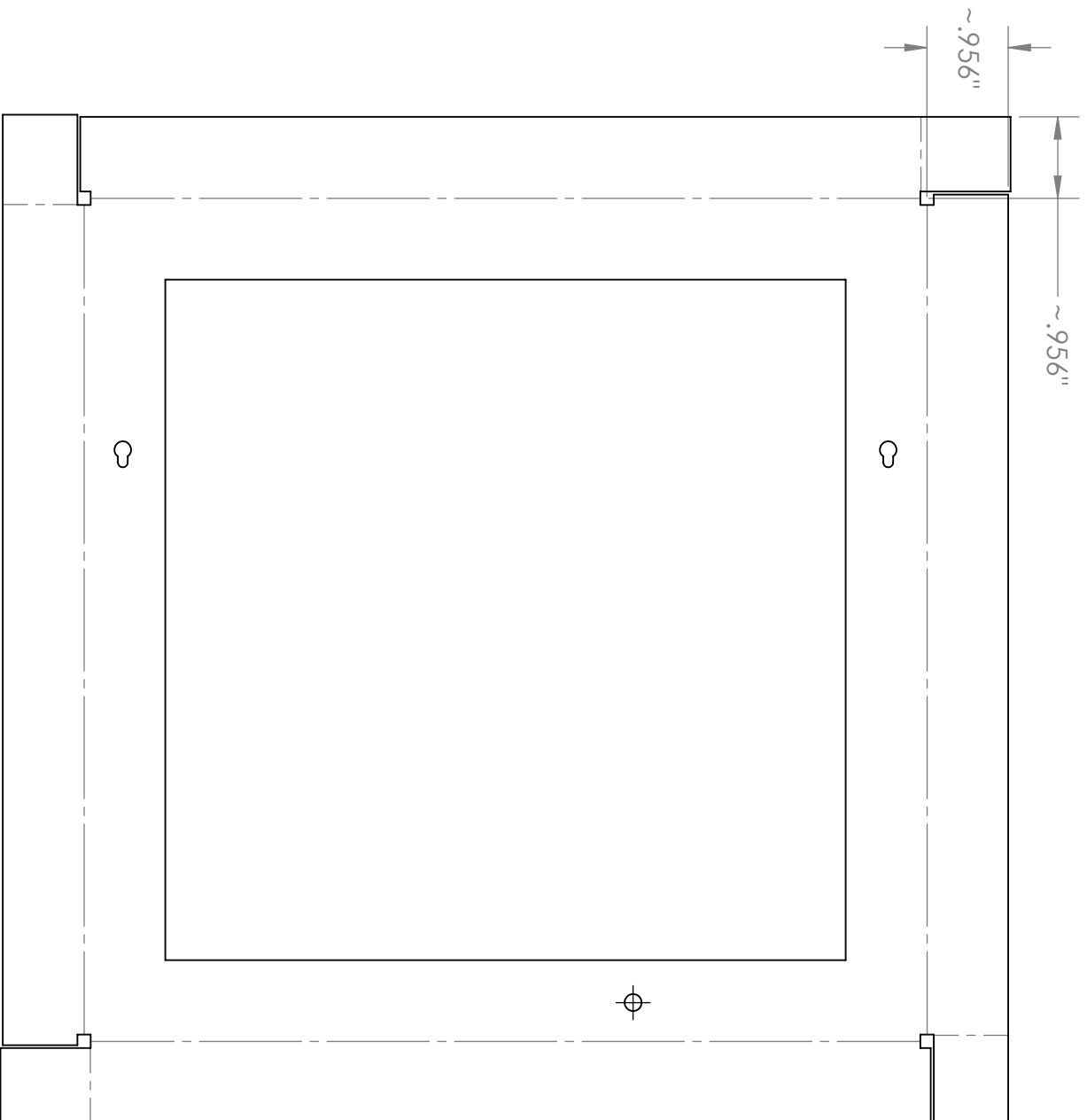


Cal Poly Mechanical Engineering
 Senior Project:
 AMA Re-design

Part #: 1
 Dwg. #: 3 of 4

Title: ENCLOSURE BOX
 Date: 5/3/2016
 Scale: --

By: MITCHELL PARKS, MINWOO SUH



NOTE:

1. Sheet metal layout before folding.
2. Fold along the annotated centerline ~.956" from the edge. The fold should result in 1" height sheet metal box.
3. Provide auto relief cut as needed
4. Sheet metal thickness: 1/16" (0.0625").

Cal Poly Mechanical Engineering

Senior Project:
AMA Re-design

Part #: 1

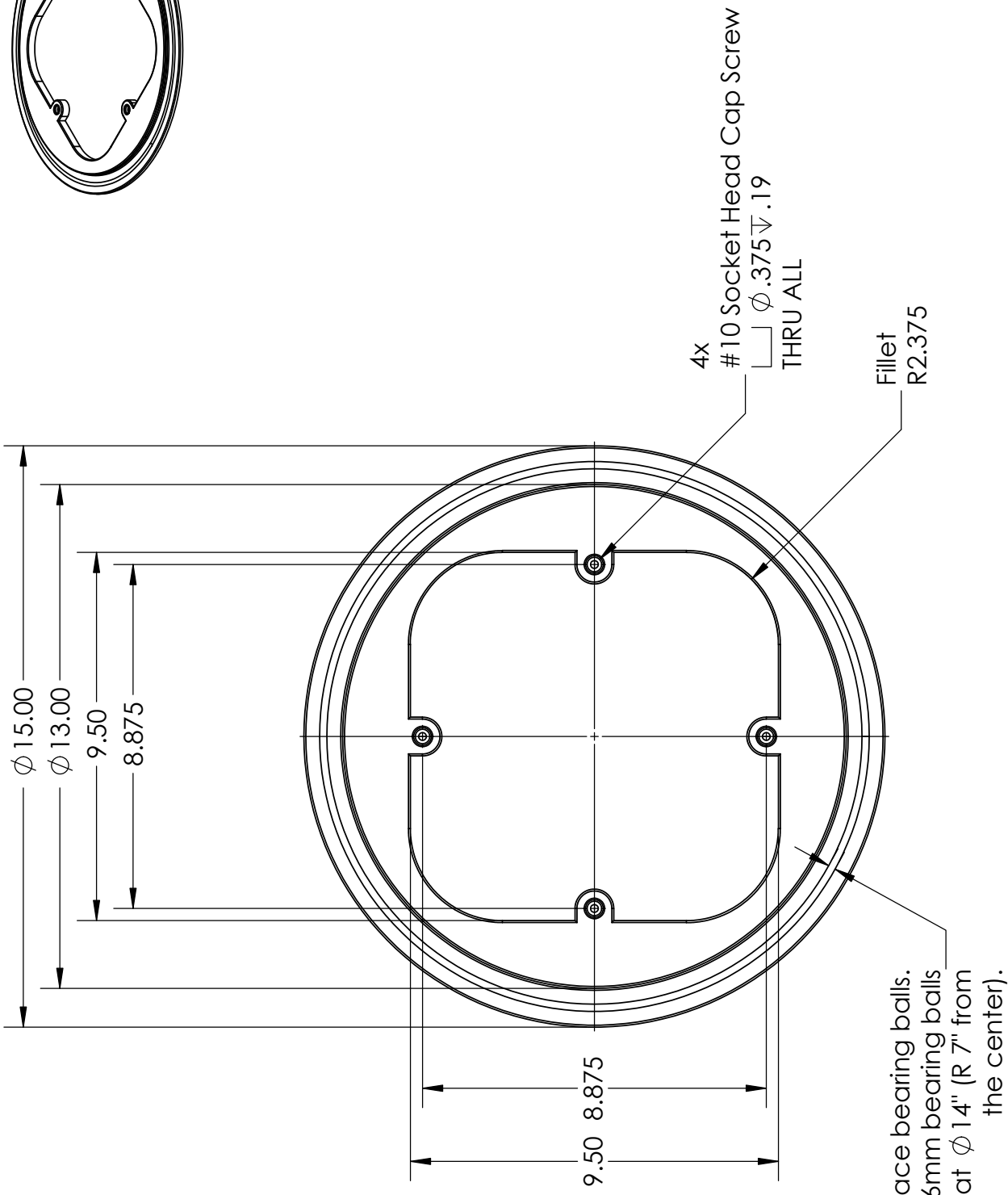
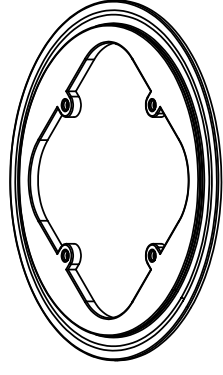
Dwg. #: 4 of 4

Title: ENCLOSURE BOX

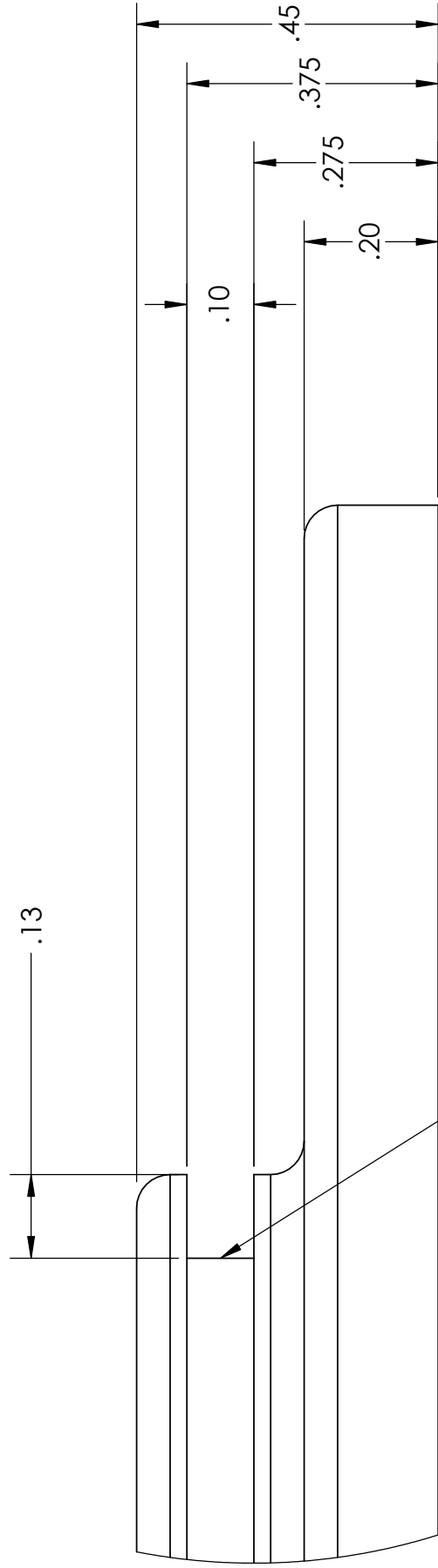
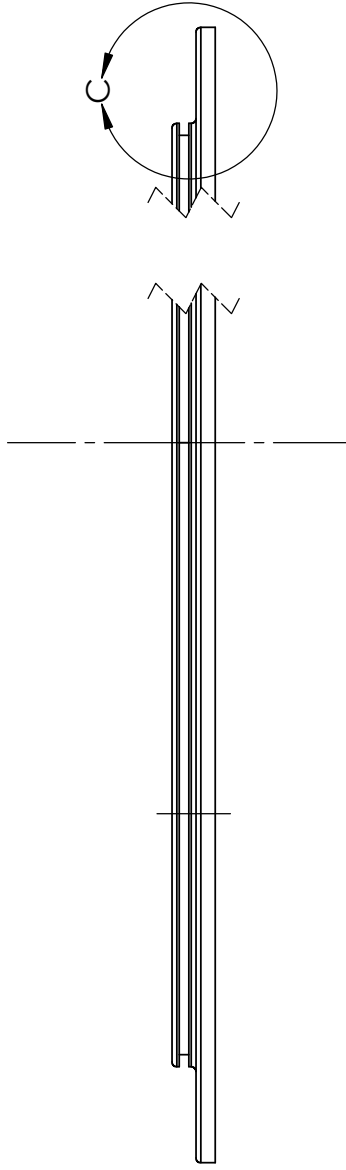
Date: 5/3/2016

Scale: --

By: MITCHELL PARKS, MINWOO SUH



Cal Poly Mechanical Engineering Senior Project: AMA Re-design	Part #: --	Title: STATIC PLATE		By: MITCHELL PARKS, MINWOO SUH
	Dwg. #: 1 of 3	Date: 5/3/2016	Scale: --	

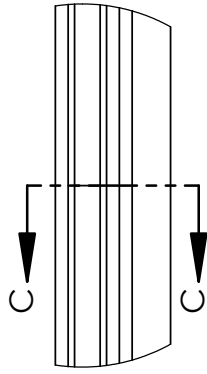
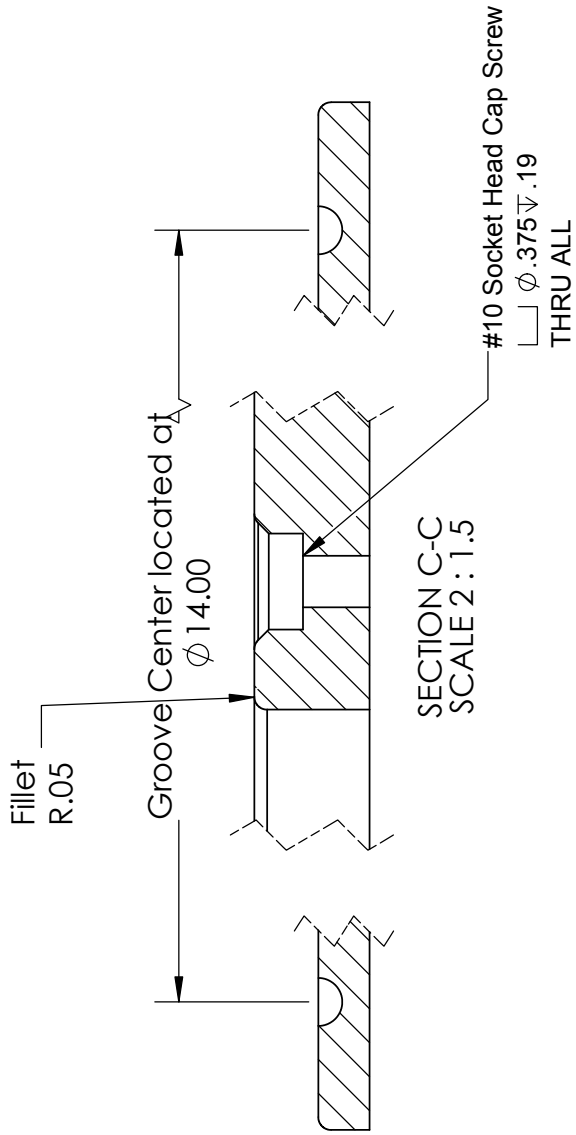
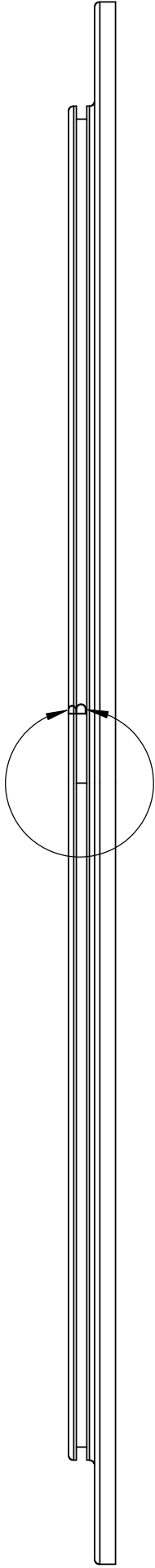


Groove to locate Bearing

DETAIL C
SCALE 4 : 1

NOTE:
1. All fillets done at 0.05"

Cal Poly Mechanical Engineering Senior Project: AMA Re-design	Part #: --	Title: STATIC PLATE	By: MITCHELL PARKS, MINWOO SUH
	Dwg. #: 2 of 3	Date: 5/3/2016	Scale: --



Cal Poly Mechanical Engineering
 Senior Project:
 AMA Re-design

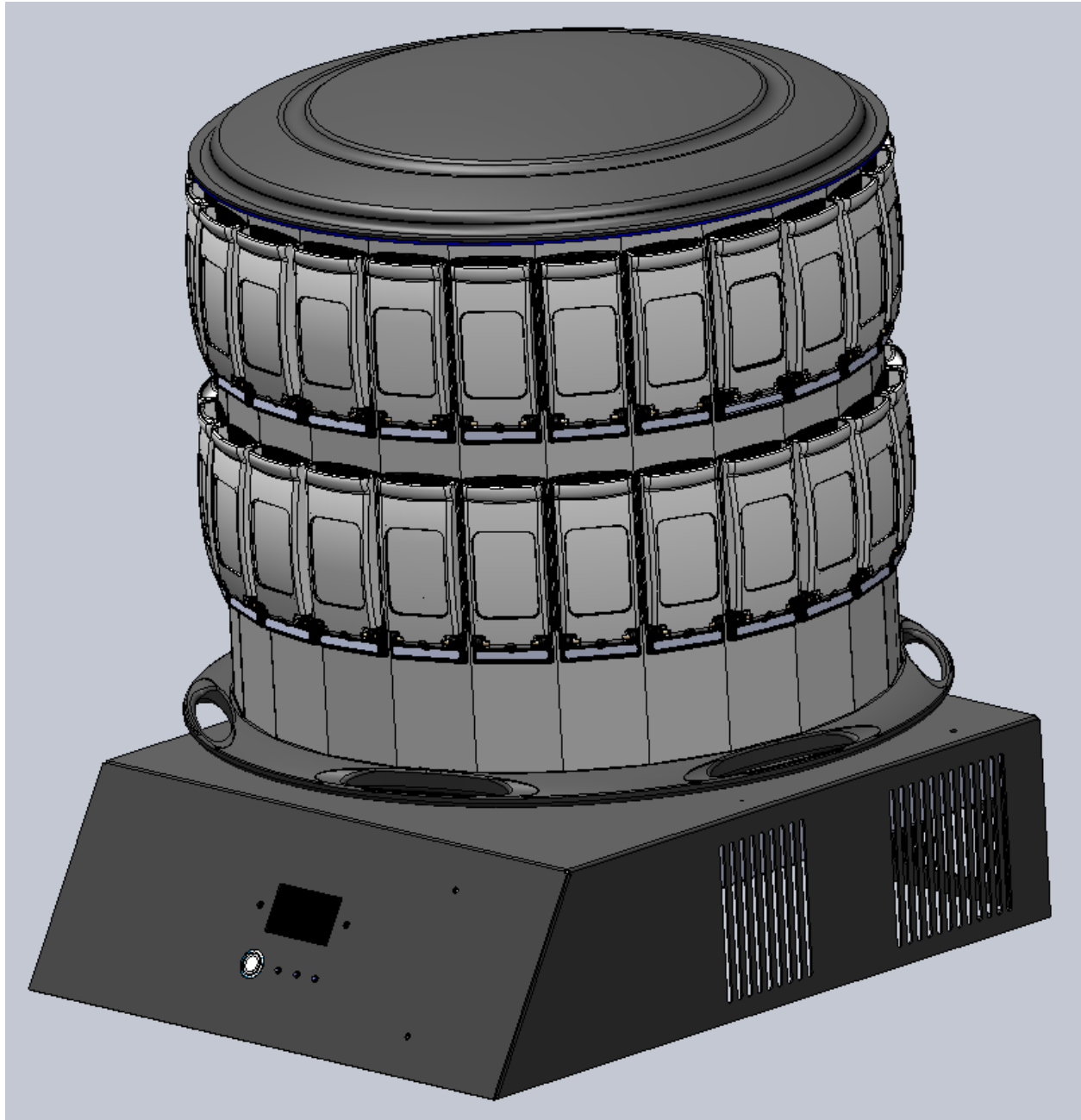
Part #: --
 Dwg. #: 3 of 3

Title: STATIC PLATE
 Date: 5/3/2016

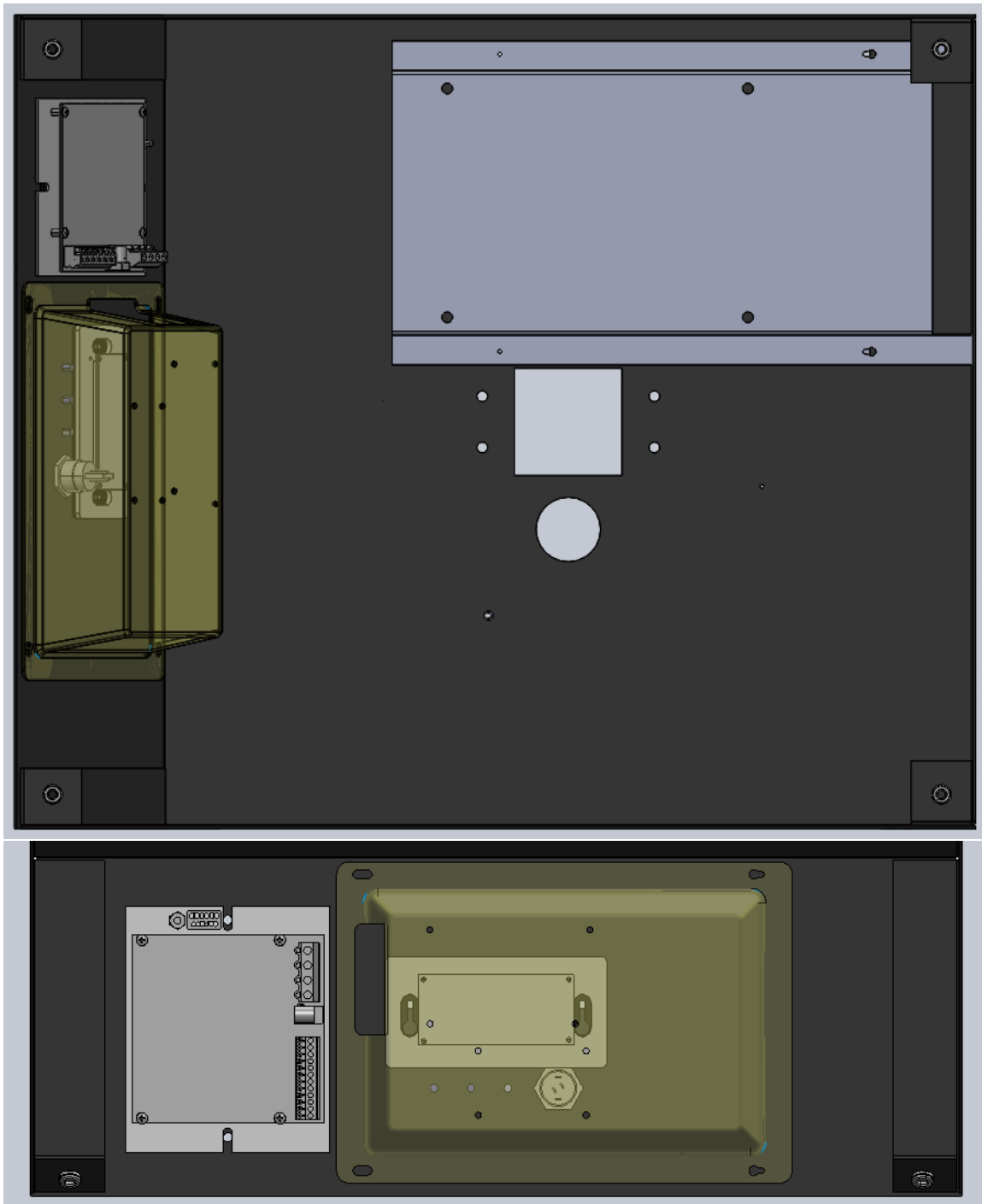
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By: MITCHELL PARKS, MINWOO SUH

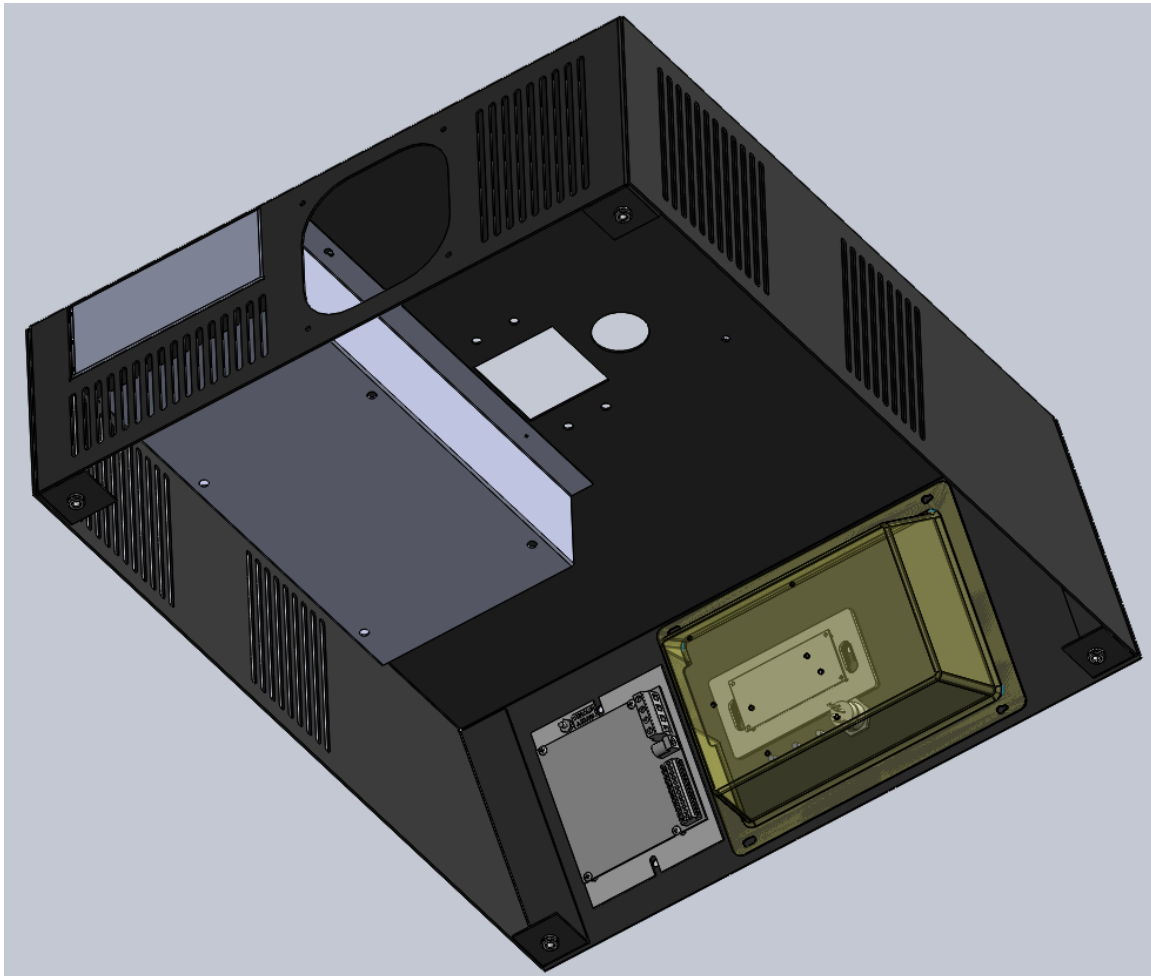
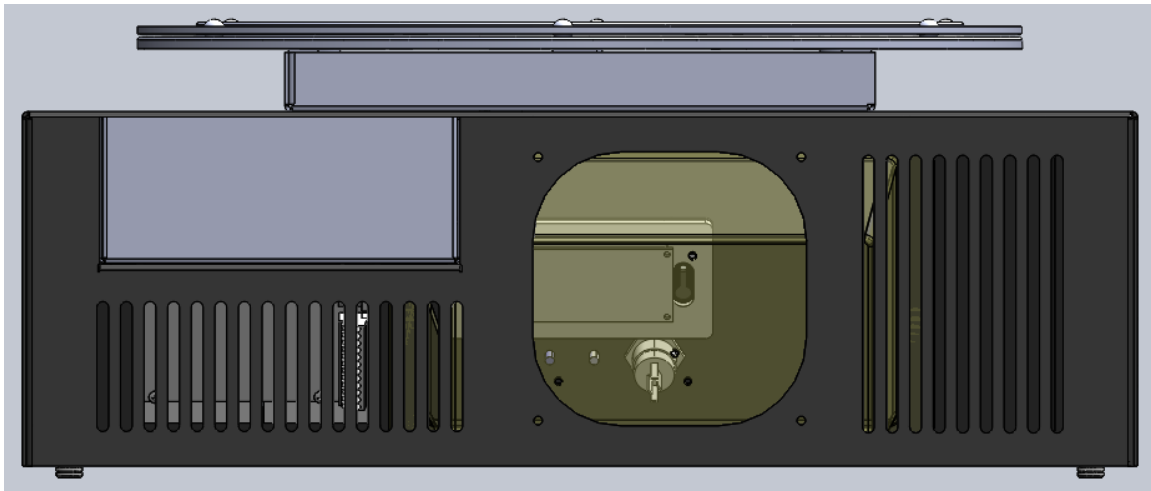
Isometric view of entire assembly



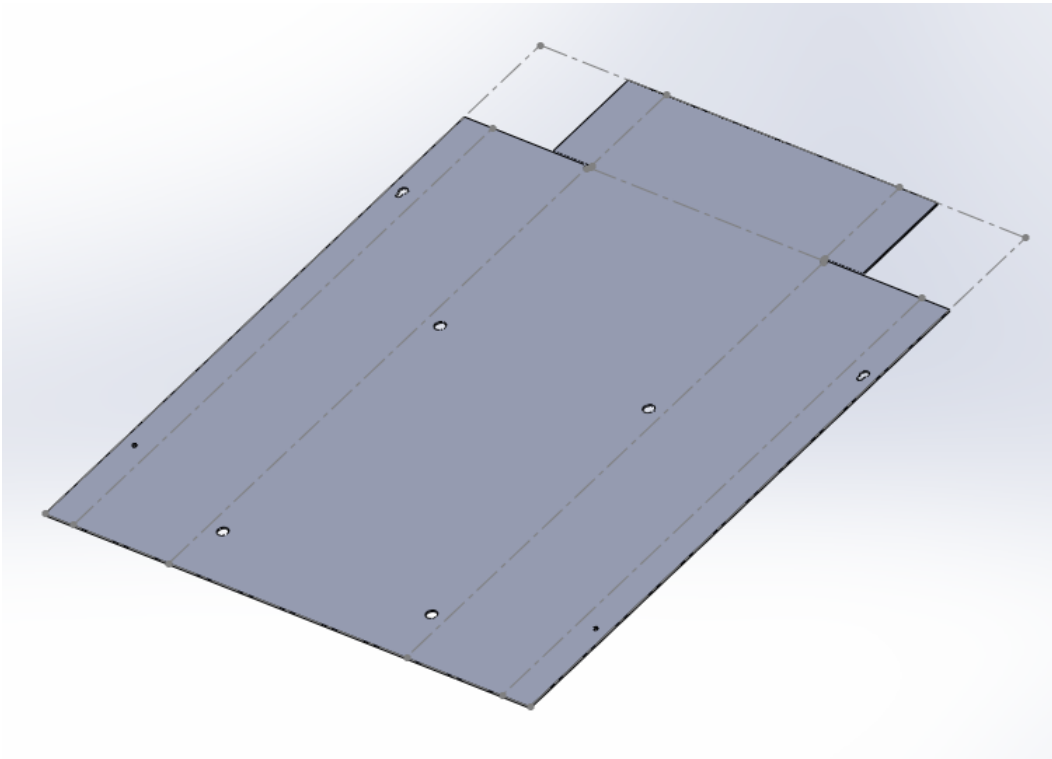
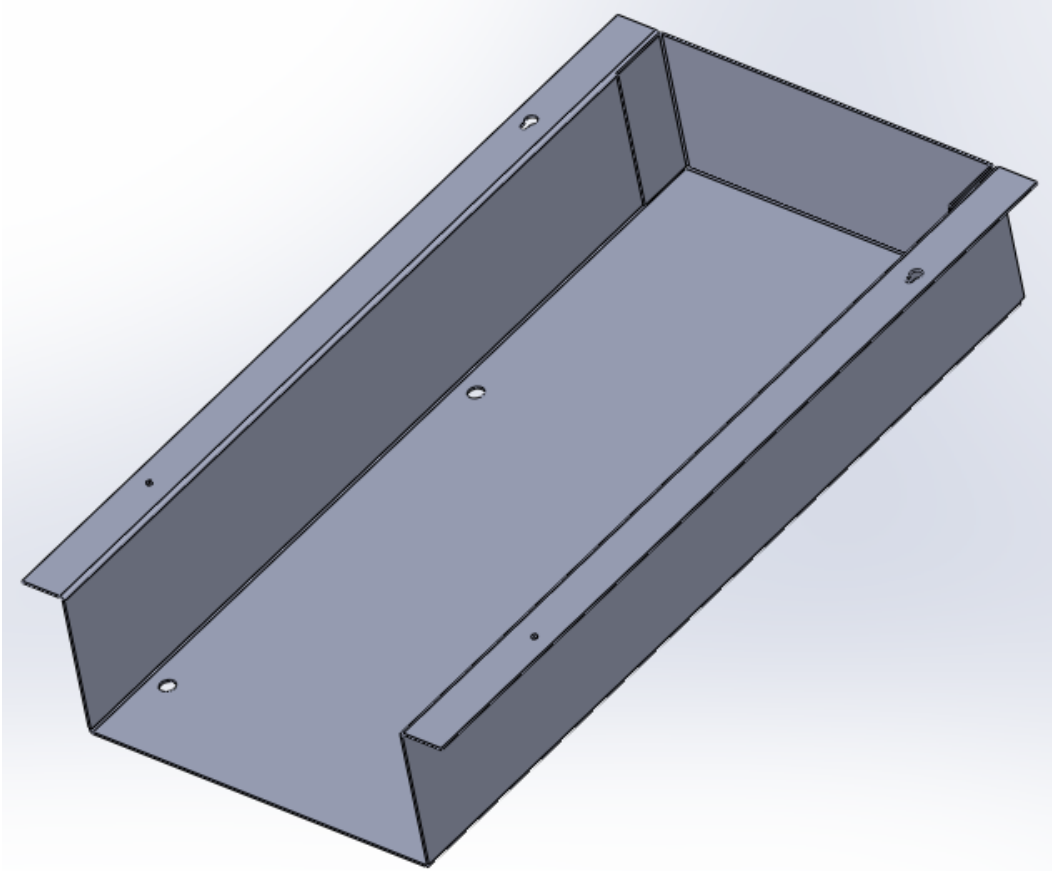
Underside view and view normal to the front face



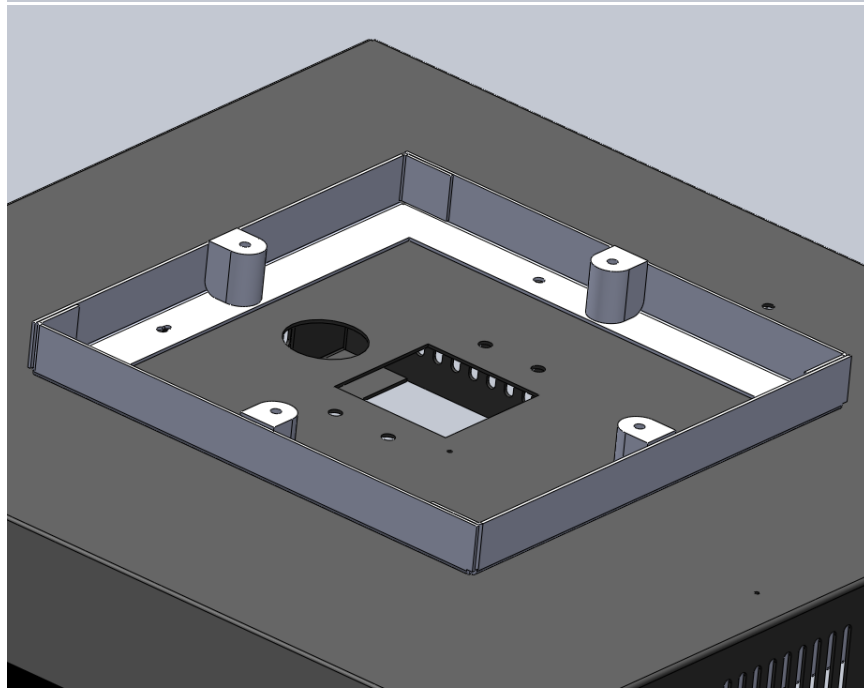
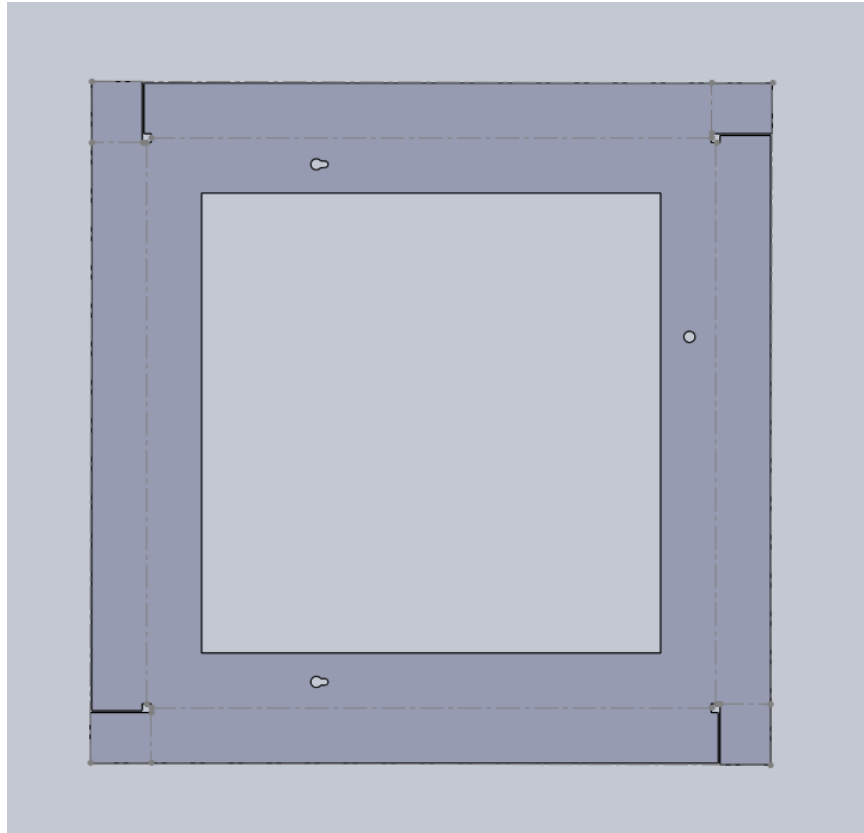
Back views of the body



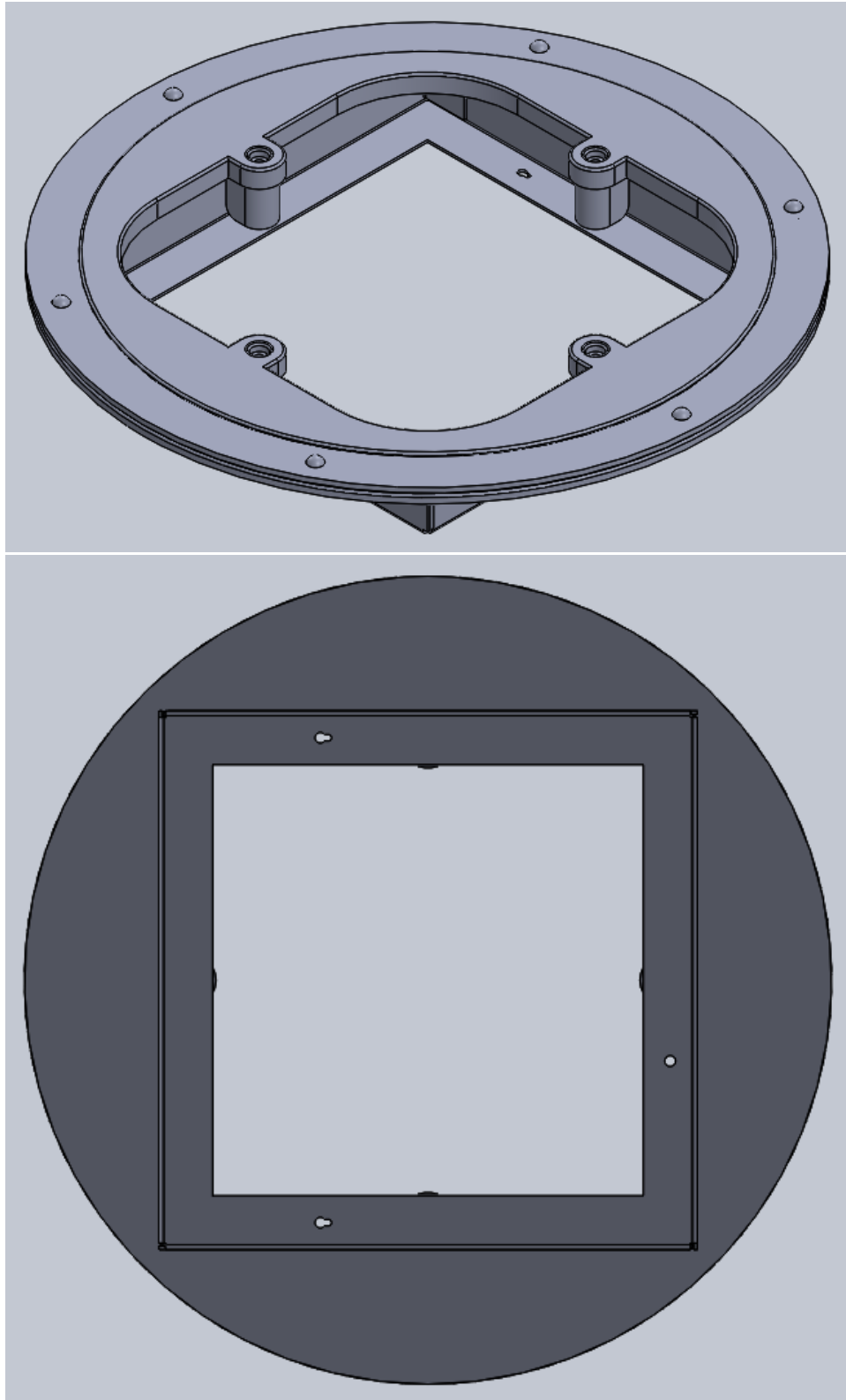
Power supply box



Bearing Box



Views of bearing retention assembly



Appendix C Vendors with Contact Information

Vendors	Description	Contact/Location
Cooler Master Technology, Inc.	Sells: Cooler Master GeminII M4 (top CPU cooler and fan assembly for cold air distribution)	CMI USA, Inc., 4820 Schaefer Ave Chino, CA 91710 Tel:1-888-624-5099
TE Technology, Inc.	Sells: 24 V _{DC} , 12.5 Amp Power Box Thermostat/Temperature Controller Peltier Cooler	1590 Keane Drive Traverse City, MI 49696 Phone: 231-929-3966 Fax: 231-929-4163 Email: cool@tetech.com
PennEngineering®	Sells: All sheet metal fasteners	5190 Old Easton Rd. Danboro, PA 18916 Phone: 215-766-8853 Toll Free Phone: 1-800-237-4736 (U.S. only) Email: info@pemnet.com Website: www.pemnet.com
Fastenal®	Sells: Grounding Screws to negate the currents in the sheet metal	Local: 4420 Broad St San Luis Obispo, CA 93401 Phone: (805) 786-4505 HQ: 4730 Service Dr Winona, MN 55987 Phone: (507) 453-8280
Eagles Precision Sheetmetal, Inc.	Sells: Their labor in sheet metal fabrication	761 N Holladay St, Cornelius, OR 97113 Phone: 503-992-1589 Fax: 503-992-0690
Xiamen Ocular Optics Co., Ltd.	Sells: LCD display	South 2/F Guangxia Building, Torch Hi-Tech Development Area Xiamen, China Post code: 361006 Tel: +86-592-5715296 +86-592-5650695 Email: lee@xmocular.com
Corsair Components, Inc.	Sells: H75 liquid CPU cooler (Bottom CPU cooler assembly for heat rejection)	47100 Bayside Pkwy, Fremont, CA 94538 Phone: (510) 657-8747

Appendix D Components Specifications and Data Sheets

1. HP-199-1.4-0.8 Thermoelectric Cooler (by TE Technology, Inc.)
2. PS-24-12.5 Power Supply (by TE Technology, Inc.)
3. TC-48-20 Controller (by TE Technology, Inc.)
4. MP-3193 Thermistor (by TE Technology, Inc.)
5. GDM1602K LCD Display (by Xiamen Ocular, Ltd.)
6. Hydro Series H75 Liquid CPU Cooler (by Corsair Components)
7. GeminII M4 (by Cooler Masters)
8. Grounding Screws (by Fastenal®)
9. Fasteners (by PennEngineering®)
10. General Socket Cap Screw Sizing Chart

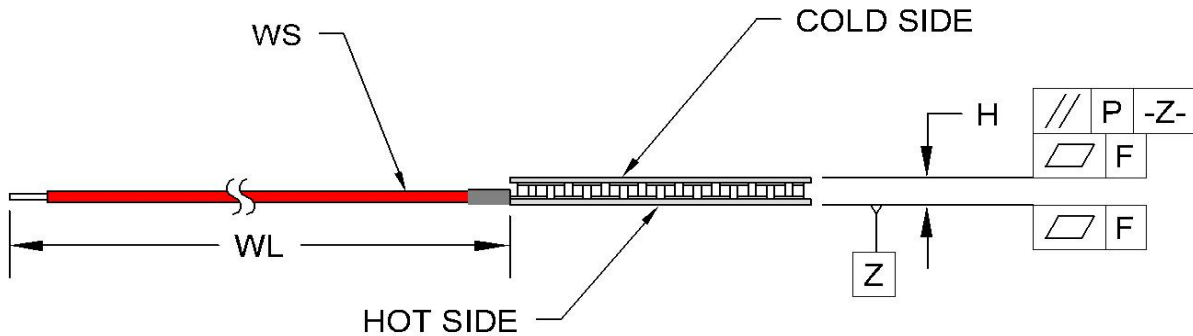
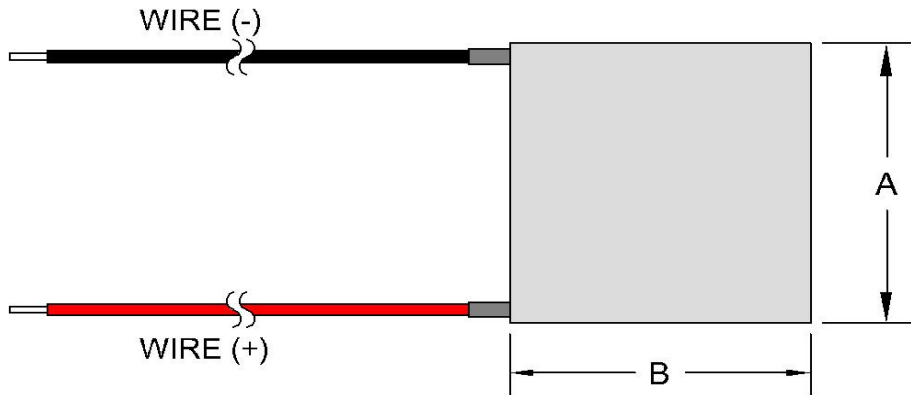
**HP-199-1.4-0.8
Thermoelectric Module
(Peltier Module)
Specifications**

	Material Specifications (27 °C hot side temperature)	Material Specifications (50 °C hot side temperature)
Vmax (V)	24.6	27.3
I _{max} (A)	11.3	11.3
Q _{max} (W)	172.0	188.7
DT _{max} (°C)	69	78
Operation/storage temperature	-40 °C to +80 °C	

Module *material* specifications are nominal values based on the hot-side temperature indicated. Thermoelectric material parameter tolerance is +/-10%.

In no case should the module temperature be allowed to exceed its maximum operation/storage temperature.

Please review all product and technical information, *Thermoelectric Module Mounting Procedure*, parameter definitions, FAQ's, and ordering information posted on our website before purchasing or using this product.



Width, A (mm)	40 +0.5/-0.2
Width, B (mm)	40 +0.5/-0.2
Height, H (mm)	3.2 ±0.05
Flatness, F (mm)	0.02
Parallelism, P (mm)	0.03
Wire Size, WS (mm ²)	0.5
Wire Length, WL (mm)	120

Optional Features and Notes:

Add "P" to part number for sealing module with epoxy potting.

Performance graphs include thermal resistance of substrates.

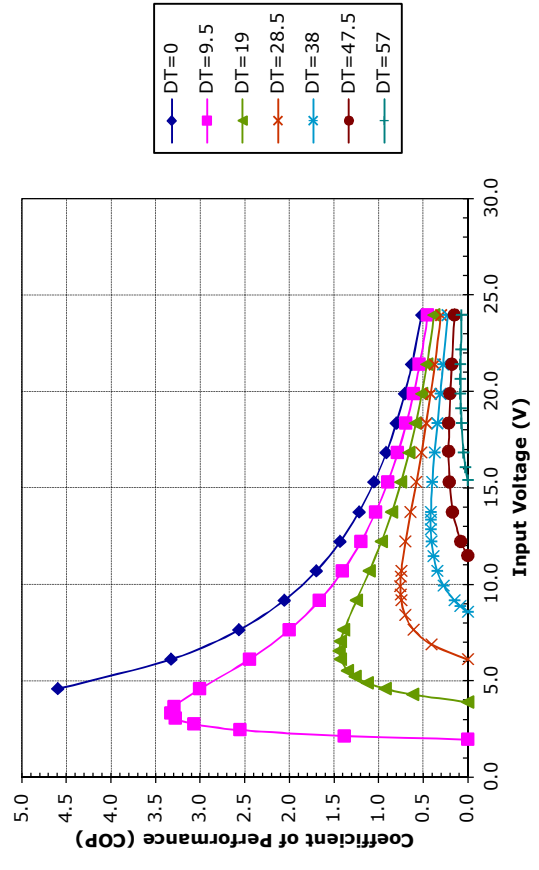
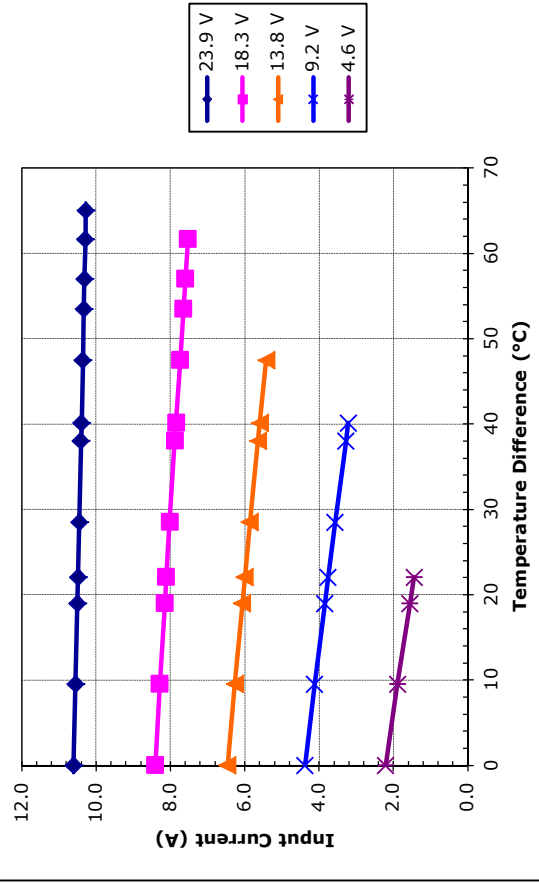
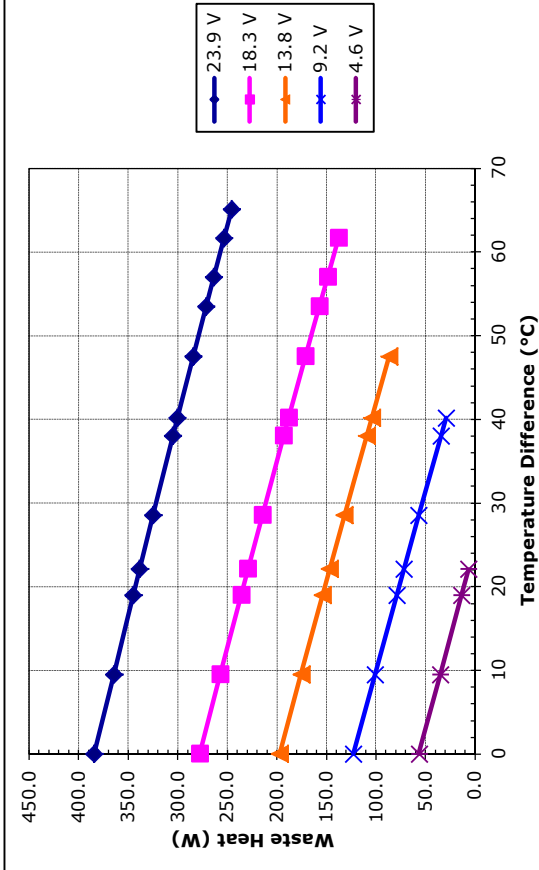
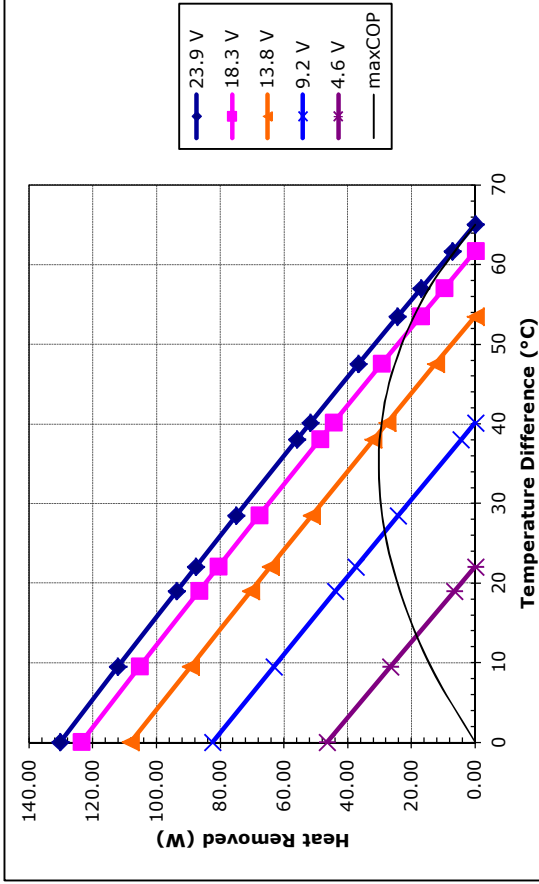
RoHS Compliant
Directive 202/95/EC



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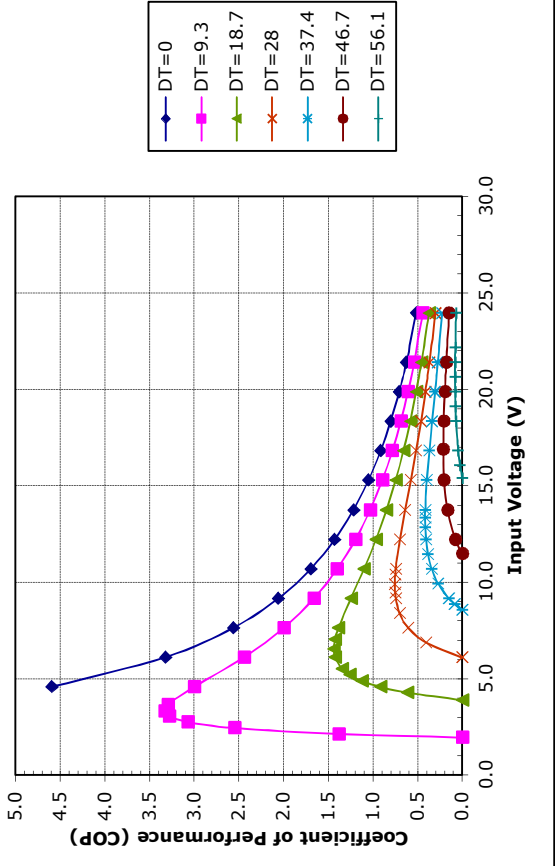
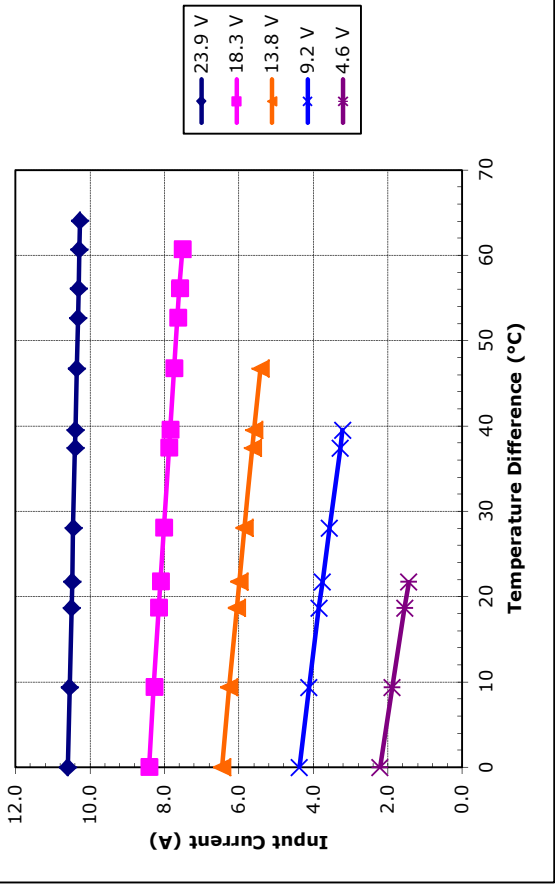
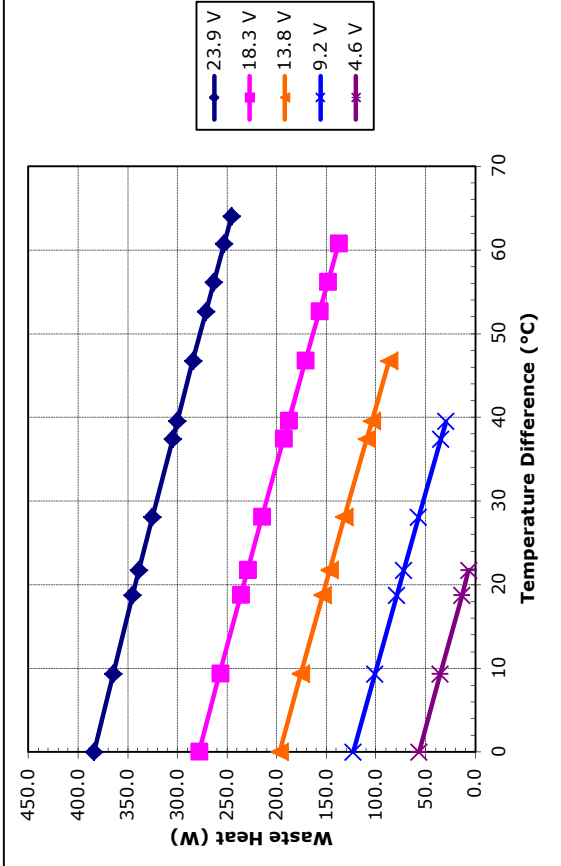
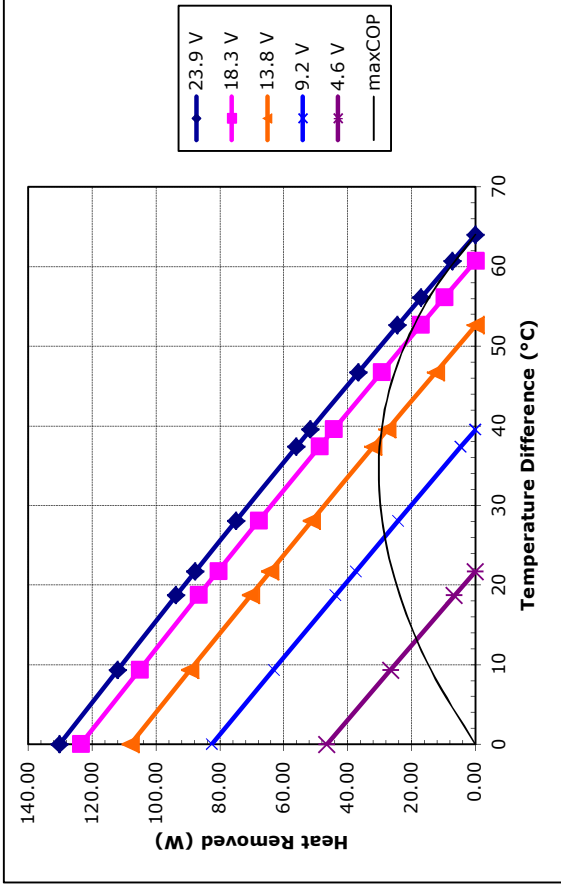
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Unpotted HP-199-1.4-0.8 at a hot-side temperature of 30 °C



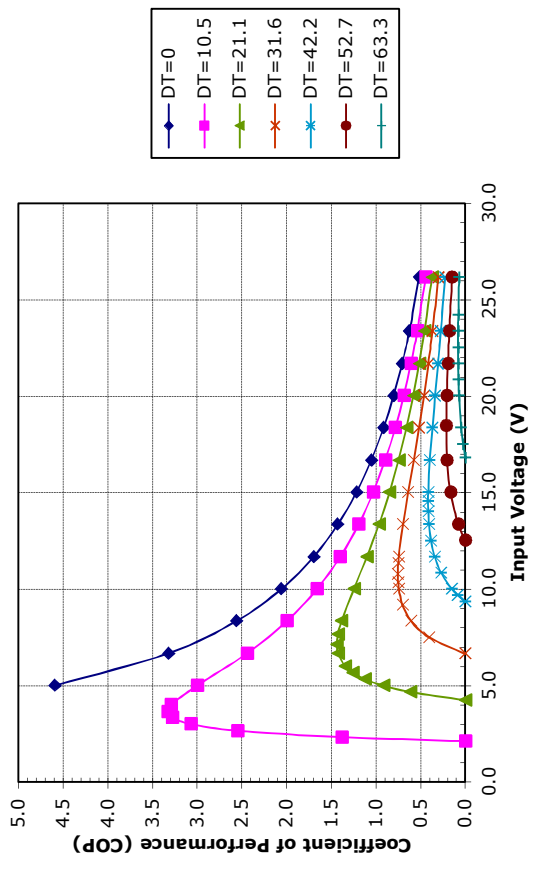
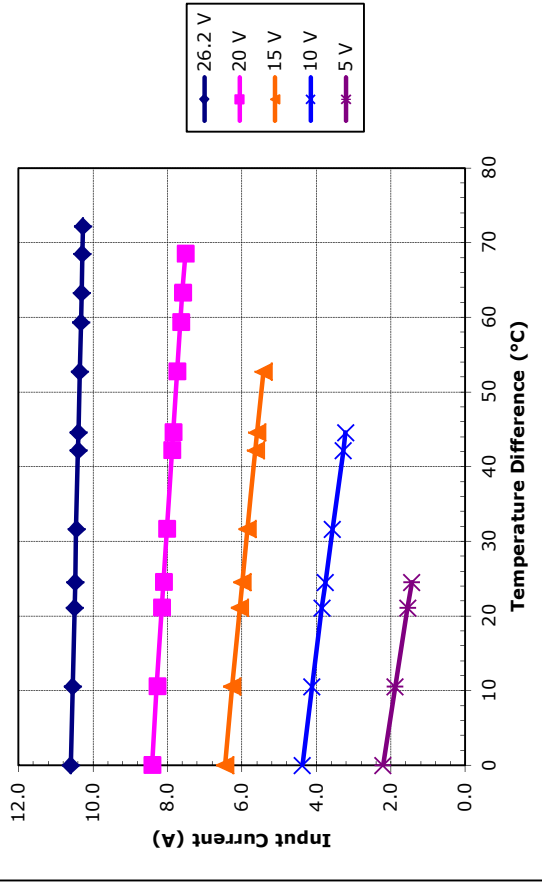
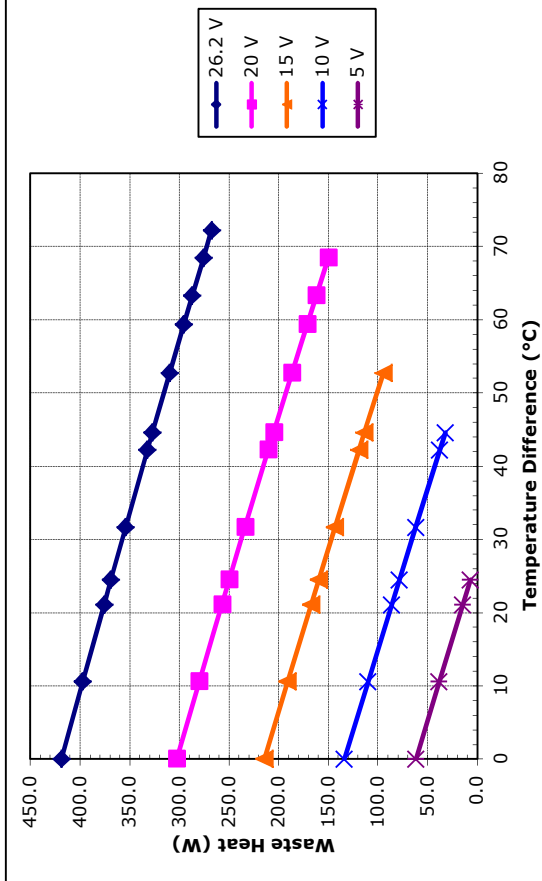
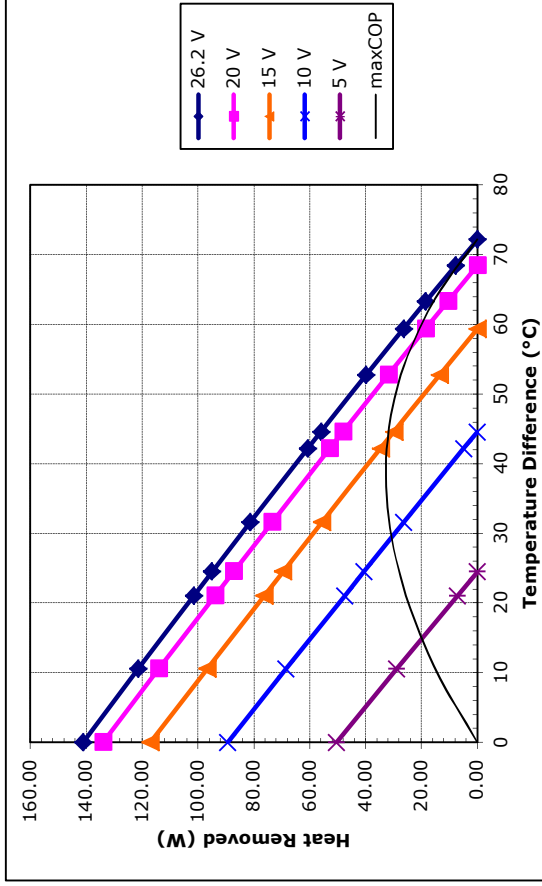
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Potted HP-199-1.4-0.8 at a hot-side temperature of 30 °C



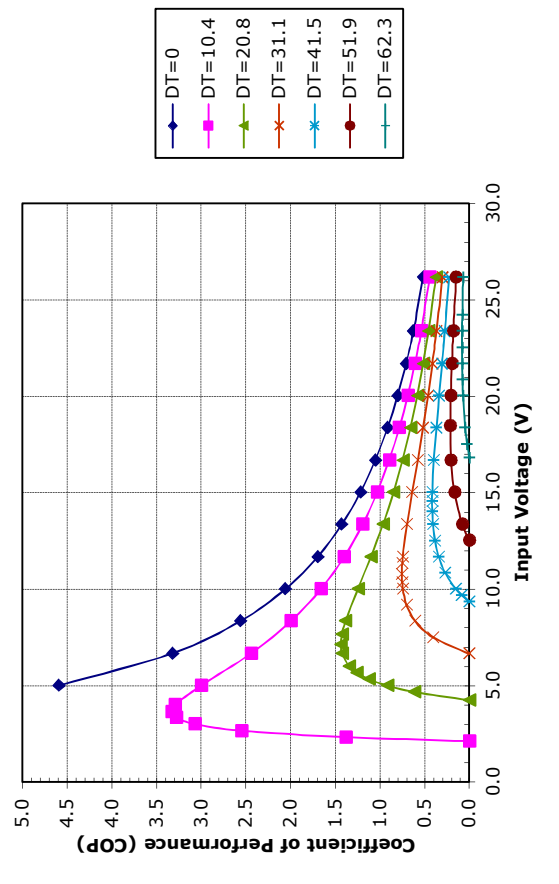
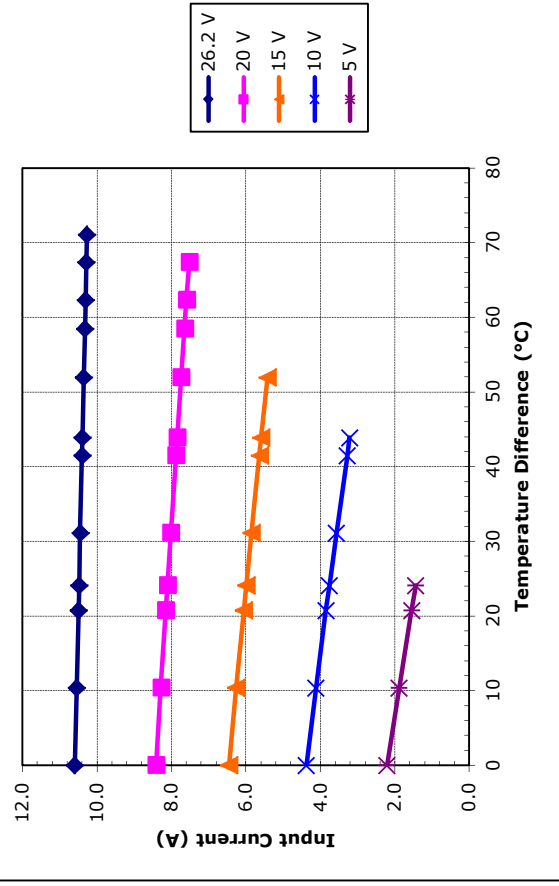
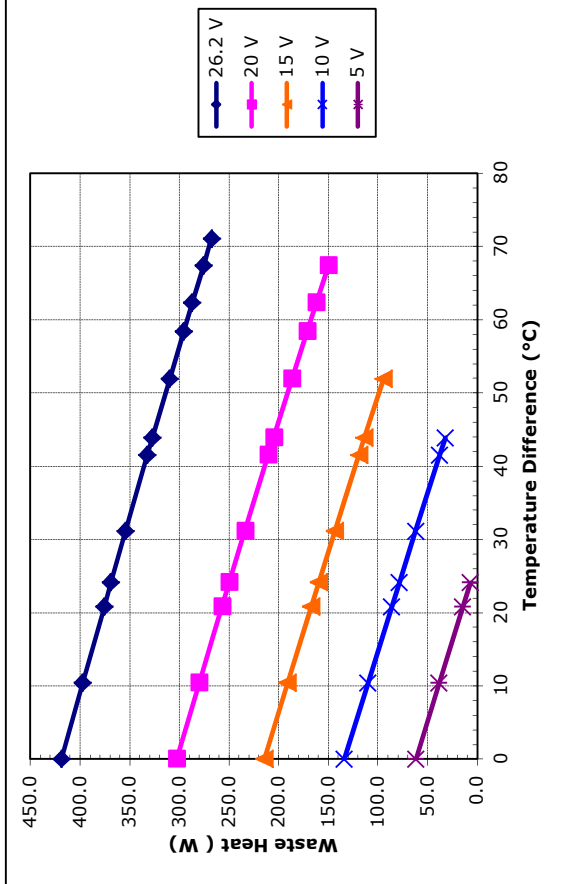
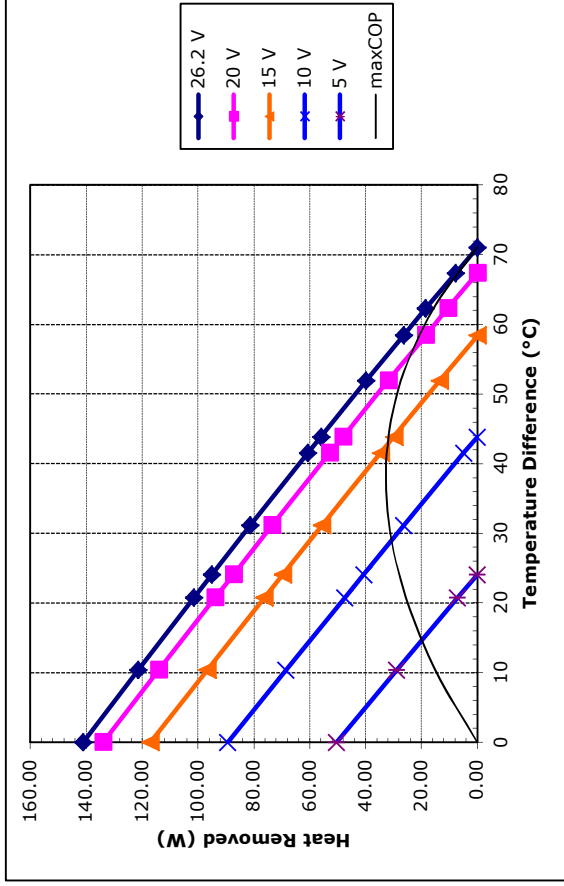
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Unpotted HP-199-1.4-0.8 at a hot-side temperature of 50 °C



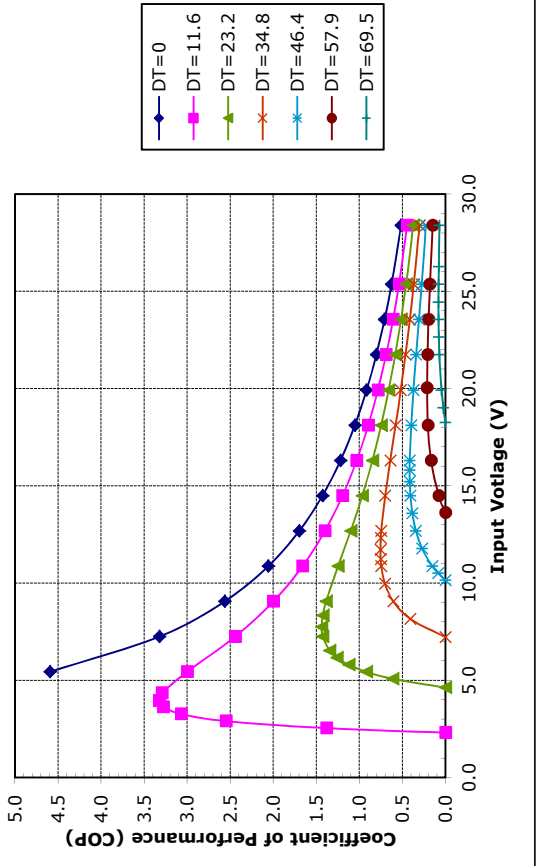
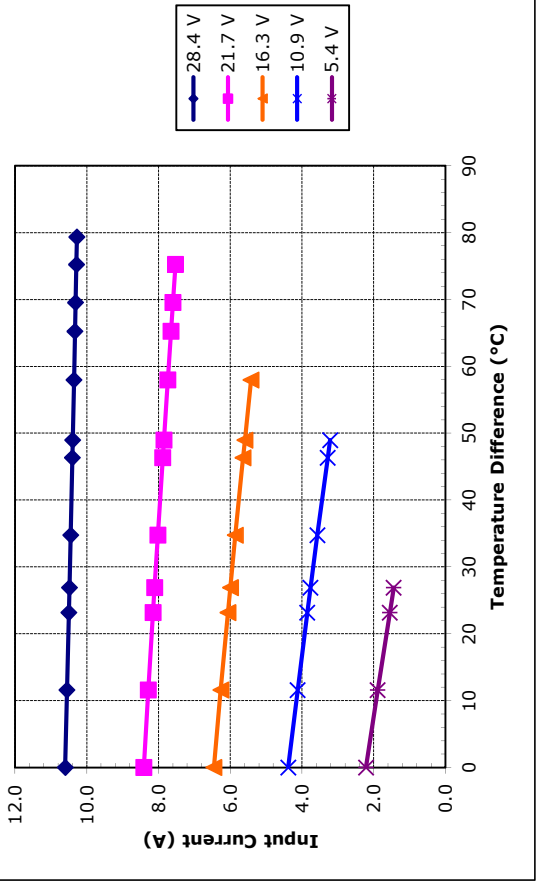
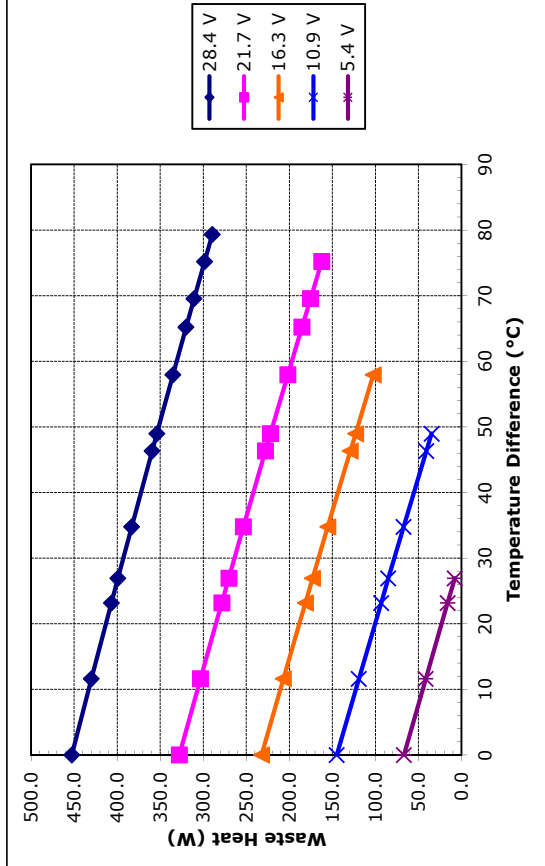
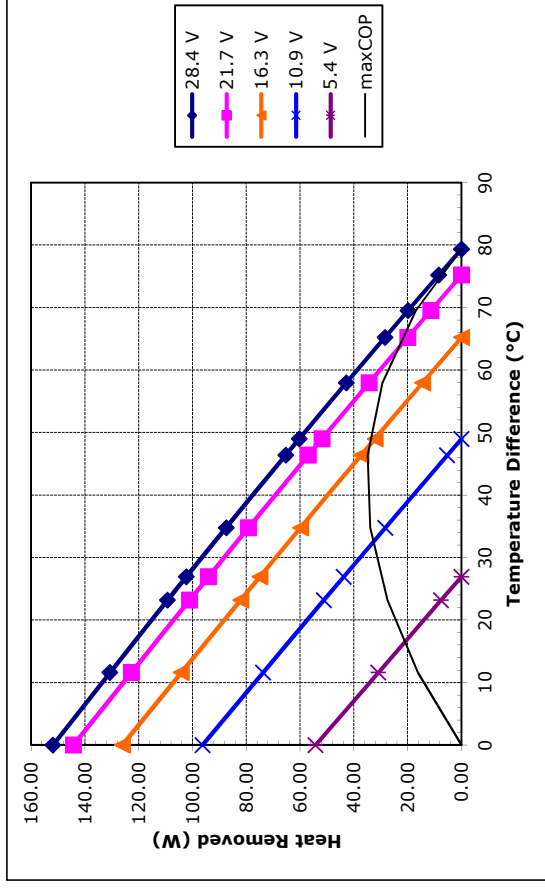
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Potted HP-199-1.4-0.8 at a hot-side temperature of 50 °C



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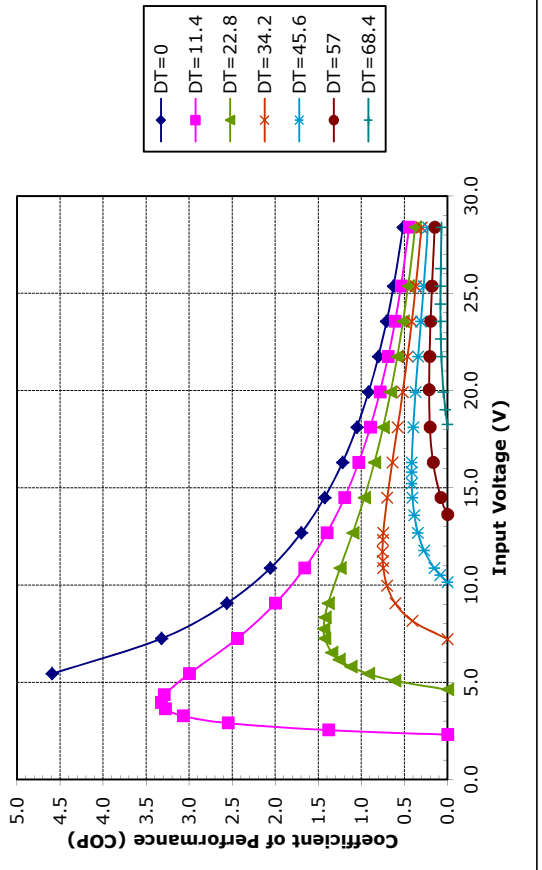
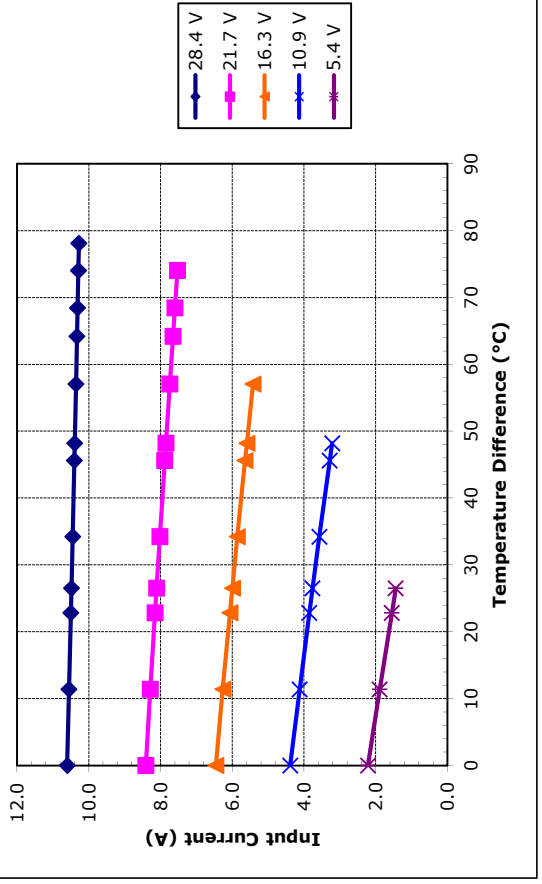
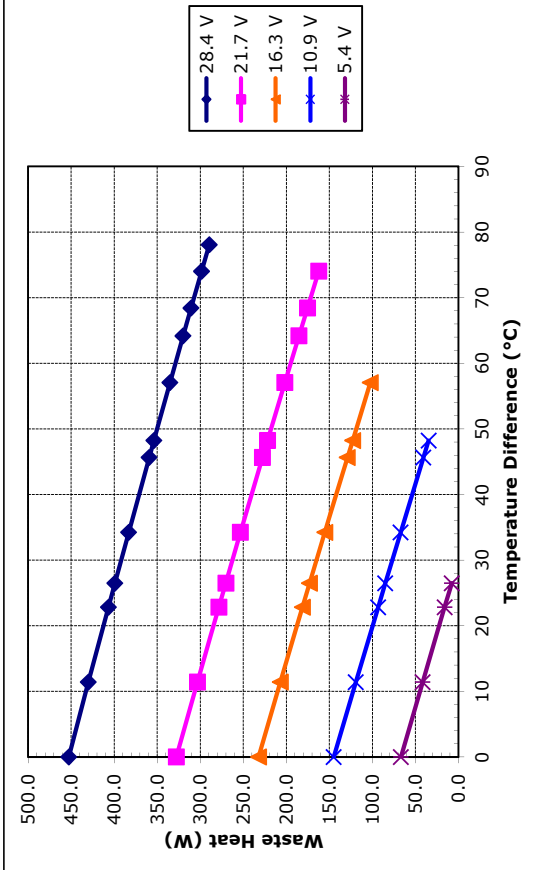
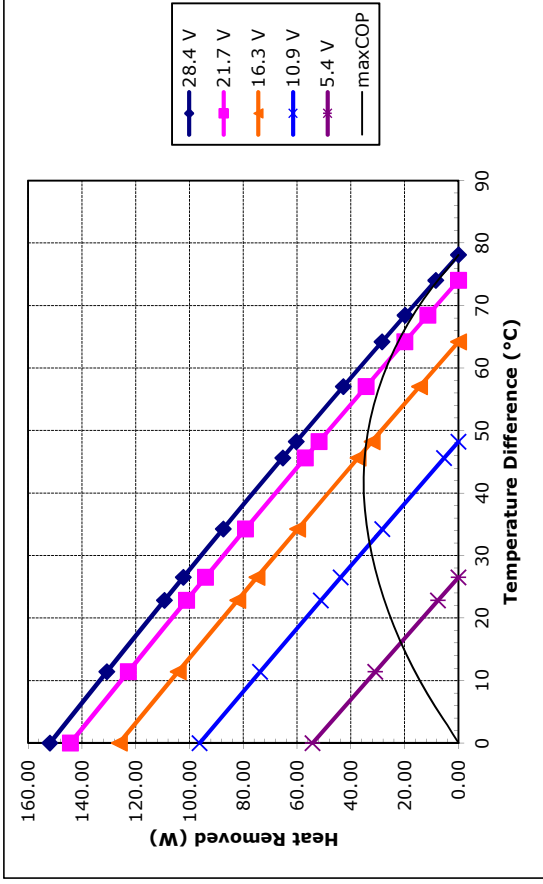
Unpotted HP-199-1.4-0.8 at a hot-side temperature of 70 °C

Note: All specifications subject to change without notice.

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Potted HP-199-1.4-0.8 at a hot-side temperature of 70 °C



■ Features :

- Universal AC input / Full range
- Built-in active PFC function, PF>0.95
- Protections: Short circuit / Overload / Over voltage / Over temperature
- Forced air cooling by built-in DC Fan
- Built-in fan speed control
- Fixed switching frequency at 100KHz

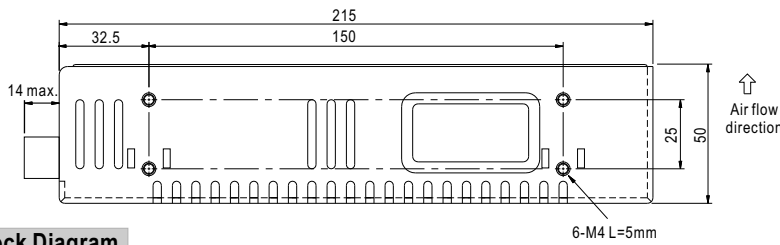
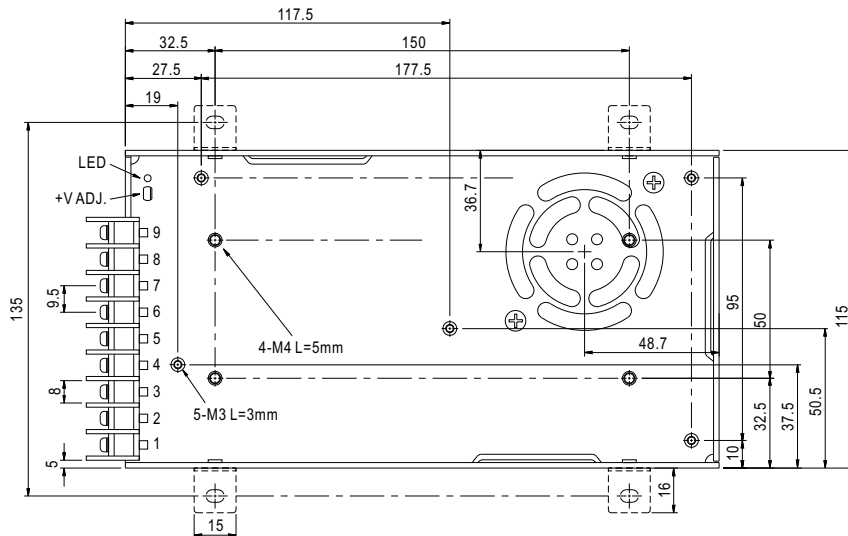


SPECIFICATION

MODEL	SP-320-3.3	SP-320-5	SP-320-7.5	SP-320-12	SP-320-13.5	SP-320-15	SP-320-24	SP-320-27	SP-320-36	SP-320-48		
OUTPUT	DC VOLTAGE	3.3V	5V	7.5V	12V	13.5V	15V	24V	27V	36V	48V	
	RATED CURRENT	55A	55A	40A	25A	22A	20A	13A	11.7A	8.8A	6.7A	
	CURRENT RANGE	0 ~ 60A	0 ~ 55A	0 ~ 40A	0 ~ 25A	0 ~ 22A	0 ~ 20A	0 ~ 13A	0 ~ 11.7A	0 ~ 8.8A	0 ~ 6.7A	
	RATED POWER	181.5W	275W	300W	300W	297W	300W	312W	315.9W	316.8W	321.6W	
	RIPPLE & NOISE (max.) Note.2	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p	200mVp-p	220mVp-p	240mVp-p	
	VOLTAGE ADJ. RANGE	3.14 ~ 3.63V	4.5 ~ 5.5V	6 ~ 9V	10 ~ 13.2V	12 ~ 15V	13.5 ~ 18V	20 ~ 26.4V	26 ~ 31.5V	32.4 ~ 39.6V	41 ~ 56V	
	VOLTAGE TOLERANCE Note.3	±1.0%	±2.0%	±2.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%	
	LINE REGULATION	±0.5%	±0.5%	±0.5%	±0.3%	±0.3%	±0.3%	±0.2%	±0.2%	±0.2%	±0.2%	
	LOAD REGULATION	±1.5%	±1.0%	±1.0%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	
	SETUP, RISE TIME	800ms, 50ms/230VAC 2500ms, 50ms/115VAC at full load										
HOLD UP TIME (Typ.)	16ms/230VAC 16ms/115VAC at full load											
INPUT	VOLTAGE RANGE Note.5	88 ~ 264VAC		124 ~ 370VDC								
	FREQUENCY RANGE	47 ~ 63Hz										
	POWER FACTOR (Typ.)	PF>0.95/230VAC		PF>0.98/115VAC at full load								
	EFFICIENCY (Typ.)	74%	79%	83%	86%	86%	86%	87%	88%	87%	89%	
	AC CURRENT (Typ.)	115VAC	2.5A	5A								
		230VAC	1.5A	2.5A								
	INRUSH CURRENT (Typ.)	20A/115VAC		40A/230VAC								
LEAKAGE CURRENT	<1mA / 240VAC											
PROTECTION	OVERLOAD	105 ~ 135% rated output power Protection type : Hiccup mode, recovers automatically after fault condition is removed										
	OVER VOLTAGE	3.8 ~ 4.5V	5.75 ~ 6.75V	9.4 ~ 10.9V	13.8 ~ 16.2V	15.5 ~ 18.2V	18 ~ 21V	27.6 ~ 32.4V	33.7 ~ 39.2V	45 ~ 52.5V	57.6 ~ 67.2V	
	OVER TEMPERATURE	80°C ±5°C (70°C ±5°C 3.3V,5V only) (TSW1 : detect on heatsink of power transistor) Protection type : Shut down o/p voltage, recovers automatically after temperature goes down										
ENVIRONMENT	WORKING TEMP.	-20 ~ +65°C (Refer to output load derating curve)										
	WORKING HUMIDITY	20 ~ 90% RH non-condensing										
	STORAGE TEMP., HUMIDITY	-40 ~ +85°C, 10 ~ 95% RH										
	TEMP. COEFFICIENT	±0.03%/°C (0 ~ 50°C)										
SAFETY & EMC (Note 4)	VIBRATION	10 ~ 500Hz, 2G 10min./1cycle, 60min. each along X, Y, Z axes										
	SAFETY STANDARDS	UL60950-1, TUV EN60950-1, CCC GB4943 approved										
	WITHSTAND VOLTAGE	I/P-O/P:3KVAC I/P-FG:1.5KVAC O/P-FG:0.5KVAC										
	ISOLATION RESISTANCE	I/P-O/P, I/P-FG, O/P-FG:100M Ohms / 500VDC / 25°C / 70% RH										
	EMI CONDUCTION & RADIATION	Compliance to EN55022 (CISPR22) Class B										
OTHERS	HARMONIC CURRENT	Compliance to EN61000-3-2, -3										
	EMS IMMUNITY	Compliance to EN61000-4-2,3,4,5,6,8,11; ENV50204, EN55024, light industry level, criteria A										
NOTE	MTBF	207K hrs min. MIL-HDBK-217F (25°C)										
	DIMENSION	215*115*50mm (L*W*H)										
	PACKING	1.1Kg; 12pcs/14Kg/0.92CUFT										
<p>1. All parameters NOT specially mentioned are measured at 230VAC input, rated load and 25°C of ambient temperature. 2. Ripple & noise are measured at 20MHz of bandwidth by using a 12" twisted pair-wire terminated with a 0.1uf & 47uf parallel capacitor. 3. Tolerance : includes set up tolerance, line regulation and load regulation. 4. The power supply is considered a component which will be installed into a final equipment. The final equipment must be re-confirmed that it still meets EMC directives. For guidance on how to perform these EMC tests, please refer to "EMI testing of component power supplies." (as available on http://www.meanwell.com) 5. Derating may be needed under low input voltages. Please check the derating curve for more details.</p>												

Mechanical Specification

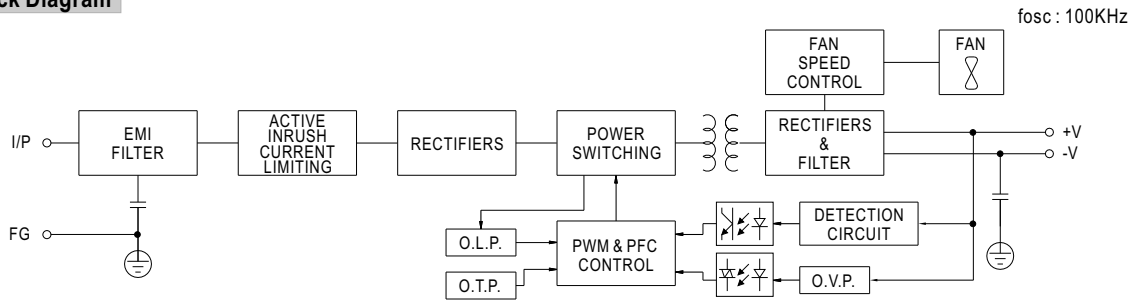
Case No. 912G Unit:mm



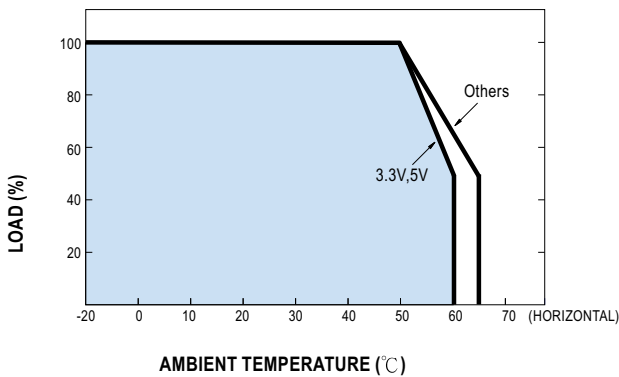
Terminal Pin No. Assignment :

Pin No.	Assignment	Pin No.	Assignment
1	AC/L	4-6	DC OUTPUT -V
2	AC/N	7-9	DC OUTPUT +V
3	FG \perp		

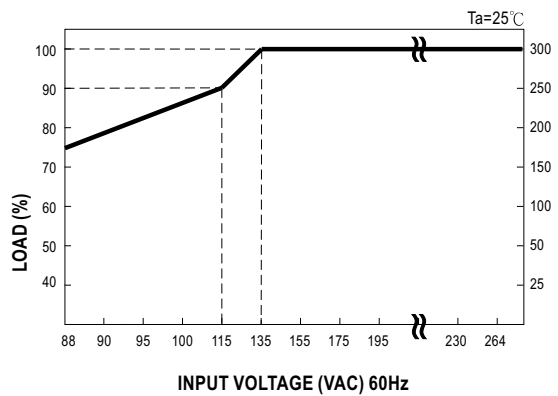
Block Diagram



Derating Curve



Static Characteristics



**Instruction Manual
for
Model TC-48-20
and
Model TC-48-20 OEM
Thermoelectric Cooler
Temperature Controller**

**May 1, 2012
Drawing #4746 Rev. D**



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General Safety Warnings



This manual is available in English only. It must be read and followed carefully before installation and operation. All warnings in this Operation Manual apply to both the TC-48-20 and TC-48-20 OEM versions of the controller. Where “TC-48-20” is referenced, it is used generically and interchangeably for both the TC-48-20 and the TC-48-20 OEM versions of the controller, except where otherwise specifically noted.



THE LATEST REVISION OF THIS MANUAL IS AVAILABLE AT www.tetech.com. Verify that you are using the latest revision available.



Do not use in an explosive or potentially explosive environment.



The TC-48-20 should not be used as a toy, or serious injury could result. The TC-48-20 should only be used for its intended purpose of providing temperature control of TE Technology’s thermoelectric devices only. The controller is intended for light industrial, laboratory, or similar use. It is not for household use or medical use.



Do not use if the controller has been damaged.



Only qualified technicians should install and operate this controller with the appropriate personal protective equipment.



Do not use the TC-48-20 to control capacitive or inductive loads or the controller could be damaged and/or overheat. Examples of capacitive or inductive loads include but are not limited to: motors, fans, filters, and solenoids.



Do not allow the electrical connections or components on the printed circuit board, including those on the reverse side of the JP3, JP4 and JP5 connectors, to touch any electrically conductive surfaces.



Do not operate in an environment where the controller could come in contact with condensation, water, metal shavings, dirt or other contaminants, or electrically conductive materials.



Use ESD (Electro Static Discharge) protection when installing the controller or coming in contact with electrical connections or components on the controller.



Do not touch any of the electrical connections or components of the TC-48-20 while the controller is energized. Doing so can disrupt the function of the controller.



The printed circuit board underneath JP4 and exposed components on the printed circuit board could exceed 70 °C under normal operation. Use caution! Protect against accidental contact with hot surfaces.



Improper tuning of this temperature controller can lead to overheating of the load (e.g. cooling assembly, heater, etcetera) and other related equipment.



Use protection devices to prevent hazardous conditions and/or damage to equipment.



Each power input that is used must be fused separately. Alternately, a power supply with integral over current protection can be used if it is appropriately sized for protecting the controller/TE device.



JP4 Pin 1 (+ power in) and JP4 Pin 3 (+ load output) are connected to each other inside the controller. When JP4 Pin 1 is energized a voltage will be present on JP4 Pin 3, even if the output of the controller is off.



The TC-48-20 OEM is intended to be used with, or incorporated into, other machinery made by TE Technology, Inc. and must not be put into service until the relevant machinery into which it is to be incorporated into has been declared in conformity with the essential requirements of the Machinery Directive 2006/42/EC.

For more information regarding protection devices read TE Technology's Thermoelectric Cooling Assembly (TCA) Instruction manual which is available for download from TE Technology's website at www.tetech.com. The terms and provisions relating to protection devices as provided in the TCA Instruction manual are hereby incorporated by reference. A copy of the TCA Instruction manual can also be sent via regular mail upon request.

TE Technology, Inc. does not make any warranty, expressed or implied, that the use or operation of the equipment will be functional or effective if the equipment is not installed and used in accordance with this manual.

TE Technology, Inc. shall not be liable, and Purchaser shall defend, hold harmless, and indemnify TE Technology, Inc. from and against, any losses, costs, expenses (including reasonable attorneys' fees), injuries, liabilities or damages of any kind or nature whatsoever, arising out of the use or inability to use this TE Technology, Inc. product, from the omission or failure to use protection devices, or from failure to comply with this manual. This provision is in addition to any other indemnification provisions which are a part of the Purchase Order or contract with Purchaser.

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Features



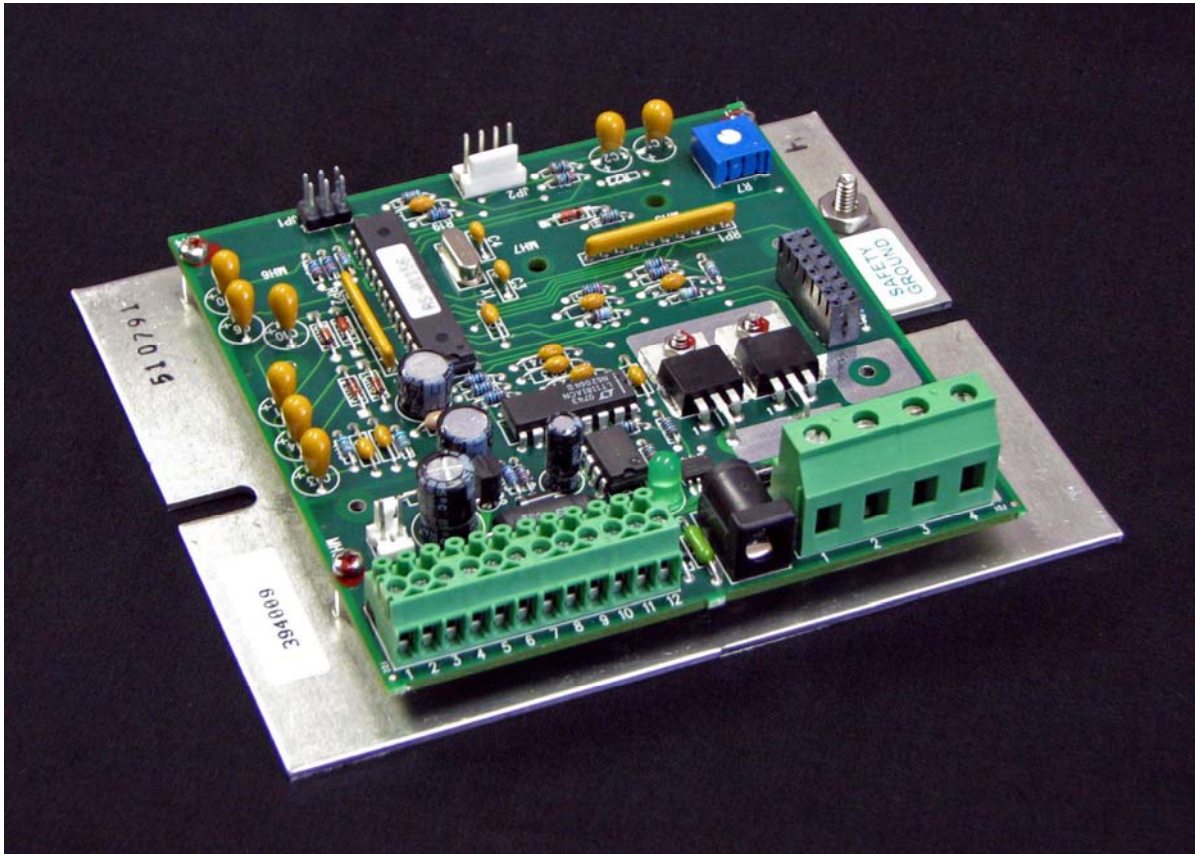
TC-48-20 Controller

The TC-48-20 is thermoelectric temperature controller capable of controlling up to 50 volts and 20 amps. Housed in a die-cast aluminum box, it incorporates a keypad and a liquid-crystal display capable of displaying two lines of text, each up to 16 characters long. The display allows the user to monitor the sensor temperature, output level, and menu settings. The integrated keypad accesses an easy-to-use menu system, allowing the user to adjust all of the basic controller parameters such as the set temperature, tuning parameters, and alarm parameters.

The controller can also be connected to a computer via RS232 port for more advanced program control, data graphing, and data logging. All of the controller parameters, including some of the advanced parameters not adjustable through the onboard menu, can be adjusted via this software. (The RS-232 cable is optional and can be purchased separately; the software is included.)

By choosing the appropriate power supply(s), the controller can control loads from 0 to <50 VDC via pulse-width modulation with the onboard power transistors. The turn-on and turn-off transition times for these transistors have been adjusted to reduce electro-magnetic interference when controlling high current levels. However, if a true linear-output control system is desired, the TC-48-20 can be used as the control head for controlling high-power, linear-output supplies. Some of these linear output supplies are available as basic switching power supplies, allowing the user to create a relatively low cost linear control system which generates much less waste heat when compared to a typical linear system. The TC-48-20 can also be configured to control DC heaters.

The TC-48-20 controller can be easily configured through its built in keypad. However, it can also interface with a computer through its serial port using the included software. The software provides all of the same configuration options that are available through the keypad plus additional programming features and the ability to log data to a computer. The command set for the controller is also provided to allow the creation of custom software applications with National Instruments LabVIEW, for example.



TC-48-20 OEM Controller

The TC-48-20 OEM is also available. This is a basic version of the controller for Original Equipment Manufacturers (OEM's). It is intended to be used in locations where the controller can be protected by a secondary enclosure and where the display, keypad, and box cover are not needed. The TC-48-20 OEM controller is the basic control circuit from the TC-48-20 mounted on an aluminum plate. One MP-3193 thermistor, software and operation manual on CD are included with each controller. The MP-3023 RS-232 cable is not included, but it can be ordered separately.

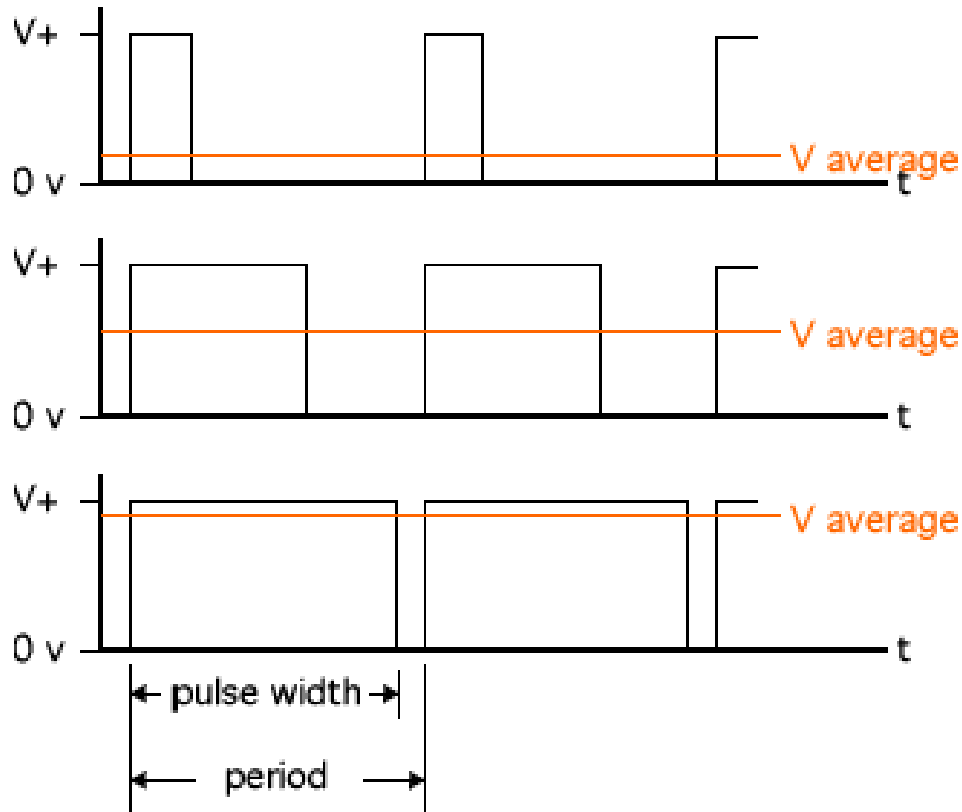
The TC-48-20 OEM uses the same main circuit board found in the TC-48-20. The connector numbers and wiring are the same for both versions of the controller. The Schematics, Hookup Diagrams, and Wiring Connections presented in this manual are the same for both controllers. However, only the TC-48-20 version of the controller is depicted for clarity.

Main Features

- Single or dual power supply configurations allow a wide range of output voltages:
 - Single power supply configuration:
 - ≥9 VDC, <50 VDC input, powering both controller and TE device
 - Dual power supply configuration:
 - ≥9 VDC, <50 VDC at 150 mA minimum for controller circuitry
 - ≥0 VDC, <50 VDC for TE device
- Maximum output current: 20 A combined TE device and alarm current (Note: controller does not have current limiting capability or internal fuse protection)
- Cool-only or heat-only control modes, menu selectable
- Temperature control range: -20 °C to +100 °C using the MP-3193 thermistor supplied with the controller, or -20 °C to +85 °C using a thermistor equivalent to 10 k-ohm, curve "B" from YSI Temperature, Inc.
- Optional secondary thermistor input for sensing alarm conditions
- Two available alarm outputs, capable of sinking up to 1 A each, for triggering alarms based on the primary (control) sensor and/or secondary sensor
- Best-case control stability ±0.1 °C (when controlling a cold plate)
- Proportional (P) bandwidth adjustment: 0.5 °C to 100.0 °C
- Integral gain (I) adjustment: 0.00 to 10.00 repeats per minute
- Derivative gain (D) adjustment: 0.00 to 10.00 cycles per minute
- Output: square wave, 337 Hz, pulse-width modulated, with soft start
- Analog proportional output signal for controlling programmable linear power supplies
- Operating temperature range (non-condensing, total combined alarm and load current):
 - Minimum: 0 °C
 - Maximum: 48 °C horizontal orientation, 20 A output; 55 °C vertical orientation, 20 A output; 53 °C horizontal orientation, 17 A output; 59 °C vertical orientation, 17 A output.
- Computer programmable via RS 232 communication; includes software (An optional RS-232 cable, part number MP-3023, is required)
- RoHS compliant

Pulse-width modulated power output

The TC-48-20 controller regulates the output power to the TE device using a method called pulse-width modulation (PWM). With PWM, power to the TE device is switched quickly "ON" and "OFF" at a constant frequency. This creates a square wave "pulse" of power with a constant time period. The "ON" time, or pulse width, can be varied to create an average output voltage (V_{average}) that is required by the TE device to maintain the set temperature.



The important advantage to PWM control is that it does not cause the extreme temperature excursions that are experienced with a thermostatic control system. This helps to extend the life and reliability of the TE device. At the same time, PWM control does not generate a large amount of waste heat as compared with most linear control systems, so large heat sinks are not required with the PWM temperature controller.

Linear control output

The controller also provides an analog proportional output signal. This cannot be used for powering TE devices directly, but it could be used for a variety of purposes including controlling programmable power supplies. For example, if the TE device were to require more than 20 A of current, or if true linear control were needed, the TE device could not be directly connected to the controller. However, the TE device could be connected to a higher current power supply that accepts an analog input, and the controller could then direct the power supply to apply its output proportional to the analog output from the controller. Because these power supplies usually have a linear output signal this method also reduces the electromagnetic noise that might otherwise come from a PWM type controller.

One such power supply that accepts an analog input is the RKW programmable series switching power supplies from Kepco (www.kepcopower.com). These power supplies accept a 0 to 5 volt input signal which causes the output voltage of the power supply to vary from 0 V to its full-scale voltage. These power supplies are available with full-scale voltages that range from 3.3 V to 48 V and they are available in 300, 600, and 1500 watt sizes. Because these are switching power supply there is again the added benefit of little waste heat as compared with most types of linear control systems. In addition, multiple power supplies can be operated in parallel to boost the total output power.

If you wish to limit the output voltage of the power supply to less than its full scale voltage you can adjust a controller parameter called the ANALOG OUTPUT MULTIPLIER. For example, assume you have chosen to use a Kepco RKW 24-65K model power supply. This is a 1500 watt power supply with a full-scale output of 24 V and 65 A. If you wish to limit the output voltage to approximately 20 V, you can set the analog multiplier to 0.83 (20V / 24V). This scales the analog output voltage to 4.15 V and thus limits the output voltage of the power supply accordingly. The ANALOG OUTPUT MULTIPLIER is scalable only by communicating with the controller via the software through the RS-232 interface. An RS-232 cable, part number MP-3023 or equivalent, is required to connect the controller to a computer. The factory default value for the ANALOG OUTPUT MULTIPLIER is 1.

Using alarm outputs for multi-speed fan control and other load control

The alarm outputs can be configured to operate a fan at two different speeds, which is useful for keeping fan noise to a minimum. For example, by using a second sensor to measure the ambient air temperature, ALARM 2 can be used to run the fan at high speed only when the ambient air temperature is high and increased cooling capacity is needed. Alternately, the second sensor can measure the heat sink temperature. If the heat sink temperature begins to rise because the ambient temperature is increasing or because the heat source is active, ALARM 2 is triggered to run the hot-side fan at full speed. An external resistor, placed in series with the fan, is required.

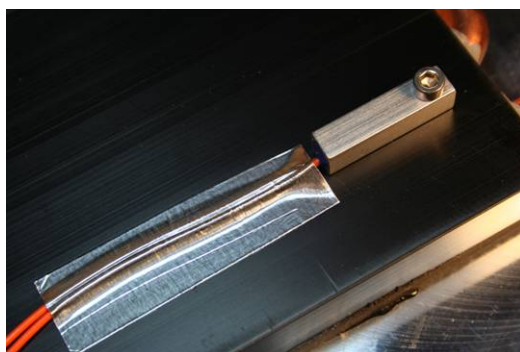
The alarms can also be configured to activate other loads such as pumps and resistive heaters. A fixed value resistor can be used in place of the second sensor, causing the controller to interpret the fixed resistance as a fixed temperature. Changing the alarm temperature above or below this fixed temperature will then cause the alarm, and consequently the load, to be activated or deactivated. The second sensor temperature display can also be turned off when the temperature data is not relevant.

Operating Instructions

1.0 Setup

- 1.1 Attach the thermistor at an appropriate temperature-control location. Locating the thermistor at the cold side of the TE device provides better control stability than locating it at the object, liquid, or air that is to be cooled/heated. However, in doing so, there will be a temperature difference between the TE device and the object, liquid, or air that is to be cooled/heated. The temperature set point can be adjusted to compensate for this temperature difference if necessary.

NOTE: When possible, it is recommended that at least 50 mm of the thermistor's wire be thermally connected to the cold side of the TE device as shown in the example below. This can be accomplished by placing aluminum tape over the thermistor wires and adhering the wires and tape to the cold side of the cooler, as shown below. If this is not done, the thermistor wires will be at a different temperature than the cold side and they will add or remove heat in the region of the thermistor, making the temperature reading **significantly less accurate** and thermal response time slower.



The wire leads of the thermistor can be lengthened if necessary. For longer lengths the use of twisted pair and/or shielded wire may be required to reduce noise.

In addition, the thermistor needs to have a good thermal connection to the temperature control location. When using the MP-3193, thermal grease should be applied to the interface of the thermistor and temperature-control location. The TP-1 thermal grease from TE Technology or other thermal grease can be used.

The TC-48-20 is supplied with the MP-3193 thermistor. Other thermistor styles directly compatible with the controller are available as options. See *“Thermistor Styles for TC-48-20”* for reference. In addition, the controller can be configured to use thermistors that have the same temperature-resistance curves as the 10 k-ohm, curve “B” thermistor from YSI Temperature, Inc. (Resistance versus Temperature curves are in Appendix A.)

If you want to use a thermistor that has a different resistance-temperature curve from the standard MP-3193 (See *“Temperature versus Resistance for MP-3193, MP-2444, and MP-2542 Thermistors”* for reference) or the 10 k-ohm thermistor, it can be done as long as the operating resistance range is within that of the standard thermistor. The thermistor must be a negative temperature coefficient device. Because the temperature controller is really measuring the thermistor's resistance and converting this to a temperature, the temperature controller will be fooled into thinking that the thermistor is at a different temperature than it really is, and the Set-Temperature will be skewed accordingly. A loss of resolution and control stability may occur as a result. The user assumes all risks associated with making any substitutions, and TE Technology assumes no liability whatsoever for the operation of the controller when a non-standard thermistor is used.

- 1.2 Connect the thermistor wire leads to JP5-1 and JP5-2. (See *“Controller Schematic”* and the *“Controller Hookup”* drawings for reference.)
- 1.3 A secondary thermistor can be connected to JP5-3 and JP5-4. The secondary thermistor can then used to monitor the hot side of the TE device for determining whether the TE device has exceeded its maximum

operating temperature. The controller can be configured to signal an alarm condition on either the control thermistor or the secondary thermistor or both.

- 1.4 The TC-48-20 can be used with either one or two separate DC power supplies, depending primarily on the nominal operating voltage of the TE device. If the maximum TE device input voltage is less than 9 V, then two power supplies must be used with the controller. If the TE device can use a voltage ≥ 9 V but < 50 V, then the controller can be used with either one or two power supplies.

The controller can also be set up to provide linear control output when used with a power supply whose output can be controlled with a 0 to 5 V signal. The power supply can then provide a power output proportional to the signal sent by the controller. This setup is also useful for situations in which the TE device requires more power than what the controller itself can directly handle. However, this setup will reduce the overall control stability. The voltage signal from the controller is actually obtained by filtering the PWM output, and this introduces a slight delay in the control response. Also, there will be a delay in the response of the power supply since it too must process the correct power output based on the sensed voltage input from the controller.



When using one power supply for powering the controller and the TE device together, the power supply input voltage is passed directly through the controller to the TE device during the “ON” pulse. The user should choose an input voltage that is required for the TE device and yet is also ≥ 9 V but < 50 V. The controller could be damaged if operated outside this voltage range.



When using two power supplies, the controller input power supply must be ≥ 9 V but < 50 V at 150 mA minimum. The power supply input voltage for the TE device can be ≥ 0 V but < 50 V.



The maximum allowable current through the controller is 20 A. The maximum allowable current draw for the TE device must therefore be less than 20 A depending on if and how much current is used to power alarm signals and the controller itself. The 20 A limit applies regardless of whether you are using one power supply or using two independent power supplies.



The controller does not have an internal fuse or circuitry to limit current. Therefore, an external fuse, appropriately sized for protecting the controller/TE device, should be connected between the power supply and the controller to prevent damage to the controller/TE device and to prevent injury to the user should an over-current condition occur. Alternately, a power supply with integral over current protection can be used if it is appropriately sized for protecting the controller/TE device.



When making a cooling system from a single TE device, the maximum operating voltage for that *system* is usually no more than 75% of the rated V_{max} of the TE module. The 75% rule is based on the TE module being thermally connected to a “good” heat sink; system modeling should be done to verify this rule is applicable though. If multiple TE modules are used in series or series-parallel combination, the V_{max} of the system will be approximately 75% of the rated V_{max} of each TE module multiplied by the number of modules in series. Applying a voltage greater than the system maximum will not necessarily damage the controller (unless voltage and/or current limits are exceeded), but the TE device could be damaged by overheating as a result.



Power supply and TE Device wire leads should be kept as short as possible to minimize electrical losses and reduce the likelihood of generating unwanted electromagnetic interference. Use wires of a sufficient gage appropriate to the amount of electrical energy each wire is to carry. Wire insulation and size must also be appropriate to the ambient temperature and/or temperature of objects in contact with the wire. Wire leads supplied by TE Technology are for prototyping purposes and should be reviewed for appropriateness in the final application. Wire length must not exceed one meter. However, see also warnings about wire length under section 1.6.



Use protection devices to prevent hazardous conditions and/or damage to the load (e.g. cooling assembly, heater, etcetera) and other related equipment. Protection devices must operate independently of the temperature controller circuitry. Protection devices should be placed at all points on the load and related equipment where a hazardous condition can be detected. These protection devices should de-energize the TC-48-20, the load, and, as necessary, other related secondary equipment. It is further recommended that such devices require the user to remove and correct the root cause of a fault before allowing the TC-48-20, the load, and related equipment to be re-energized. Protection devices should include, but are not limited to:

- Fuses to prevent against electrical overloads,
- Over/under temperature thermostats to prevent against hazardous and/or damaging temperatures,
- Liquid flow meters to prevent against damage due to loss of coolant flow

The TC-48-20 controller (in conjunction with the standard and optional sensors) can detect under-temperature and over-temperature conditions, and it can be configured to de-energize the load when such a condition is detected. However, hazards and/or risk of loss or damage to the load (e.g. cooling assembly, heater, etcetera), and/or secondary equipment could still occur if the temperature controller and/or sensors were to malfunction. Therefore, independent, redundant protection devices are recommended in addition to the safeguards provided by the temperature controller. For the purposes of this manual the temperature controller and sensors are not considered protection devices.



The controller does not have an internal fuse or circuitry to limit current. Therefore, an external fuse, appropriately rated for protecting the controller/TE device, should be connected between the power supply and the controller to prevent damage to the controller/TE device and to prevent injury to the user should an over-current condition occur. Alternately, a power supply with integral over current protection can be used if it is appropriately sized for protecting the controller/TE device.

1.4.1 One Power Supply Operation:



Make sure the power supply is **NOT** energized while making electrical connections to the controller.

- a) Connect the constant DC voltage power supply, ≥ 9 V but < 50 V to the controller:
 - Positive (+) power supply terminal to JP4-1
 - Negative (-) power supply terminal to JP4-2
- b) Do **NOT** connect the TE device to the controller at this time (unless you are certain the set point is within the allowable range of the TE device).
- c) See the “*Controller Hookup Diagram (One Power Supply Setup)*” for further details.

1.4.2 Two Power Supplies Operation:



Make sure the power supplies are **NOT** energized while making electrical connections to the controller.

- a) Connect the constant DC voltage power supply, ≥ 9 V and < 50 V, 150 mA minimum, to the controller (for powering the controller electronics):

Positive (+) power supply terminal to JP5-6

Negative (-) power supply terminal to JP5-5

OR

Connect to JP3 via the DC power plug, ≥ 9 V and ≤ 16 V, 150 mA minimum (inside-positive; outside-negative)



Do not connect power to JP3 and JP5 at the same time; otherwise the controller and/or power supplies might be damaged and a risk of fire might result.

- b) Connect the constant DC voltage power supply, ≥ 0 V but < 50 V, to the controller (for powering the TE device):

Positive (+) power supply terminal to JP4-1

Negative (-) power supply terminal to JP4-2

- c) Do **NOT** connect the TE device to the controller at this time (unless you are certain the set point is within the allowable range of the TE device).

- d) See the “*Controller Hookup Diagram (Two Power Supplies Setup-Option 1)*” or “*Controller Hookup Diagram (Two Power Supplies Setup-Option 2)*” for further details.

1.4.3 Linear Control Operation:



Make sure the power supplies are **NOT** energized while making electrical connections to the controller.

- a) Connect the constant DC voltage power supply, ≥ 9 V and < 50 V, 150 mA minimum, to the controller (for powering the controller electronics):

Positive (+) power supply terminal to JP5-6

Negative (-) power supply terminal to JP5-5

OR

Connect to JP3 via the DC power plug, ≥ 9 V and ≤ 16 V, (inside-positive; outside-negative)



Do not connect power to JP3 and JP5 at the same time; otherwise the controller and/or power supplies might be damaged and a risk of fire might result.

- b) Connect the remote voltage control points of the programmable power supply to the controller; consult the power supply manual for remote control setup:

Positive (+) remote control terminal to JP5-12

Negative (-) remote control terminal to JP5-5

NOTE: depending on the power supply remote control input requirements, an external voltage buffer might be required between the controller and the power supply.

- c) Do **NOT** connect the TE device to the power supply at this time (unless you are certain the set point is within the allowable range of the TE device).

- d) See the “*Linear Control Hookup Diagram*” for further details.

- 1.5 Turn on power to the power supply (which then powers the controller). When the controller is first turned on, it goes through an initialization sequence which shows the TE Technology website address and that the controller is indeed the TC-48-20. The display then switches to the primary screen.

Verify that the set point is set to a temperature that is within the allowable temperature range of the TE device and/or the application and that the controller is set to the appropriate cooling or heating mode.



The factory default is set to have output power to the TE device enabled when the controller is powered. This can only be turned off by using the software. Therefore, **DO NOT CONNECT THE TE DEVICE TO THE OUTPUT OF THE CONTROLLER UNTIL THE APPROPRIATE CONTROL TEMPERATURE AND HEATING/COOLING MODE HAVE BEEN SET.**

Set point adjustment and other parameter adjustments are described in the Section 2 below.

- 1.6 Turn off power to the controller and connect the TE device to the controller as follows:

COOLING MODE:

- a) Connect the positive (+) terminal of TE device to JP4-3
- b) Connect the negative (-) terminal of TE device to JP4-4
- c) Verify/set controller to “COOL” mode; see Section 2 below.

HEATING MODE:

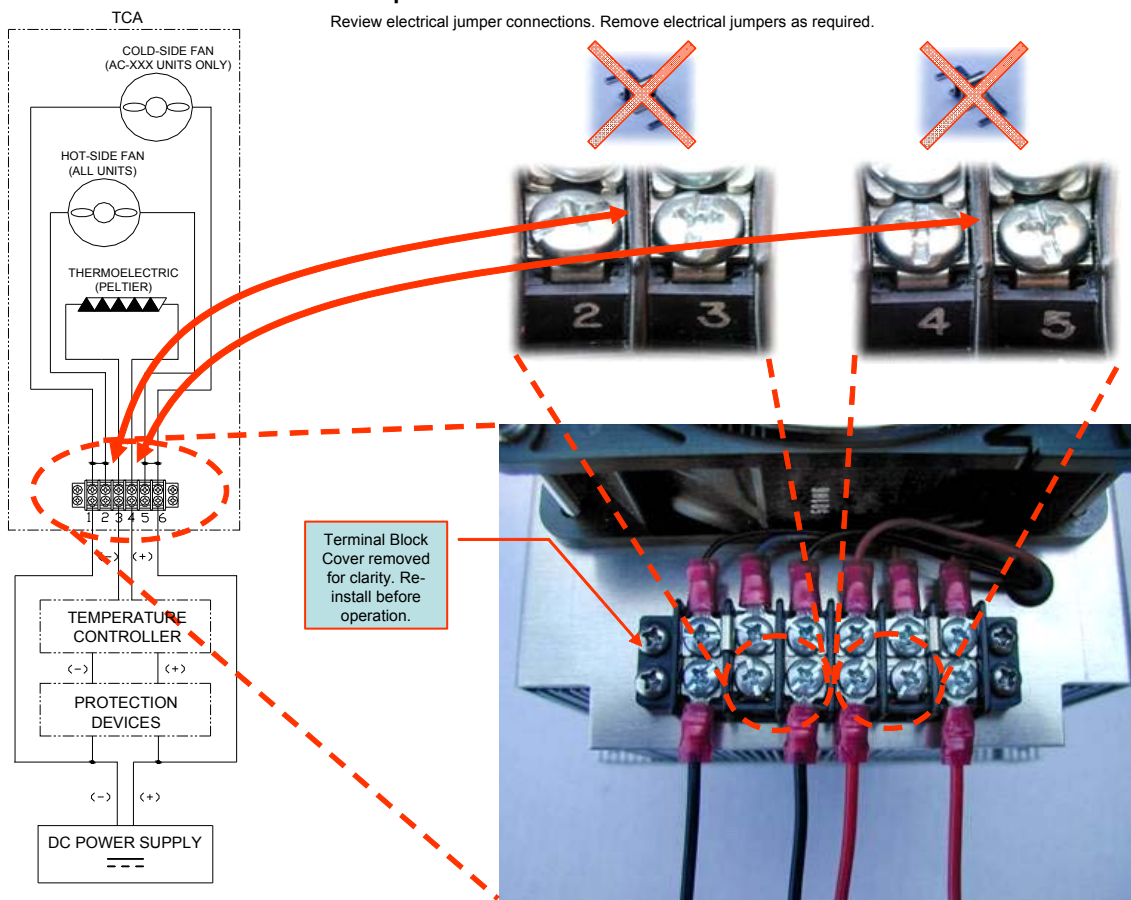
- a) Connect the negative (-) terminal of TE device to JP4-3
- b) Connect the positive (+) terminal of TE device to JP4-4
- c) Verify/set controller to “HEAT” mode; see Section 2 below.



TE Technology's standard thermoelectric cooling assemblies (TCA) usually have at least one fan on the heat sink. The standard configuration has the thermoelectric modules and fan(s) wired to a terminal block with jumpers across the terminals so that the fans and TE modules are connected electrically in parallel. However, this configuration is applicable only when applying power directly from the power supply. When using the TCA with the temperature controller, two jumpers **MUST** be removed so that the controller is controlling power only to the thermoelectric modules. There must be no electrical connection between the fans and the TE modules; fans must be connected directly to the power supply, not to the controller. *The controller will be damaged if this is not followed.* See the TCA manual for further details, but the picture below shows the basic setup.

Temperature Controller Connection

Review electrical jumper connections. Remove electrical jumpers as required.





The printed circuit board underneath the JP4 terminal block can reach a normal operating temperature of approximately 90 °C. The controller specifications are based on using wires connecting to JP4 to meet UL 1015 requirements and have a wire size of 2.02 mm² effective cross-sectional area, which is comprised of 41 strands of 0.254 mm diameter copper wire. The effective equivalent wire size is 14 AWG. The specifications are further based on a wire length of 410 mm between the power supply and the controller and a wire length of 920 mm between the controller and the TE device. Using wire with a smaller conductor cross section and/or shorter in length might cause abnormally high temperature to be present on the JP4 terminal block and wire. If smaller and/or shorter wire must be used, the amount of current the controller can safely accept might need to be decreased and/or the ambient temperature at which the controller can operate might need to be lowered.



The wires inserted into connector JP4 should have a strip length of 7 mm, be fully inserted into the connector, and the JP4 screw terminals should be tightened with a minimum torque of 0.5 N-m. The wires inserted into connector JP5 should have a strip length of 5 mm, be fully inserted into the connector, and the JP5 screw terminals should be tightened with a minimum torque of 0.25 N-m.

- 1.7 Turn on power supply to the controller and power supply to the TE device if applicable and adjust controller settings as necessary. Controller tuning is discussed in section 3. Remember, the factory default is set to have output power to the TE device enabled when the controller is powered. This can only be turned off by using the software. Therefore, you should also be prepared to de-energize the controller power in case there is an incorrectly set parameter which could cause a hazard.

NOTE: The factory default assumes a secondary thermistor is connected to the controller. **When not using a thermistor on the second sensor input the user will need to adjust the ALARM 2 FUNCTION to KEEP OUTPUT ON.** See section 2.3.10 and 2.3.11 for further details.



The keypad can reach a normal operating temperature of 70 °C.



When vertically mounted the terminal blocks should be positioned pointing upwards, with the direction of gravity parallel to the plane of the controller mounting surface. The maximum temperature specifications (vertical orientation) are based on this positioning. When mounted in an orientation between horizontal and vertical, the terminal blocks should be mounted in the upward most position (with the direction of gravity defined as point downward). These positions allow heat to rise upward, out of the opening of the box. Orientations differing from this could cause the controller to overheat.



Do not mount the controller to a surface which is exposed to a source of heat, such as from electronics, machinery, or solar radiation.



Do not cover the controller with any object or otherwise restrict natural convection airflow around the controller. Doing so could cause the controller to overheat.



Do not mount the controller to an insulating surface. Doing so could cause the controller to overheat.



Do not operate the controller in such a manner as to cause the surface temperature of the case or internal temperature to reach 70 °C. Otherwise the controller might be damaged and there might be a risk of fire as a result.



Do not allow the controller to be exposed to water (such as from dripping or leaking water lines or in which the controller is operating at or below the dew point temperature)



Do not allow metallic dust/shavings to enter into the controller box.

2.0 Display and Menu Options

Note: this section applies only to the TC-48-20. Setup, programming, and communications with the TC-48-20 OEM controller can only be accomplished by using the computer software with the optional MP-3023 RS232 cable. Changes made to the controller using the keypad are always stored in the EEPROM regardless of EEPROM WRITE ENABLE setting.

2.1 Initialization screen

1. Displays for 1.5 seconds: TE TECHNOLOGY
www.tetech.com
2. Displays for 1.5 seconds: TE TECHNOLOGY
TC-48-20 Rev. ****

2.2 Primary screen

TEMP = ###.# °C
OUT = ###% T2=##

The controller displays information about the following items:

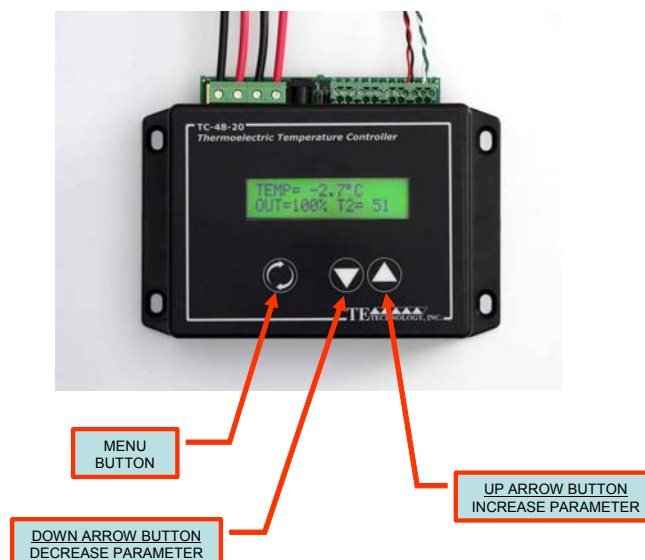
- 1) The temperature of the control sensor (TEMP) to a 0.1 °C resolution
- 2) The output level (duty cycle) to the thermoelectric modules (OUT)
- 3) The temperature of the second temperature sensor (T2)

- If the control sensor is either an open circuit or a short circuit (indicating that the sensor is not connected or has failed), the controller will display SENSOR 1 ERROR on the top line of the display instead of TEMP = ###.# °C. The output % will also be forced to 0% until the error is resolved.
- If a secondary sensor is not connected to the controller, T2= ### will not be displayed (unless it is forced to display by using the software menu setting).

If ALARM 1 or ALARM 2 has caused the power output to be turned off, the words ALARM and OUT= 0% will flash in alternating sequence in the place of the normal OUT=###% indicator. **When not using a thermistor on the second sensor input the user will need to adjust the ALARM 2 FUNCTION to KEEP OUTPUT ON.**

Parameters Menu

When at the Primary Screen (shown below), depressing the MENU key allows the user to scroll through and adjust the various controller parameters.



- Press the “MENU” button momentarily to select the parameter to be changed.
- Press the Up/Down arrow keys to adjust the parameter value.
- If there is more than one value for any given parameter the MENU key will scroll from the first value to the next value and then on to the next parameter.
- Holding the Up/Down arrow keys will cause the value to increment faster.
- The display will return to the primary screen after eight seconds if no keys are depressed.

2.3.1 SET TEMPERATURE

Values: -20.0 °C to +199.0 °C, or as defined by the limits set by CONTROL RANGE

Default value = 25.0 °C

Description: SET TEMPERATURE is the control temperature that the controller tries to maintain. Note that controller set point should not be set outside the range suitable for the temperature sensor. Consult TE Technology for customization if you need a thermistor that can provide a different control range. Also, be sure that the set point is also appropriate to the TE device.

2.3.2 PROPORTIONAL BW

Values: 0.5 °C to 100.0 °C

Default value = 5.0 °C

Description: The proportional bandwidth is the temperature span over which the power is proportioned from 100% to 0% power, centered about the temperature set point. That is, the controller output decreases to 50% power as it reaches the set point and to 0% as it reaches the end of the bandwidth range below the set point (when in the cooling mode).

For example, suppose the controller is being operated in the cooling mode, the set point is 10.0 °C, and the bandwidth is set to 5 °C. The controller power starts to proportionally decrease as the sensor temperature cools below 12.5°C. The power will be reduced to 50% when the sensor is at 10.0 °C. Finally, the power will be at 0% when the sensor is at 7.5°C. (Of course, this example presumes that the INTEGRAL GAIN and DERIVATIVE GAIN are set to 0 and that the cooler would have enough capacity to cool to 7.5 °C.)

If the bandwidth is set too narrow, the temperature will oscillate around the set point. If the bandwidth is too wide, the controller will be slow to respond or may never reach set point.

2.3.3 INTEGRAL GAIN

Values: 0.00 to 10.00 (repeats per minute)

Default value = 1.00

Description: This corrects for any offset between the set temperature and the sense temperature by averaging the offset with respect to time. This essentially shifts the proportional bandwidth.

For example, suppose the set temperature is 10.0 °C, the bandwidth is set to 5 °C, and the controller settled to a constant 11.2 °C (corresponding to 74% power). If the integral control is then set to 1 repeat per minute, the controller will increase the power to 98% in 1 minute, providing extra cooling to move the temperature closer to the set temperature. In this example, after one minute of operation the controller calculated that the difference between the desired set temperature and the actual temperature was +1.2 °C. With a bandwidth of 5 °C, the controller uses the INTEGRAL GAIN to add an additional 24% output per minute ($100\% \text{ output} / 5 \text{ °C} * 1.2 \text{ °C} = 24 \%$). This additional 24% output was added to the existing 74% output to yield 98% output. The integral portion of the output is continuously recalculated at the rate specified by the integral gain setting. The INTEGRAL GAIN always adds or subtracts from the present output power. Of course, the maximum output is limited to 100% and the minimum is limited to 0%.

If the integral control is set too high, the temperature will oscillate. If integral control is set too low, it will take a long time for the temperature to settle to steady state.

2.3.4 DERIVATIVE GAIN

Values: 0.00 to 10.00 (cycles per minute)

Default value = 0.00

Description: This senses the rate of change of the temperature and allows the controller to anticipate the power needed to compensate for rapid changes in the system loading. The derivative gain is generally used on very sluggish systems or where very quick response is necessary. It works in a similar way to the integral gain, but it acts upon the change in the error, not the absolute error.

2.3.5 SENSOR TYPE

Values: 15K-1 or 10K-1

Default value = 15K-1

Description:

15K-1 should be selected when using the supplied MP-3193 thermistor or other thermistors with equivalent temperature-resistance curves. See Appendix for further details.

10K-1 should be selected when using thermistors equivalent to 10 k-ohm, curve "B" temperature-resistance curve as defined by YSI Temperature, Inc.



If you are using two thermistors, they must have the same resistance versus temperature characteristics. Also be sure that you have selected the correct sensor type. Otherwise a dangerous condition could exist because the actual temperature could be higher or lower than the temperature being interpreted by the controller.

2.3.6 CONTROL MODE

Values: COOL or HEAT

Default value = COOL

Description:

COOL mode causes the controller to increase the output power when the control sensor temperature is greater than the set temperature.

HEAT mode causes the controller to increase the output power when the control sensor temperature is less than the set temperature. (This mode can also be used with resistive heaters.)

Note: If you are using a TE device in the cool mode and you want to switch to the heat mode, you must also switch the connection between JP4-3 and JP4-4.

2.3.7 CONTROL RANGE

Values: -20 to 199, applies to both HIGH and LOW settings

Default value for HIGH = 070

Default value for LOW = -20

Description: Sets the maximum and minimum temperatures available in the SET TEMPERATURE menu. This is a safety feature that helps to limit the set point to the safe operating temperature of the system being controlled. Adjustments are in 1 °C increments, and the high setting must be higher than the low setting.

Note: If the CONTROL RANGE is adjusted such that it is no longer inclusive of the SET TEMPERATURE, the controller will continue to control to that SET TEMPERATURE. However, once you scroll to the SET TEMPERATURE menu, the SET TEMPERATURE will automatically reset to be within the CONTROL RANGE, and the output power will adjust accordingly. The SET TEMPERATURE can then only be set within the CONTROL RANGE.

2.3.8 TEMP OFFSET

Values: -10.0 °C to +10.0 °C
Default value = 0.0 °C

Description: Offsets the control sensor value for both the display and control algorithm.

2.3.9 ALARM 1 TEMPS

Values: -20 to 199 or OFF for HIGH setting; -20 to 199 or OFF for LOW setting
Default value for HIGH = 60
Default value for LOW = -20

Description: This sets the high and low temperatures for signaling an alarm based on the control sensor temperature. Adjustments are in 1 °C increments, and the high setting must be higher than the low setting. If the HIGH setting is increased past 199, OFF is indicated and no alarm will be signaled based on the control sensor for over-temperature conditions. If the LOW setting is decreased past -20, OFF is indicated and no alarm will be signaled based on the control sensor for under-temperature conditions.

Note: If the controller senses an open circuit or a short circuit on the control sensor, the controller will automatically turn off output power, regardless of the ALARM 1 FUNCTION setting.

2.3.10 ALARM 1 FUNCTION

Values: KEEP OUTPUT ON or TURN OFF OUTPUT
Default value = TURN OFF OUTPUT

Description: This setting determines what action will be taken when there is an alarm condition on the control sensor. When KEEP OUTPUT ON is selected, output power to the TE device stays on during the alarm condition, and the alarm 1 signal on JP5-10 is activated. When TURN OFF OUTPUT is selected, output power to the TE device is turned off, and the alarm 1 signal on JP5-10 is activated.



The ALARM 1 and ALARM 2 outputs on JP5-10 AND JP5-11 will momentarily pulse on and off several times in the first second after the controller is turned on. This happens as the microprocessor in the controller configures itself, regardless of any alarm condition.

2.3.11 ALARM 2 TEMPS

Values: -20 to 199 or OFF for HIGH setting; -20 to 199 or OFF for LOW setting
Default value for HIGH = 60
Default value for LOW = -20

Description: This sets the high and low temperatures for signaling an alarm based on the optional, secondary sensor temperature. Adjustments are in 1 °C increments, and the high setting must be higher than the low setting. If the HIGH setting is increased past 199, OFF is indicated and no alarm will be signaled based on the secondary sensor for over-temperature conditions. If the LOW setting is decreased past -20, OFF is indicated and no alarm will be signaled based on the secondary sensor for under-temperature conditions.

Note: If the controller senses an open circuit or a short circuit with respect to the thermistor, the controller will signal an alarm condition (presuming it is not set to OFF). In addition, if the controller senses an open thermistor circuit, T2 will not be displayed in the primary screen.

2.3.12 ALARM 2 FUNCTION

Values: KEEP OUTPUT ON or TURN OUTPUT OFF
Default value = TURN OUTPUT OFF

Description: This setting determines what action will be taken when there is an alarm condition on the secondary sensor. When KEEP OUTPUT ON is selected, output power to the TE device stays on during the alarm condition, and the alarm 2 signal on JP5-11 is activated. When TURN OFF OUTPUT is selected, output power to the TE device is turned off, and the alarm 2 signal on JP5-11 is activated.



The ALARM 1 and ALARM 2 outputs on JP5-10 AND JP5-11 will momentarily pulse on and off several times in the first second after the controller is turned on. This happens as the microprocessor in the controller configures itself, regardless of any alarm condition.

2.3.13 ALARM LATCHES

Values: NO LATCHES, ALARMS 1&2 LATCH, ALARM2 LATCH, ALARM1 LATCH

Default value = NO LATCHES

Descriptions:

NO LATCHES: If an alarm condition occurs but then clears itself, the alarm signal will automatically turn off and power to the TE device will be restored (if ALARM 1 FUNCTION and ALARM 2 FUNCTION are set to TURN OUTPUT OFF).



If the alarm condition is recurring and the ALARM 1 FUNCTION and/or ALARM 2 FUNCTION is set to TURN OUTPUT OFF, the TE device can be damaged by thermal fatigue stress imposed by repeated long-term power cycling.

NOTE: The default deadband for the latch reset is 0 °C. However, the deadband can be reprogrammed using the RS232 interface to allow for the latch to reset at a specified temperature difference above/below the alarm set point. You can use the software provided with the controller or you can create your own software and use the controller commands as described in “*Serial Communications*” in the appendix.

ALARMS 1&2 LATCH: if an alarm condition occurs from either the control or secondary sensor or both, the controller will continue to signal an alarm until reset, even if the alarm condition is cleared. Power to the controller must be turned off and then on again to turn off the alarm signal. **Alternatively, press and hold the UP ARROW button for three seconds to clear the alarm signal and reset the latches.**

ALARM2 LATCH: if an alarm condition occurs from the secondary sensor, the controller will continue to signal the alarm until reset, even if the alarm condition is cleared. Power to the controller must be turned off and then on again to turn off the alarm. **Alternatively, press and hold the UP ARROW button for three seconds to clear the alarm and reset the latch.**

ALARM1 LATCH: if an alarm condition occurs from the control sensor, the controller will continue to signal the alarm until reset, even if the alarm condition is cleared. Power to the controller must be turned off and then on again to turn off the alarm. **Alternatively, press and hold the UP ARROW button for three seconds to clear the alarm and reset the latch.**

Multi-Speed Fan Control and control of other loads: The alarms can be used for controlling the hot-side fan of a TE device at two different speeds. The low-speed setting is useful for reducing noise when the demand for cooling is low. The high-speed setting can be triggered when an alarm condition is sensed to maintain cooling performance as required. Alarm deadband can be added to keep the fan speed from oscillating. See the “*Optional Multi-Speed Fan Control Setup*” drawing for further details. Note: each alarm output can handle other load types with up to 1 A of current draw. The controller can handle up to 20 A overall combines output and alarm current.

3.0 Controller Tuning

This tuning method follows the Ziegler-Nichols closed-loop tuning principals. Briefly, the controller will first be set to a high proportional bandwidth setting with no integral or derivative function (integral gain and derivative gain = 0). Then, the bandwidth is gradually decreased until the temperature approaches set point and a small, sustained oscillation in temperature is observed. The other tuning parameters are then readjusted based on the time period of the temperature oscillation (natural period) and the proportional bandwidth needed to cause this oscillation.



Improper tuning of this temperature controller can lead to excessive thermal cycling and/or overheating of the thermoelectric device, either of which are known to reduce the lifetime of any thermoelectric device. Care should be taken to prevent the temperature of the thermoelectric device from going beyond the range specified by the device manufacturer. Care should also be taken so that any thermal cycling of the thermoelectric device is a result of changes in the controller's set-point temperature and not instability at a given set point due to improper selection of the tuning variables.

- 3.1 Set the desired control temperature in the SET TEMPERATURE menu.
- 3.2 Set the PROPORTIONAL BW to 20. This is just a starting value; the goal is to determine the proportional bandwidth at which the temperature of the TE device will first begin to oscillate. The bandwidth needs to be adjusted in incremental steps and allow the controller to reach steady state between each adjustment. You might be able to start with a smaller bandwidth, depending on the system, thereby reducing the time it takes to determine the proper bandwidth for good control stability.
- 3.3 Set the INTEGRAL GAIN and DERIVATIVE GAIN to zero.
- 3.4 Decrease the PROPORTIONAL BW incrementally, allowing the TE device to reach steady state at each increment, until the temperature of the TE device begins to oscillate. The system temperature will usually begin to oscillate before it actually reaches the set point temperature; this is normal. You can decrease the bandwidth in initial increments of 5 °C or perhaps even more. Then, once an initial oscillation is observed, increase the bandwidth in small increments until the oscillations are barely detectable.

Measure the time period of oscillation in minutes. This will be used to determine the INTEGRAL GAIN setting below.

- 3.5 Multiply the current PROPORTIONAL BW setting by 2.2 and enter this as the new bandwidth. The system should now maintain a steady state temperature near the set point.
- 3.6 The integral gain is calculated as follows: $I = 0.54/T$ where I is the integral gain and T is the time period, in minutes, determined in section 3.4 above. Enter this value in the INTEGRAL GAIN setting.
- 3.7 The derivative gain is often times difficult to use and might cause more trouble than it is worth. If you are not experience with process control, you might be better off leaving the DERIVATIVE GAIN set to zero.

If you decide to use derivative gain, the other control parameters should be adjusted first.

- a) Instead of multiplying the initial proportional bandwidth setting by 2.2, multiply it by 1.7, and enter this as the new PROPORTIONAL BW setting.
 - b) Calculate the integral gain as follows: $I = 1.2/T$, and enter this into the INTEGRAL GAIN setting.
 - c) Calculate the derivative gain as follows: $D = 0.075 \times T$, and enter this into the DERIVATIVE GAIN setting.
- 3.8 The control parameters are approximate settings. Further adjustments might be needed.

Tuning Example using proportional bandwidth and integral gain:

- A. Suppose that smallest PROPORTIONAL BW setting that causes oscillation was determined to be 2.1 °C.
- B. It was then observed that the natural period of this oscillation was 2 minutes.

- C. The PROPORTIONAL BW setting should then be set to 4.6 °C (This is calculated from $2.1\text{ °C} \times 2.2 = 4.6\text{ °C}$).
- D. The INTEGRAL GAIN should be set to 0.27 (This is calculated from $0.54/(2\text{ minutes}) = 0.27\text{ repeats per minute}$).

4.0 Controller Software and RS-232 Communication

The TC-48-20 and TC-48-20 OEM can be controlled through the supplied software operating on a Windows based computer. In addition, see “Serial Communications” for descriptions of the command set for the controller. The command set can be used to create your own custom software using National Instruments LabVIEW, for example, if the supplied software does not quite meet your requirements.

A dedicated serial port is required. See “RS-232 Communications Connections” for proper connection to the serial port of the computer. **An optional serial port cable is available and is required to connect to the computer.** Contact TE Technology for more information. Always be sure the computer is shut down before connecting or disconnecting the controller from the computer.

Note: If you need to communicate to the controller via a USB port you can use our optional RS232 Adapter for USB to RS232 conversion in conjunction with the optional RS-232 cable. If you use your own USB to RS232 converter, be aware that some converters might “inject” noise on the transmit line from the computer. This will disrupt communication to the controller. This noise problem can be alleviated by adding a 0.001 microfarad, 50 V ceramic capacitor between JP5-7 and JP5-8.

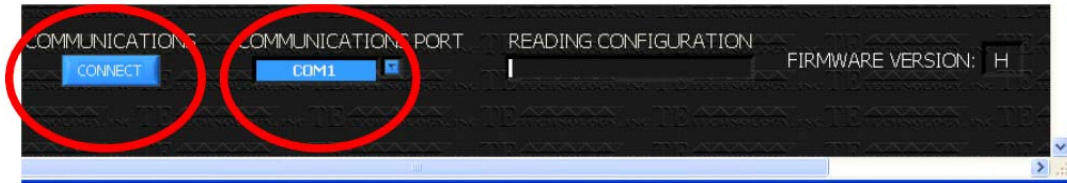
Software Installation: insert the CD into your CD drive in any Windows 2000 (service pack 3) or Windows XP based computer and double-click the setup.exe file (the runtime engine requires a minimum of approximately 320 MB of hard-disk space and 256 MB of RAM). This process will install the National Instruments LabVIEW runtime engine, the TC-48-20.exe file, and various support files to your hard drive. The LabVIEW runtime engine is required since the TC-48-20.exe is actually an executable version of a LabVIEW .vi file. The computer will then ask you to restart. However, you might want to shut down the computer all the way first if you have not connected the controller to the serial port yet. If you have connected it already, then a simple restart will suffice.

To start the software, navigate to the directory in which you installed the TC-48-20.exe file (default location is C:\Program Files\TE Technology\TC-48-20\TC-48-20.exe), then double-click the .exe file. The software will start and you should see the following screen:



The pop-up screen reminds you that you must first establish communication between the controller and the computer. Click the OK button to clear the pop-up screen.

Next, click the COMMUNICATIONS PORT menu key and select the port to which you have the controller connected. Then click the CONNECT button. Controllers with firmware version H or later will display the version on the lower right side of the screen. If earlier than version H this area will be blank.

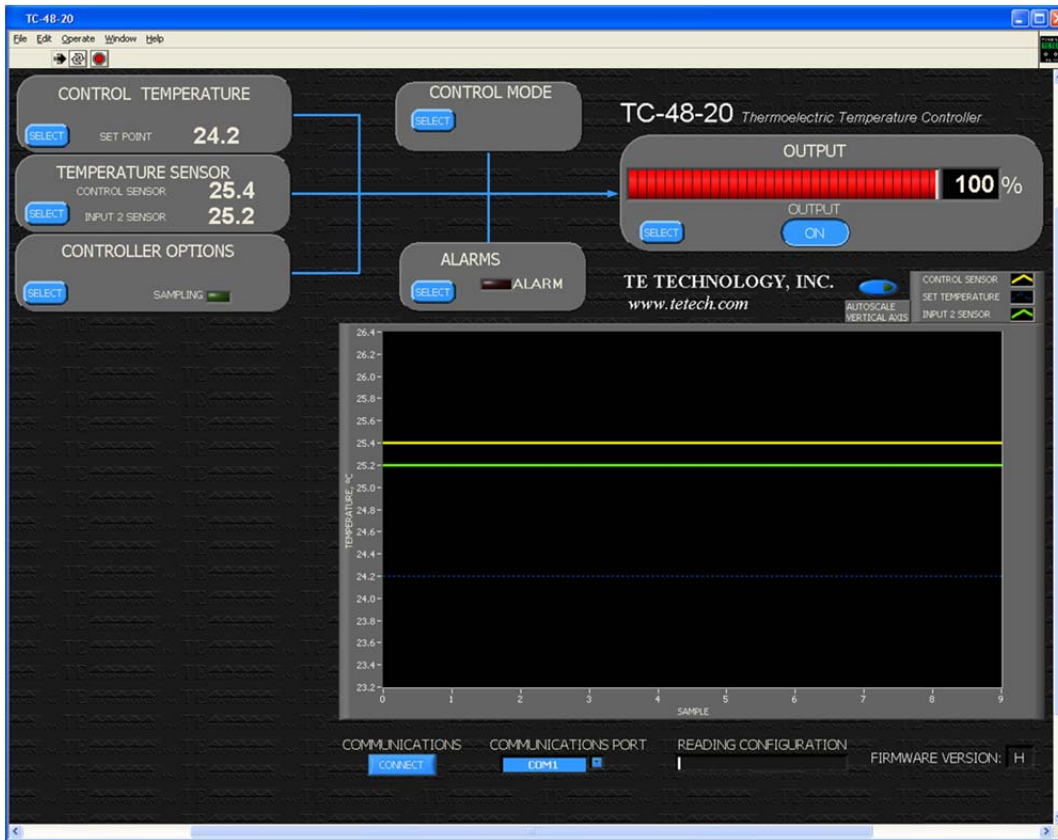


If you make changes to the controller setting via the keypad, the software will automatically detect this change the next time the software polls the controller.

If you are not able to establish communication with the controller, check the following conditions:

- 1) Verify the controller itself is on.
- 2) Make sure you selected the correct serial port and the interface cable is securely connected to the correct port.
- 3) Verify the cable is wired correctly to the controller.
- 4) Verify the computer serial port is configured per RS-232 standards.
- 5) Check that the serial port has not been disabled by your hardware configuration.

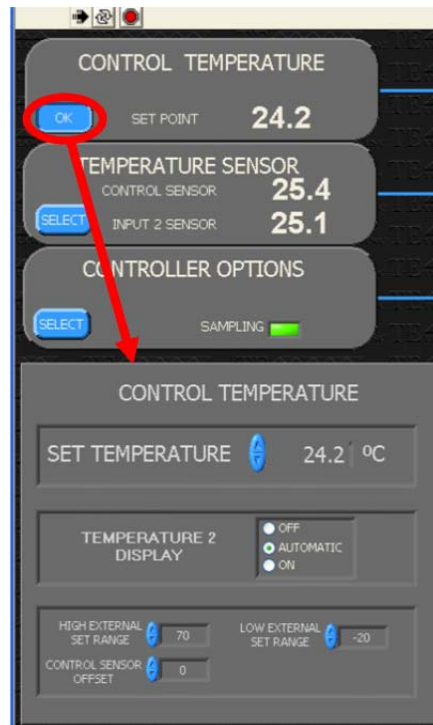
The controller software settings are arranged into six sections:
 CONTROL TEMPERATURE TEMPERATURE SENSOR
 CONTROLLER OPTIONS CONTROL MODE
 ALARMS OUTPUT



The options for each section box are revealed when you click the corresponding SELECT button. This opens up a menu box next to the left of the graph box. When you make a change to any of the menu options, the controller is updated immediately. The menu box is closed when you click the OK button on the corresponding section box.

CONTROL TEMPERATURE box

This shows the set temperature for the controller. The menu options allow for adjustment of the set temperature, whether a temperature from the secondary thermistor is displayed, and for adjusting the high and low limits of the set temperature. The values can be changed using the up or down menu buttons or by clicking on the number and typing in the desired value.



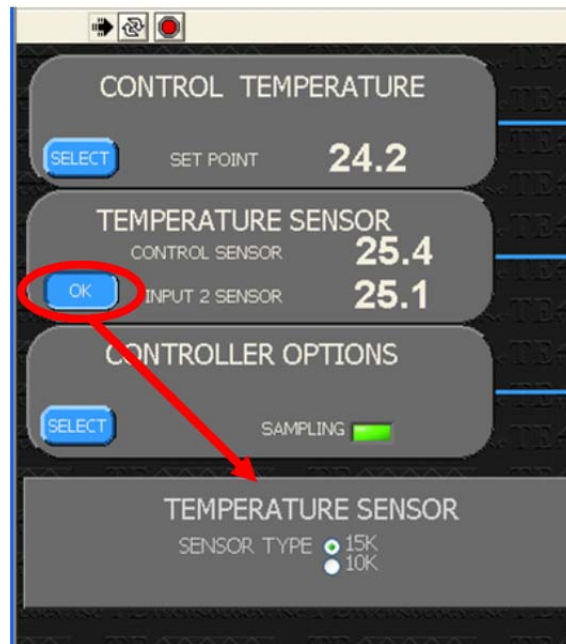
The allowable SET TEMPERATURE is limited to the range defined by the HIGH EXTERNAL SET RANGE and the LOW EXTERNAL SET RANGE.

The SET TEMPERATURE 2 DISPLAY can be set to OFF to prevent the display of the temperature of the secondary thermistor, regardless of whether a secondary thermistor is attached to the controller or not. If it is set to AUTOMATIC, then the controller will automatically display the temperature if a sensor is attached, and turn it off if no sensor is attached. Setting it to ON will always display the temperature from the secondary thermistor.

The CONTROL SENSOR OFFSET can be used to correct for known sensor errors or differences between the sensed temperature and the actual temperature.

TEMPERATURE SENSOR box

This shows the present temperature of the control sensor and the secondary sensor.



The menu options allow for selecting which temperature-resistance curve the controller is to reference for reporting the present temperatures of the thermistors. The 15K sensor type should be selected if using the MP-3193, MP-2444, or MP-2542 thermistor.

The 15K sensor provides an effective control range of -20 °C to +100 °C.

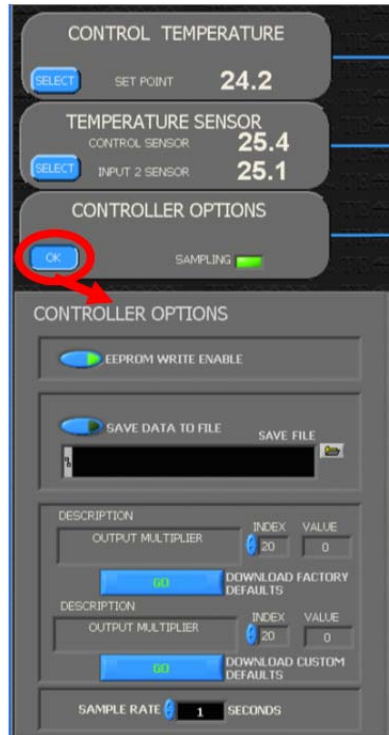
The 10K sensor provides for an effective control range of -20 °C to +85 °C. The temperature-resistance curve for the 10K sensor is the same as curve “B” from YSI Temperature, Inc. See “*Temperature versus Resistance*” below for further details on the 15K and 10K data.



If you are using two thermistors, they must have the same resistance versus temperature characteristics. Also be sure that you have selected the correct sensor type. Otherwise a dangerous condition could exist because the actual temperature could be higher or lower than the temperature being interpreted by the controller.

CONTROLLER OPTIONS box

The SAMPLING indicator will flash green each time the software updates the sensor temperatures and power output. The menu options allow for enabling/disabling EEPROM write enable, adjusting the sampling frequency and for determining where to save test data to a file. NOTE: if you use the software with controllers having firmware version G or earlier, the EEPROM WRITE ENABLE button will be disabled and grayed out. This control operates only on firmware versions H and later.



The EEPROM, Electrically Erasable Programmable Read Only Memory, is a non-volatile memory used to store controller settings. This allows the controller to remember its settings even after power to the controller has been turned off. The TC-48-20 and TC-48-20 OEM automatically turn on EEPROM WRITE ENABLE when power is applied to the controller regardless of whether EEPROM WRITE ENABLE was turned off when power to the controller was removed. With EEPROM WRITE ENABLE turned on, any changes to the controller settings are automatically written to EEPROM. With EEPROM WRITE ENABLE turned off, any subsequent changes to the controller settings are only saved in RAM and will not be stored to EEPROM. The maximum number of writes to an EEPROM location is 1,000,000. Even though this provides for many write cycles, you might want to turn EEPROM WRITE ENABLE off if for example you are writing your own code to ramp set points via the computer.

The SAMPLE RATE determines the amount of time the software waits before updating the status of the controller. This is particularly useful if you will be operating controller for a long time and you want to limit the amount of data you save. The minimum time is 1 second, and it can be adjusted in 1 second increments.

To SAVE DATA TO FILE, enter a filename in the text box, including the entire path to the file, such as <C:\PROGRAM FILES\TE TECHNOLOGY\TC-48-20\TESTDATA.TXT>. Alternatively, if you want to append data to an existing file, you can click the folder icon to select an existing file. Then click the SAVE DATA TO FILE button to begin saving test data. If you click the SAVE DATA TO FILE button before entering a filename and path in the text box, an error screen will pop up and a default filename and path will automatically be entered in the text box. Click the continue button on the error pop-up if applicable. The arrow on the button will turn green to indicate that the software is saving test data. The software saves the data into a TAB-delimited format which can then be readily imported into a spreadsheet program for further analysis.

To view the data in Microsoft Excel:

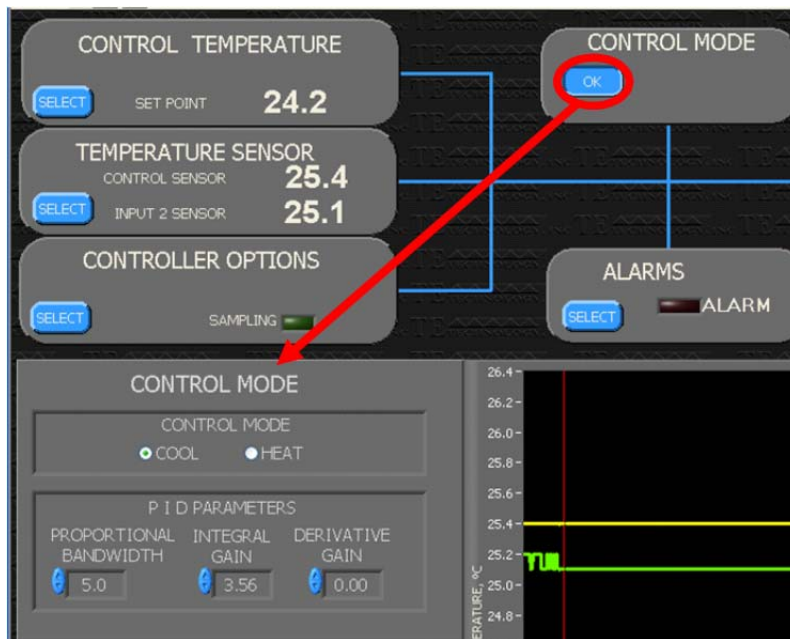
1. Open a blank worksheet
2. Select **Data > Import External Data > Import Data**, and click **Next**
3. Select the file you wish to import and click **Next**
4. Choose to import **Delimited Data Type** and click **Next**
5. Select **TAB** as the delimiter and click **Finish**

Clicking the GO button next to the “DOWNLOAD FACTORY DEFAULTS” label downloads the original default controller settings. You can review these settings by clicking on the INDEX scroll arrows. These default settings can not be changed.

Alternatively, you can click the GO button next to the “DOWNLOAD CUSTOM DEFAULTS” label to download customized settings from a pre-configured, comma-delimited text file which is saved in the C:\Program Files\TE Technology\TC-48-20\custom settings.csv (unless you changed your default install directory). You can change these settings as needed.

CONTROL MODE box

The menu options provide for adjusting whether the controller is in the heat or cool mode and for adjusting the proportional bandwidth, integral gain and derivative gain.

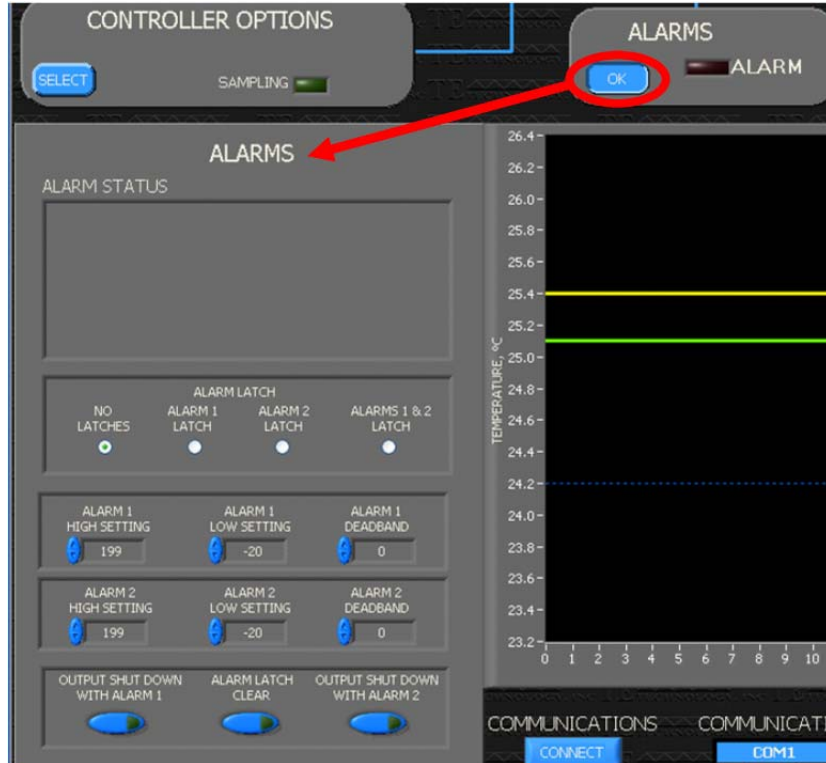


The COOL or HEAT control mode does not automatically reverse the polarity applied to the TE device. It only defines whether power is increased if the control sensor temperature rises above the set point (COOL mode) or decreases power if the control sensor temperature rises above set point (HEAT mode). The TE device connection to the controller will need to be physically reversed if you initially configure for COOL mode and then decide to switch to HEAT mode, for example.

See the Controller Tuning section for details on the proper settings for the PROPORTIONAL BANDWIDTH, INTEGRAL GAIN, and DERIVATIVE GAIN settings.

ALARMS box

The ALARM indicator will be grey if no alarm condition exists. It will flash between yellow and red if an alarm condition exists. The menu provides for adjusting alarm settings.



The ALARM STATUS text box will indicate the nature of the alarm if an alarm conditions exists.

NO LATCHES: if an alarm condition clears itself, the alarm will automatically reset.

ALARM 1 LATCH: if an alarm is triggered from the control sensor, the software will continue to signal an alarm condition until the condition is cleared *and* the ALARM LACTH CLEAR button is clicked.

ALARM 2 LATCH: if an alarm is triggered from the secondary sensor, the software will continue to signal an alarm condition until the condition is cleared *and* the ALARM LACTH CLEAR button is clicked.

ALARM 1&2 LATCH: if an alarm is triggered from either the control or the secondary sensor, the software will continue to signal an alarm condition until the condition is cleared *and* the ALARM LACTH CLEAR button is clicked.

ALARM 1 HIGH SETTING: this sets the temperature at which an alarm will occur if the control sensor temperature exceeds the set value. The set value must be greater than the value set in the ALARM 1 LOW SETTING but less than 200. If the set value is set to greater than 199, no alarm will be signaled for any over-temperature condition.

ALARM 1 LOW SETTING: this sets the temperature at which an alarm will occur if the control sensor temperature becomes less than the set value. The set value must be less than the ALARM 1 HIGH SETTING but greater than -21. If the set value is less than -20, no alarm will be signaled for any under-temperature condition.

ALARM 1 DEADBAND: this defines a temperature difference above or below the ALARM 1 LOW SETTING or ALARM 1 HIGH SETTING at which the alarm status can be cleared (either automatically or manually depending on latch settings). For example, if ALARM 1 HIGH SETTING is set for 70 and the ALARM 1 DEADBAND is set for 10, and an alarm condition occurs, the control sensor would have to cool to 60 °C before the alarm can be reset.

The ALARM 2 HIGH SETTING, ALARM 2 LOW SETTING, and ALARM 2 DEADBAND function in the same manner as described above for ALARM 1 settings except that they are referenced to the secondary sensor.

OUTPUT SHUTDOWN WITH ALARM1: if this option is turned on and an alarm condition occurs relative to the primary sensor, then the controller will shut power off to the TE device. Power will automatically be restored if you have the NO LATCHES option selected. If the ALARM 1 LATCH or the ALARM 1&2 LATCH option is selected, then power will stay off, even if the alarm condition clears itself, until you click the ALARM LATCH CLEAR button.

OUTPUT SHUTDOWN WITH ALARM2: same as the OUTPUT SHUTDOWN WITH ALARM1 except as referenced to the secondary sensor.

OUTPUT box

This shows the percentage of maximum power output that the controller is providing to the TE device.



The output can be turned on and off by clicking the output button either ON or OFF. Whenever a change is made in the software, the controller is updated in real time. However, it might be beneficial to turn off the output first and then make all of your software/controller settings before turning on the output. **Be sure that the output is set to ON prior to shutting down the software though; otherwise, if you attempt to use the controller again without the software, you will not be able to turn the output on.**

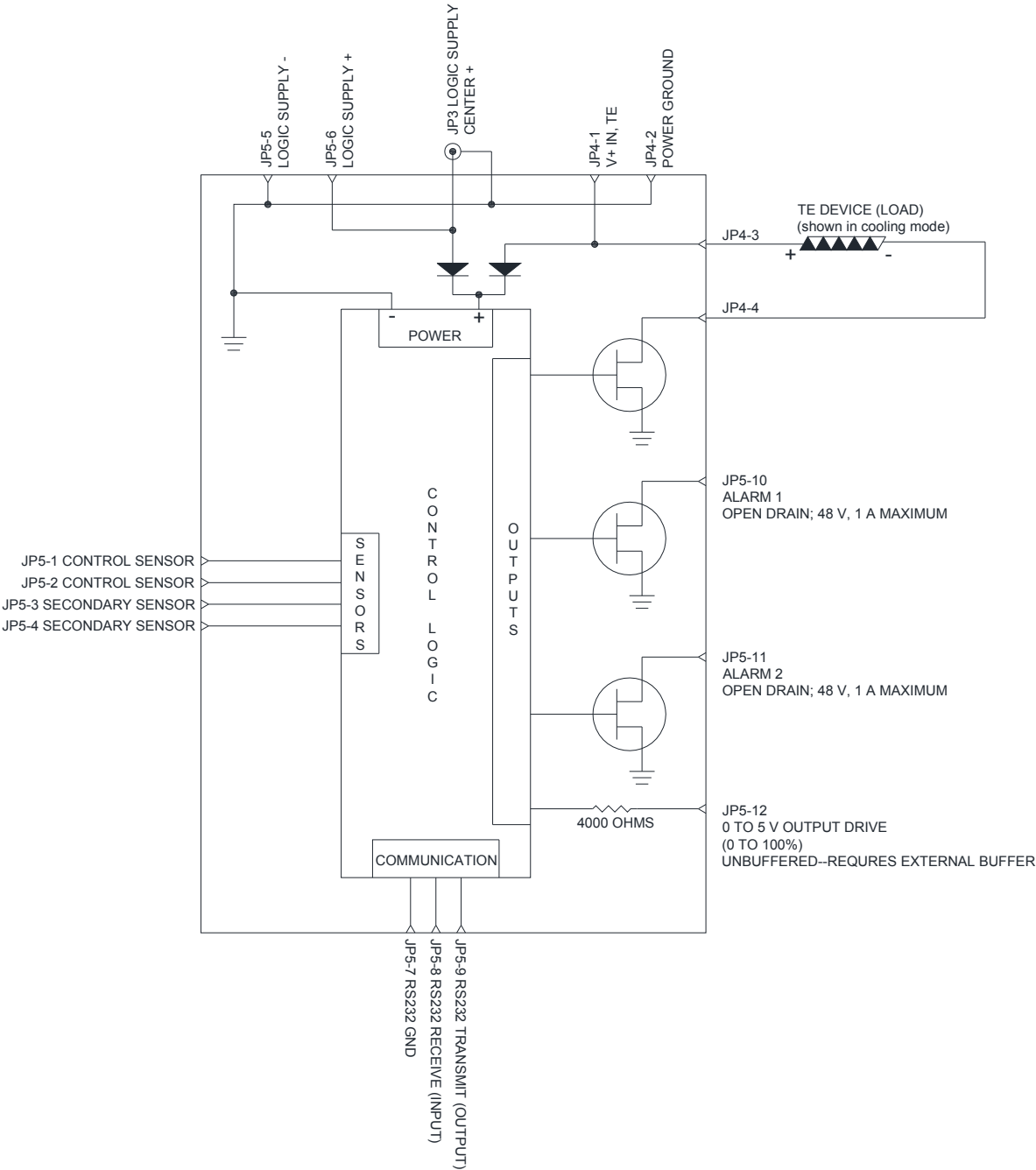
The menu provides for adjusting the analog output voltage. The analog output voltage provided by the controller (see "Controller Schematic for further details") is a 0-5V DC control signal which corresponds to 0 to 100% power output. The ANALOG OUTPUT MULTIPLIER can be set from 0 to 1. When it is set to 1, the analog output voltage can range from 0 to 5 V. If, for example, it is set to 0.5, then analog output voltage can range from 0 to 2.5 V. This can be useful for limiting the output voltage of power supply.

AUTOSCALE VERTICAL AXIS button

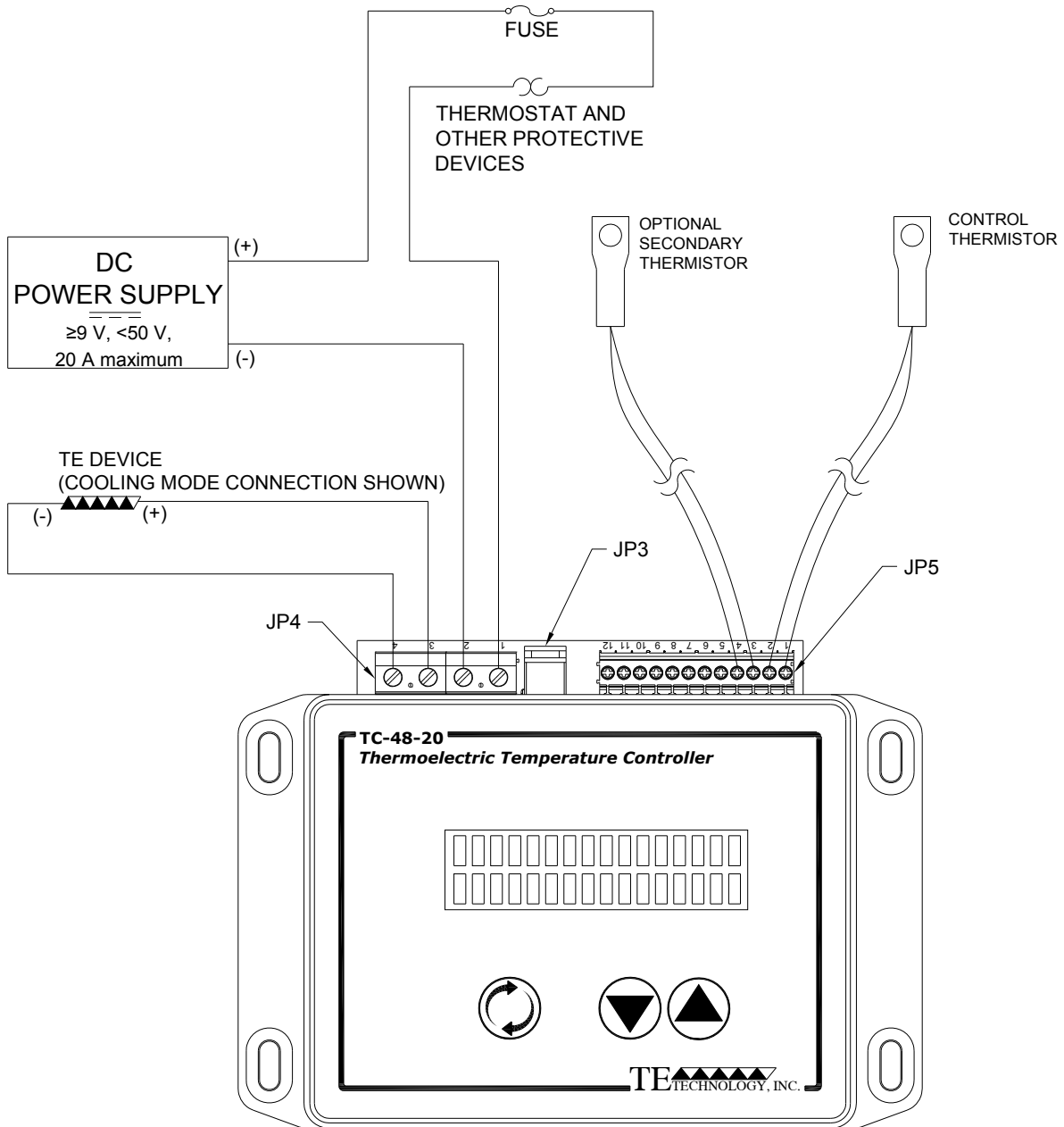
Clicking this button automatically scales the graph so that all data plots can be seen. You can also right-click on the axes for further options or enter minimum and maximum Y-axis numbers directly to rescale.



Controller Schematic



Controller Hookup Diagram (One Power Supply Setup)

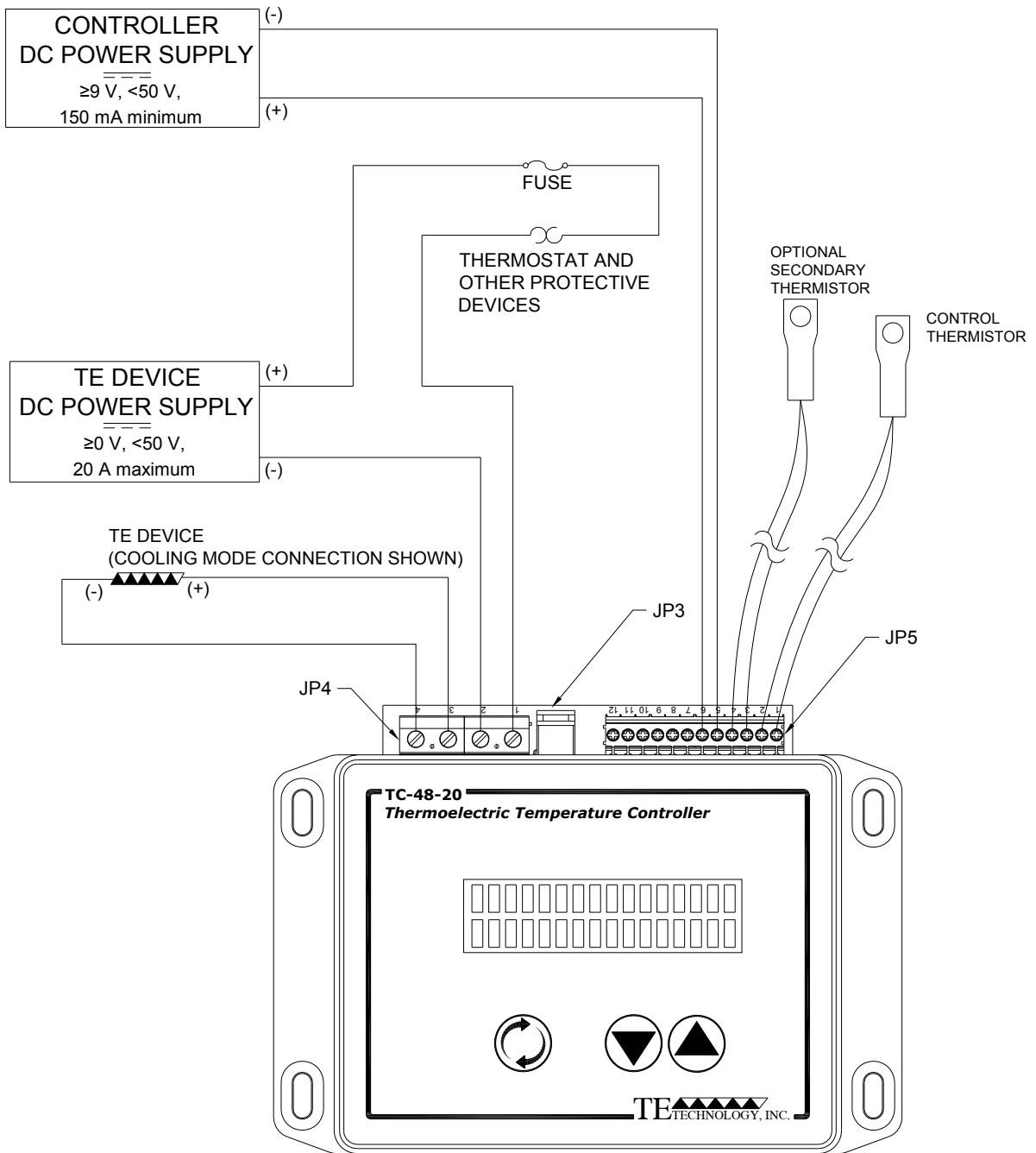


When one or more external fans are used on the TE device, these should be wired directly to a fixed voltage power supply for constant operation.

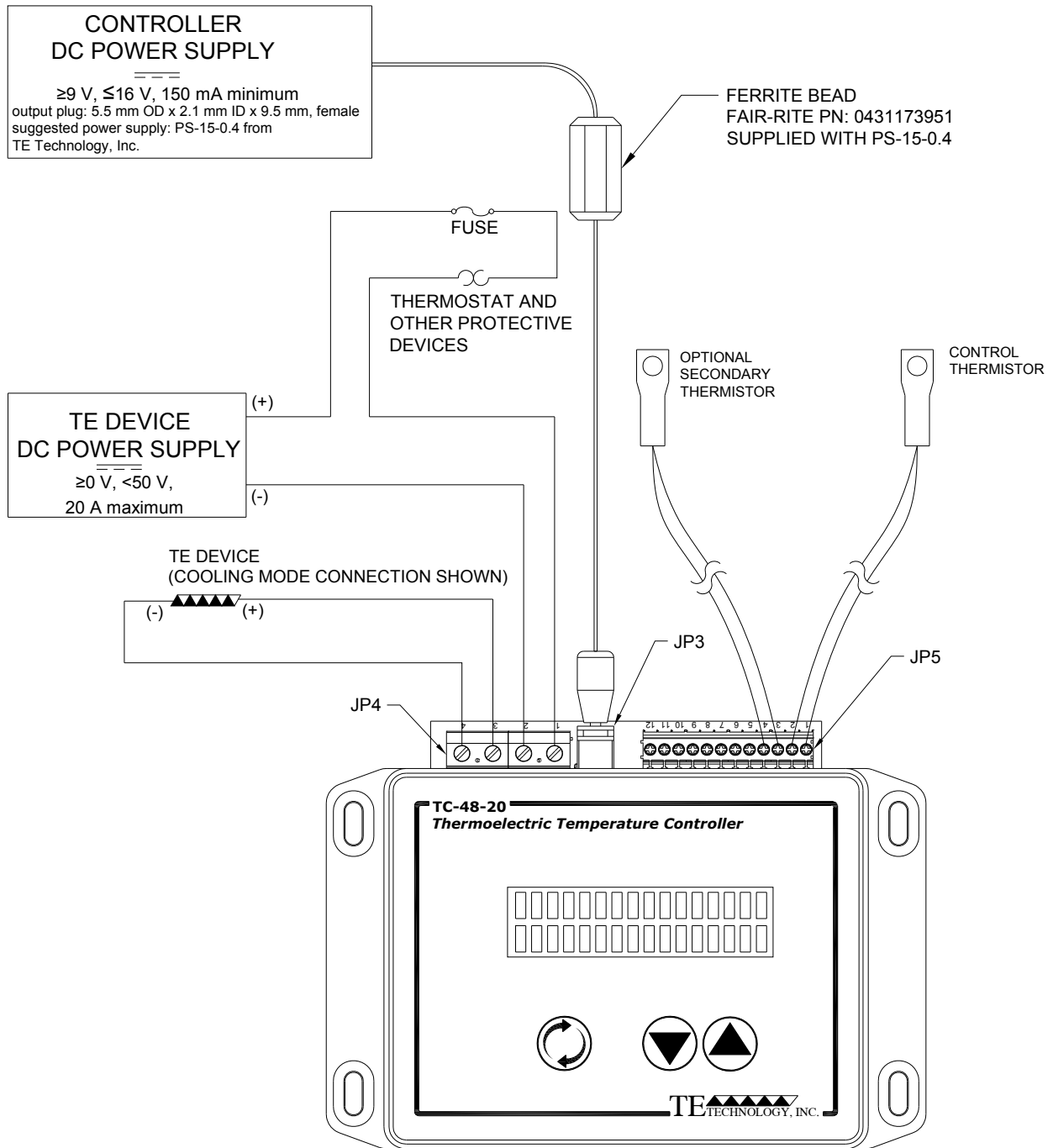


When connecting the controller to a TE Technology Thermoelectric Cooling Assembly (TCA) verify that the electrical jumpers (shorts) located on the TCA terminal block are installed/removed per the TCA operating manual before powering the controller.

Controller Hookup Diagram (Two Power Supplies Setup-Option 1)

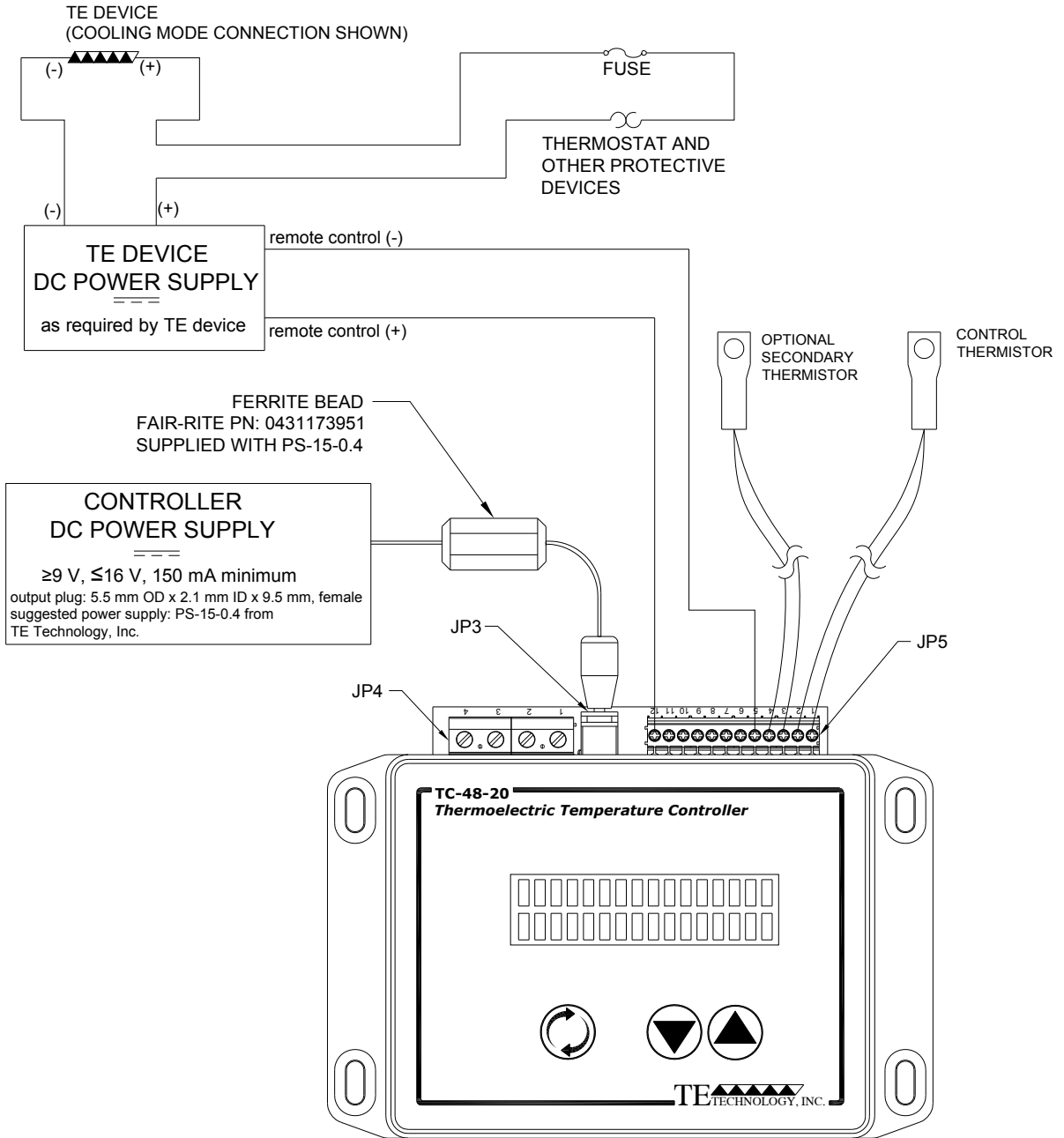


Controller Hookup Diagram (Two Power Supplies Setup-Option 2)



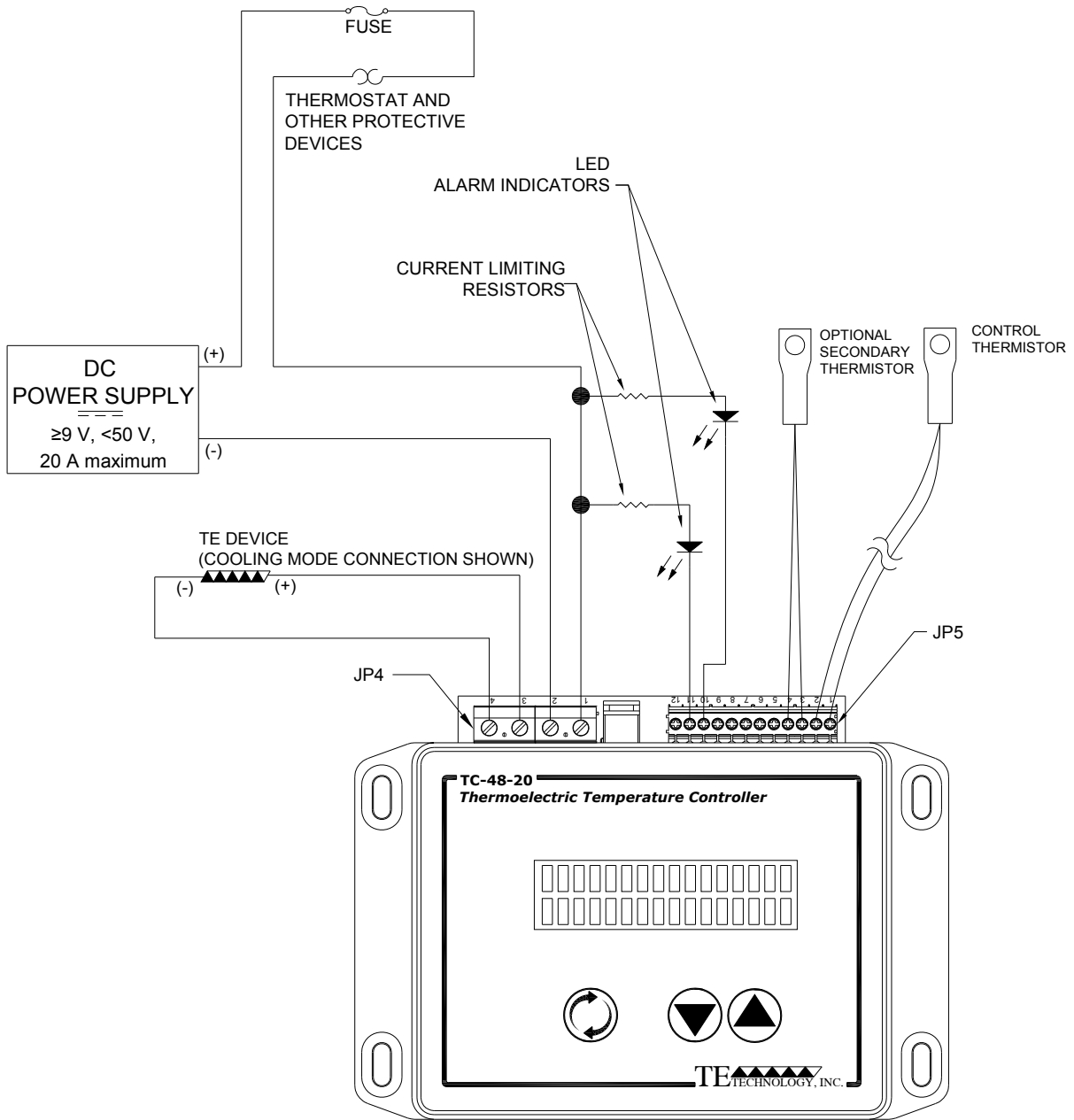
Linear Control Hookup Diagram

Note: Check the power supply manual to determine if an external buffer is required between the power supply and the voltage signal output from JP5-12.



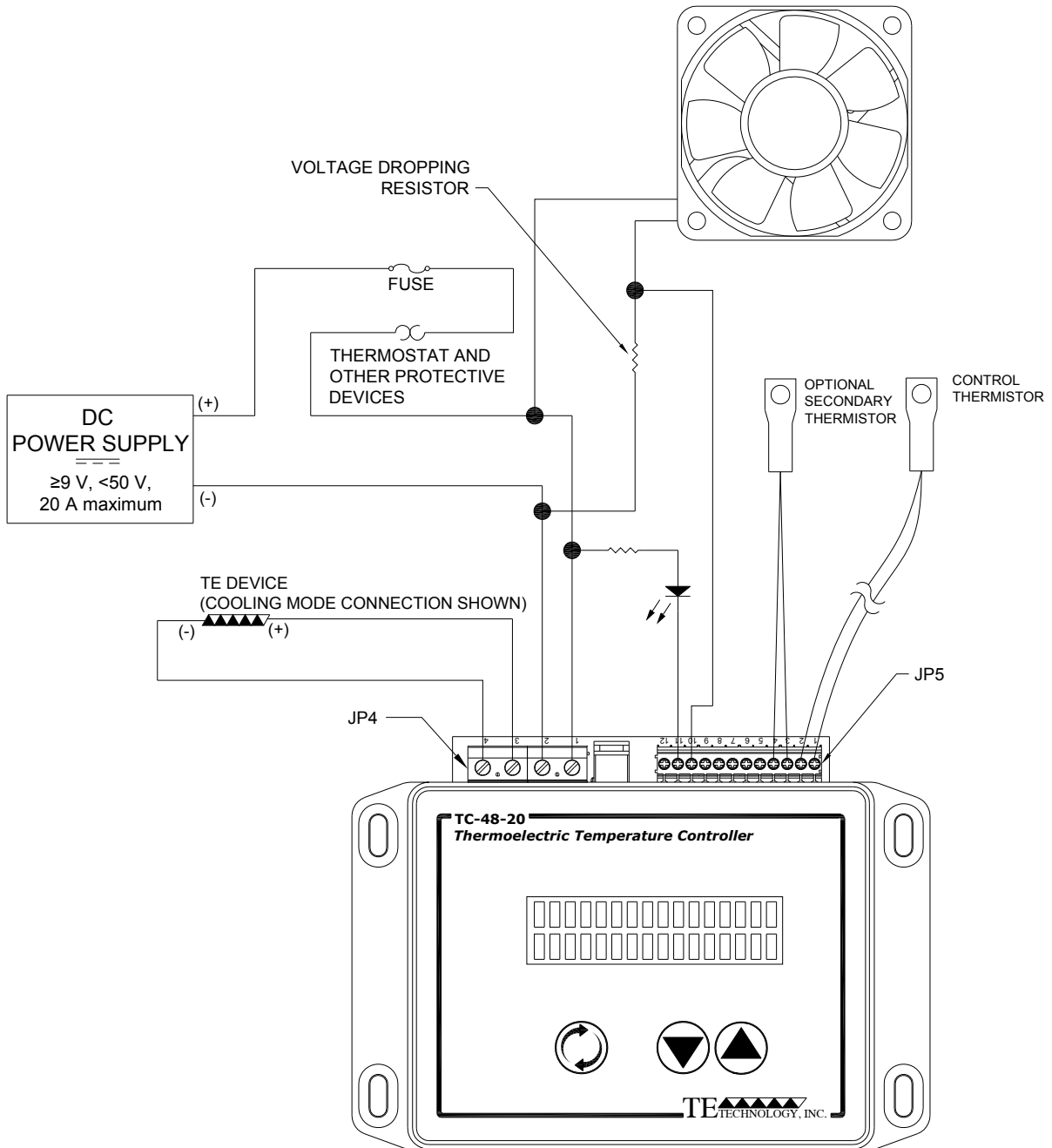
Optional External Alarms Setup

Other loads, requiring up to 1 amp of current, can also be controlled



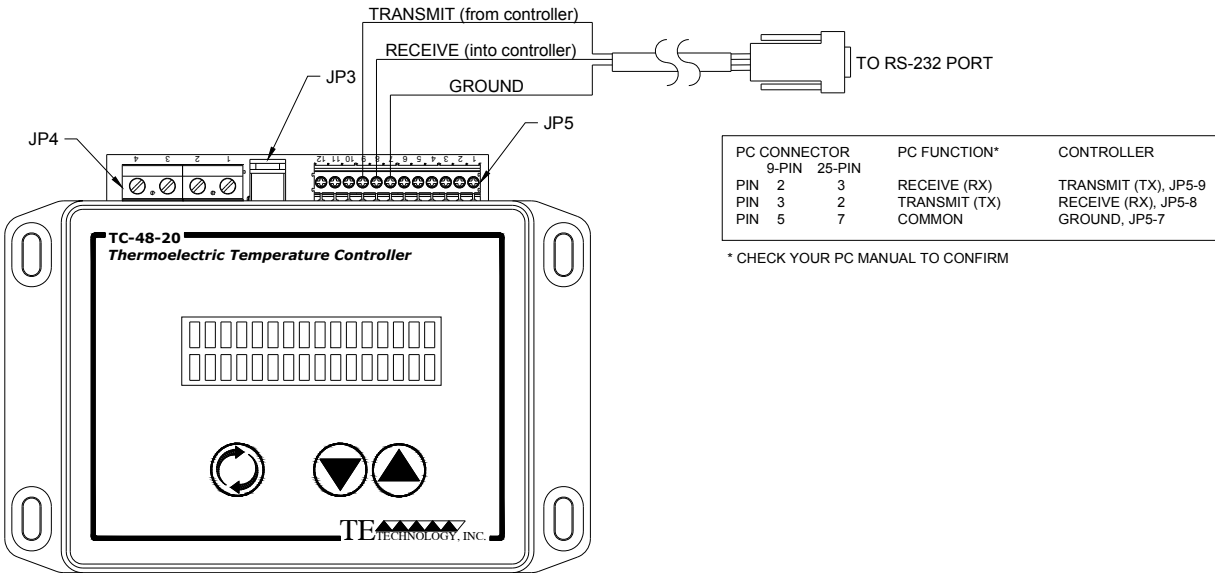
Optional Multi-Speed Fan Control Setup

Other loads, requiring up to 1 amp of current, can also be controlled



NOTE: ADJUST ALARM DEADBAND TO PREVENT FAN SPEED FROM RAPIDLY CYCLING.

RS232 Communications Connections



Note: the RS232 cable is not included as a standard accessory. However, TE Technology can provide this as optional accessory, part number MP-3023. If using the MP-3023, connect the leads as follows:

- red lead to JP5-9
- clear (or white) lead to JP5-8
- black lead to JP5-7

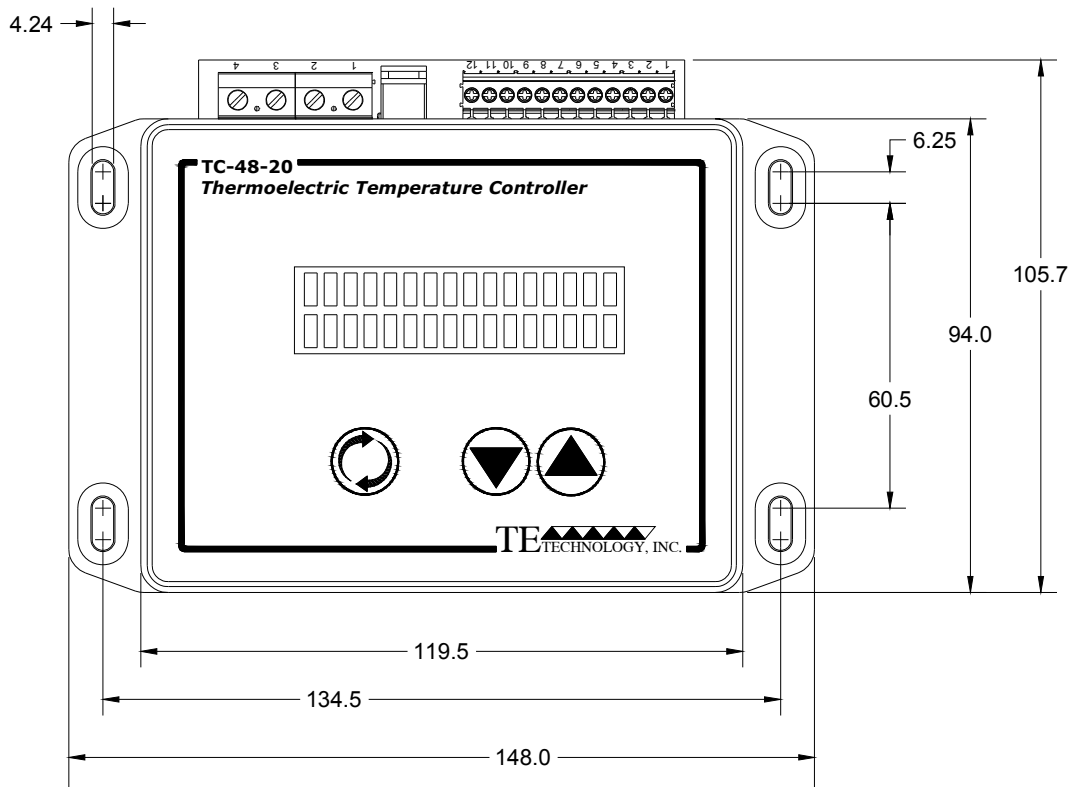
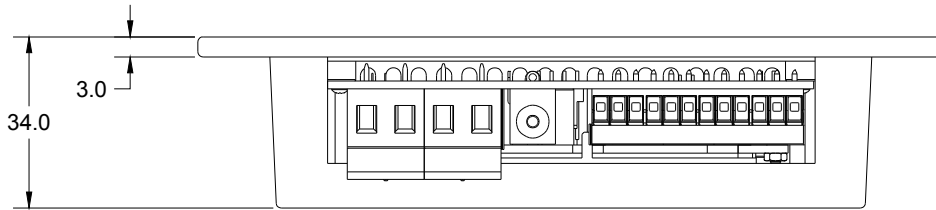
Note: other connections to controller have been removed for the sake of clarity.

Note: If you are using a USB to RS232 converter, some converters might induce electronic noise and interfere with communication. If this occurs, install a 0.001 microfarad, 50V- rated, ceramic capacitor across JP5-7 to JP5-8.

RS232 Communications Parameters:

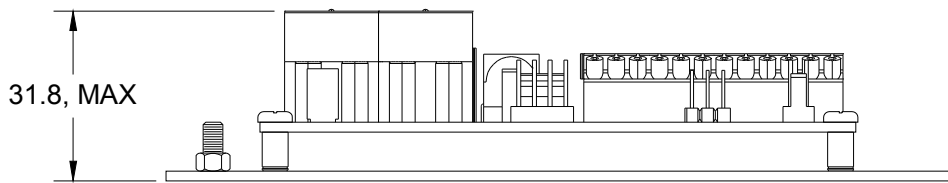
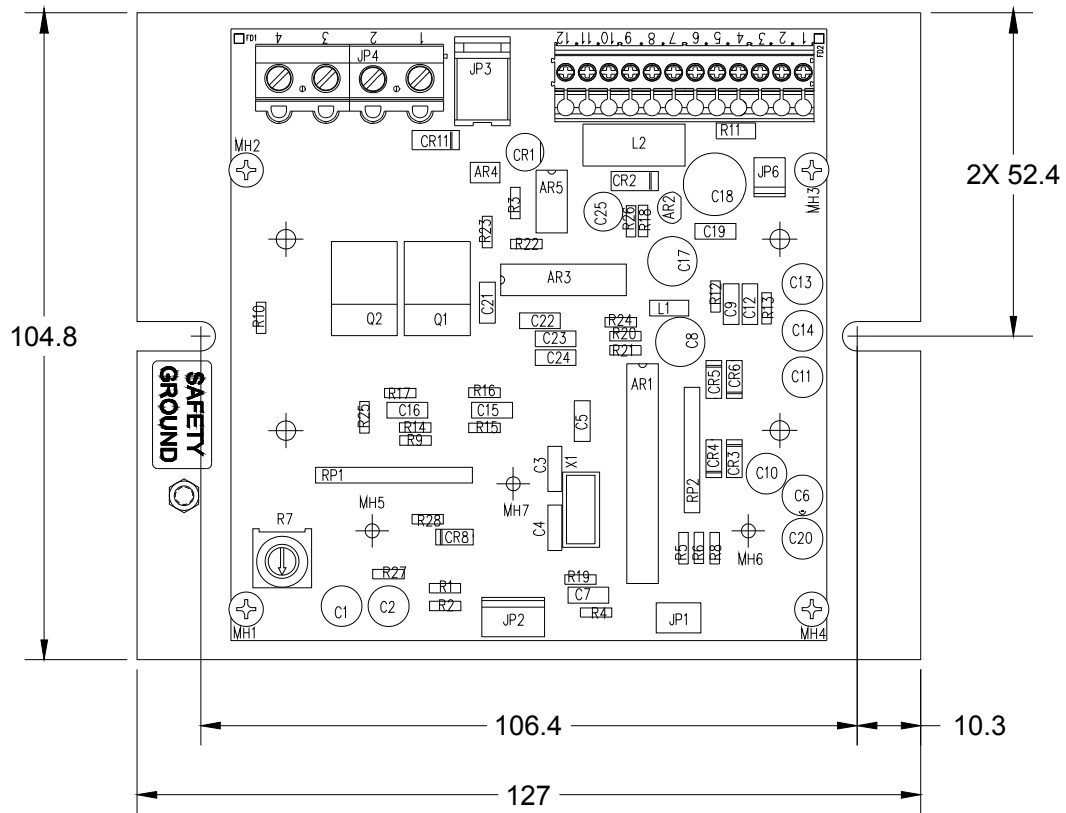
- A. Baud Rate 115,200
- B. No Parity
- C. 1 Start Bit 1 Stop Bit

TC-48-20 Mechanical Package Drawing



NOTE: ALL DIMENSIONS IN MILLIMETERS

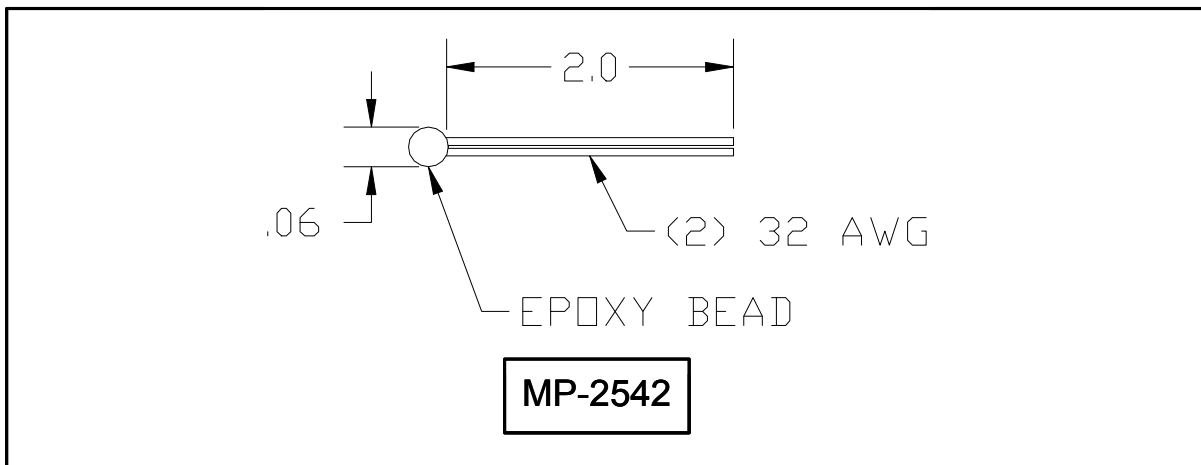
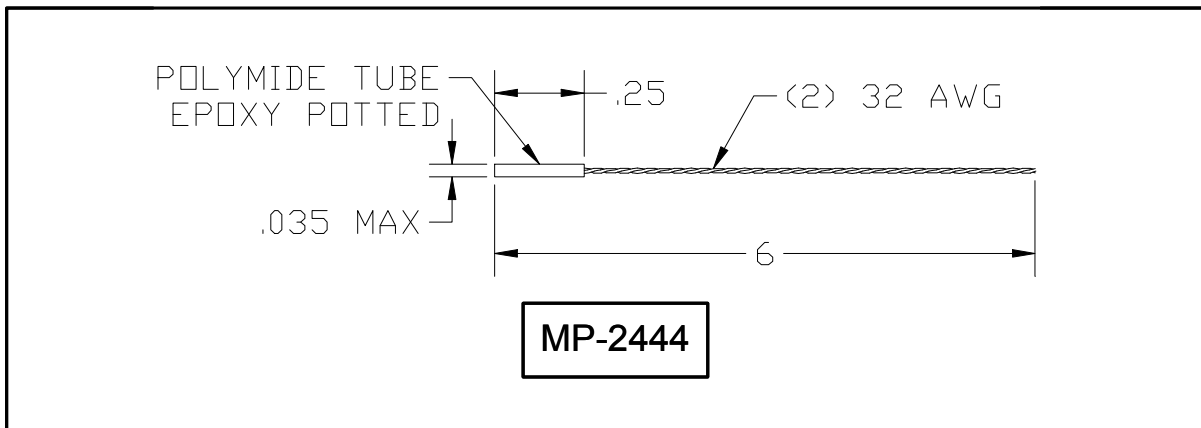
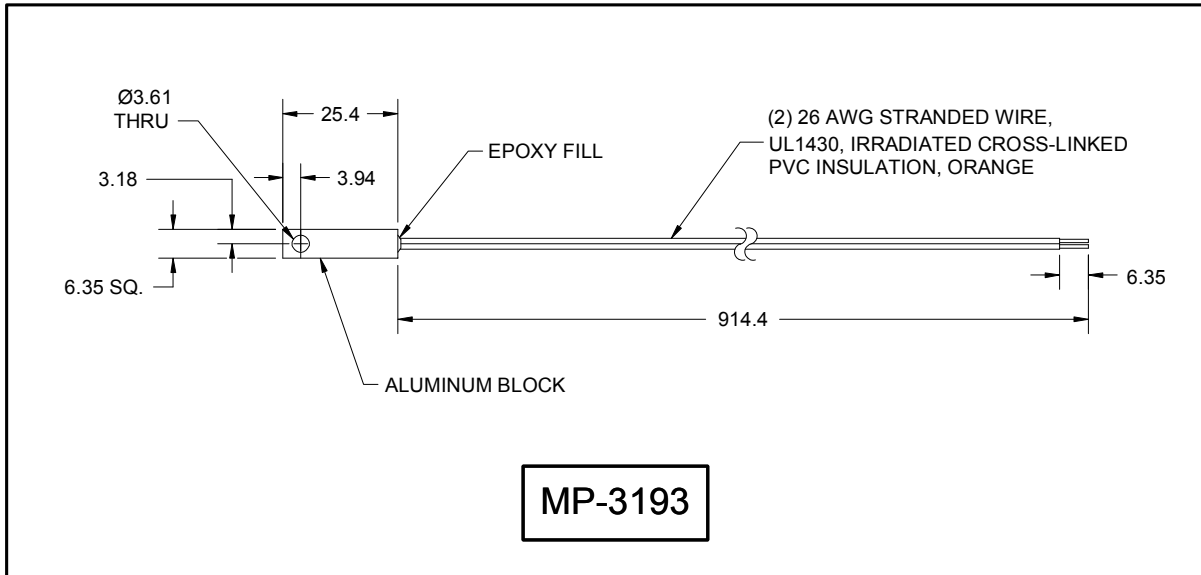
TC-48-20 OEM Mechanical Package Drawing



NOTE: ALL DIMENSIONS IN MILLIMETERS

Standard Thermistors Available for TC-48-20

Note: All dimensions in millimeters. Standard 15 k-ohms.



**Appendix A Temperature versus Resistance Curves
for MP-3193, MP-2444, and MP-2542 Thermistors (15 k-ohm)**

-20	146735	1	46709	22	17136	43	7075	64	3227	85	1601
-19	138447	2	44397	23	16388	44	6801	65	3115	86	1551
-18	130677	3	42213	24	15676	45	6539	66	3008	87	1503
-17	123390	4	40150	25	15000	46	6289	67	2905	88	1457
-16	116554	5	38199	26	14356	47	6049	68	2806	89	1412
-15	110138	6	36354	27	13744	48	5820	69	2711	90	1369
-14	104113	7	34608	28	13161	49	5600	70	2620	91	1328
-13	98454	8	32957	29	12606	50	5391	71	2532	92	1288
-12	93137	9	31394	30	12078	51	5190	72	2448	93	1250
-11	88138	10	29914	31	11574	52	4997	73	2367	94	1212
-10	83438	11	28512	32	11095	53	4813	74	2288	95	1176
-9	79016	12	27183	33	10637	54	4637	75	2213	96	1142
-8	74855	13	25925	34	10202	55	4467	76	2141	97	1108
-7	70938	14	24731	35	9786	56	4305	77	2072	98	1076
-6	67249	15	23600	36	9389	57	4150	78	2005	99	1045
-5	63773	16	22526	37	9011	58	4001	79	1940	100	1014
-4	60498	17	21508	38	8650	59	3858	80	1878		
-3	57410	18	20541	39	8306	60	3721	81	1818		
-2	54498	19	19623	40	7976	61	3590	82	1761		
-1	51750	20	18751	41	7662	62	3464	83	1705		
0	49157	21	17923	42	7362	63	3343	84	1652		

Note: Tolerance for standard thermistors is $\pm 650 \Omega$, corresponding to $\pm 1 \text{ }^\circ\text{C}$ over a $0 \text{ }^\circ\text{C}$ to $100 \text{ }^\circ\text{C}$ range.

**Temperature versus Resistance Curves
for Compatible 10 k-ohm Thermistors**

-20	97110	2	29500	24	10450	46	4202	68	1876
-19	91650	3	28060	25	10000	47	4042	69	1813
-18	86500	4	26690	26	9574	48	3889	70	1752
-17	81710	5	25400	27	9165	49	3743	71	1693
-16	77220	6	24170	28	8779	50	3603	72	1636
-15	72960	7	23020	29	8410	51	3469	73	1582
-14	69010	8	21920	30	8060	52	3340	74	1530
-13	65280	9	20880	31	7722	53	3217	75	1479
-12	61770	10	19900	32	7402	54	3099	76	1431
-11	58440	11	18970	33	7100	55	2986	77	1385
-10	55330	12	18090	34	6807	56	2878	78	1340
-9	52440	13	17260	35	6532	57	2774	79	1297
-8	49690	14	16470	36	6270	58	2675	80	1255
-7	47070	15	15710	37	6017	59	2580	81	1215
-6	44630	16	15000	38	5777	60	2488	82	1177
-5	42340	17	14330	39	5546	61	2400	83	1140
-4	40170	18	13680	40	5329	62	2316	84	1104
-3	38130	19	13070	41	5116	63	2235	85	1070
-2	36190	20	12500	42	4916	64	2157		
-1	34370	21	11940	43	4725	65	2083		
0	32660	22	11420	44	4543	66	2011		
1	31030	23	10920	45	4369	67	1942		

Appendix B Serial Communications

I. Definitions:

All numeric values are in hexadecimal format. Use lowercase ASCII characters.

Note: where applicable, the base of a number is indicated by its subscript. So, 20_{10} is the number 20 in decimal (base 10) format, and it converts to 14_{16} in hexadecimal (base 16) format.

(stx)	Start of text character (*) $2a_{16}$
(etx)	End of text character (carriage return) or $0d_{16}$
(ack)	Acknowledge character (^) or $5e_{16}$
CC	Command characters are ASCII characters from 0 through 9 or a through f.
DDDD	This is the ASCII representation of the hexadecimal return or send value. Negative numbers are represented by the hex 2's complement of the number (16-bit word size): 1 decimal = 0001_{16} in hex two's complement -1 decimal = $ffff_{16}$ in hex two's complement
SS	The 8-bit (modulo 256) checksum of characters sent to/from the controlling computer. This is represented as 2 ASCII hex characters. The checksum calculation excludes the characters (stx), SS, and (etx). <i>TC-48-20 sums (in an 8-bit register) the ASCII values of the characters sent to/from the controlling computer. Any overflow is truncated, leaving the 8-bit (modulo 256) checksum. When the controller is receiving data, this number (as represented by two hex characters) is compared to the two ASCII character hex checksum sent by the controlling computer. The TC-48-20 will respond as shown below depending on whether or not the checksums match. When the controlling computer is receiving data the checksum sent by the controller can be used to make sure the data has not been received with an error. Remember, when finding the ASCII value for a hex number (a, b, c, d, e, and f) be sure to use lower case letters.</i>

To write a command to a controller, the controlling computer must send the following ASCII characters:

(stx)CCDDDDSS(etx)

If the temperature controller receives the command and the checksum is correct, the temperature controller will respond by sending back the "send value" and the checksum of those four ASCII data characters, DDDD:

(stx)DDDDSS(ack)

To query a controller, there is no send value so the controlling computer only needs to send the ASCII command characters with the "D"s filled with zeros:

(stx)CC0000SS(etx)

If the checksum for a query is correct the temperature controller will respond by sending back a "return value" and then SS, which is the checksum of the four return value (DDDD) characters:

(stx)DDDDSS(ack)

If the checksum for a command or query is not correct the temperature controller will respond with four upper case X's and then 60, which is the checksum of these four X's:

(stx)XXXX60 (ack)

II. Examples:

A) Send the set temperature of 10.0 to the controller.

1. The control command, CC, for "DESIRED CONTROL TEMPERATURE (SET TEMPERATURE)" is 1c.
2. Multiply the desired set-point temperature by 10 ($10.0_{10} \times 10_{10} = 100_{10}$).
3. Convert 100 decimal to hexadecimal (64_{16}) and add on leading zeros to make the eight-character send value DDDD (0064).
4. Compute the checksum (SS) by adding the hexadecimal values of the following ASCII characters: 1, c, 0, 0, 6, and 4:

<u>ASCII Character:</u>	<u>Hexadecimal Value:</u>
1	31
c	63
0	30
0	30
6	36
<u>4</u>	<u>34</u>
Sum	15e₁₆

The 8-bit checksum is the 8 least significant binary bits of the sum, represented as 5e in hexadecimal.

5. Combining all of these characters in one string we send: (stx)1c00645e(etx).
6. If the temperature controller receives the command and the checksum is correct, it will send back: (stx)0064ca(ack). If the checksum is not correct the temperature controller will send back: (stx)XXXX60(ack).

B) Send the set temperature of -1.5 °C.

1. The controller command, CC, is by definition 1c.
2. Multiply the desired set-point temperature by 10_{10} ($-1.5 \times 10 = -15$).
3. Convert -15_{10} to hexadecimal by taking the two's complement of the number. (This can be easily done by using the formula $2^n - N$, where n is the word-bit size and N is the absolute value of the number being converted.) Hence, you have $2^{16} - 15 = 65521_{10}$. This value then converts to $fff1_{16}$.
4. Compute the checksum (SS) by adding the hexadecimal ASCII values of the following characters: 1, c, f, f, f, 1,:

<u>ASCII Character:</u>	<u>Hexadecimal Value:</u>
1	31
c	63
f	66
f	66
f	66
<u>1</u>	<u>31</u>
Sum	1f7₁₆

The 8-bit checksum is the 8 least significant binary bits of the sum, represented as f7 in hexadecimal.

5. Combining all of these characters in one string we send: (stx)1cff1f7(etx).
6. If the temperature controller receives the command and the checksum is correct, it will send back: (stx)fff163(ack). If the checksum is not correct the temperature controller will send back: (stx)XXXX60(ack).

C) Read the actual temperature of the control thermistor.

1. Let us assume the actual temperature is 2.5 °C
2. The control command, CC, for "CONTROL SENSOR TEMPERATURE" is 01.
3. There is no send value, so we calculate the checksum (SS) by adding the ASCII values of the characters 0, 1, 0, 0, 0, 0:

<u>ASCII Character:</u>	<u>Hexadecimal Value:</u>
0	30
1	31

0	30
0	30
0	30
<u>0</u>	<u>30</u>
Sum	121₁₆

The 8-bit checksum is the 8 least significant binary bits of the sum, represented as 21 in hexadecimal.

- Combining the characters in one string we send: (stx)0100021(etx).
- If the temperature controller receives the command and the checksum is correct, it will send back: (stx)0019ca(ack). The “ca” at the end of the string is the checksum of “0019”. The value 0019_{16} converts to 25_{10} . This number, when divided by 10, is 2.5--the temperature in °C. As in the other examples, if the controller did not calculate the correct checksum from the query it would send back: (stx)XXXX60(ack).

III. RS232 Communications Parameters:

JP5 PINS 7, 8, and 9

Communications Parameters:

- A. Baud Rate 115,200
- B. No Parity
- C. 1 Start Bit 1 Stop Bit

NOTE if you are using communications software different from the one supplied with the controller: *The demands of temperature control require a relatively large portion of the processing power of the onboard microcontroller. It is possible for a host computer to send data too quickly for the controller to receive and update. If communications is disrupted after repeated queries, TE Technology recommends adding a delay between each command sent to allow the controller sufficient time to process and respond to the query.*

IV. Serial Commands:

1. MODEL CODE

Write Command: NA

Read Command: 00

Interpret: 9613 returned.

2. CONTROL SENSOR TEMPERATURE

Write Command: NA

Read Command: 01

Interpret: Convert returned value to decimal and divide by 10.0_{10} for temperature in °C.

3. POWER OUTPUT

Write Command: NA

Read Command: 02

Interpret: 511_{10} represent 100% output.
 0_{10} returned is 0% output.

4. SECONDARY SENSOR TEMPERATURE

Write Command: NA

Read Command: 04

Interpret: Convert returned value to decimal and divide by 10.0_{10} for temperature in °C

5. ALARM STATUS

Write Command: NA

Read Command: 03

Interpret:

Convert the hex number to binary and interpret bits as follows:

All zeros==means no alarms.

Bit 0==1 means HIGH ALARM 1.

Bit 1==1 means LOW ALARM 1.

Bit 2==1 means HIGH ALARM 2.

Bit 3==1 means LOW ALARM 2.

Bit 4==1 means OPEN CONTROL SENSOR.

Bit 5==1 means OPEN SECONDARY SENSOR.

Bit 6==1 means a value has changed via keypad entry.

For example, suppose the returned value is 0009₁₆. This converts to 001001₂, which means that there is a low alarm condition for the secondary sensor and a high alarm condition for the control sensor.

"Bit 0" is the rightmost bit, or the least significant bit.

6. DESIRED CONTROL TEMPERATURE (SET TEMPERATURE)

Write Command: 1c

Read Command: 50

Interpret:

ASCII characters which represent a hex value in two's complement form. Convert the two's complement value to a decimal value and divide by 10.0 to represent the temperature as a degrees decimal value.

7. PROPORTIONAL BANDWIDTH

Write Command: 1d

Read Command: 51

Interpret:

Proportional bandwidth in degrees.

For writing, multiply desired bandwidth by 10₁₀ then convert to hexadecimal. For reading, convert to decimal then divide by 10₁₀.

1 degree bandwidth would be 10₁₀.

20 degree bandwidth would be 200₁₀.

8. INTEGRAL GAIN

Write Command: 1e

Read Command: 52

Interpret:

Gain in repeats/minute

For writing, multiply desired integral gain by 100₁₀ then convert to hexadecimal. For reading, convert to decimal then divide by 100₁₀.

0.01 repeats/minute would be 1₁₀.

1.00 repeats/minute would be 100₁₀.

9. DERIVATIVE GAIN

Write Command: 1f

Read Command: 53

Interpret:

Gain in minutes.

For writing, multiply desired integral gain by 100₁₀ then convert to hexadecimal. For reading, convert to decimal then divide by 100₁₀.

0.01 minutes would be 1₁₀.

1.00 minutes would be 100₁₀.

10. ALARM1 TYPE
 Write Command: 27
 Read Command: 5b
 Interpret: 0 no load effect.
 1 load off on alarm.
11. ALARM2 TYPE
 Write Command: 2a
 Read Command: 5e
 Interpret: 0 no load effect
 1 load off on alarm
12. SENSOR CHOICE
 Write Command: 20
 Read Command: 54
 Interpret: 0 = 15K sensor is selected.
 1 = 10K sensor is selected.
13. CONTROL MODE
 Write Command: 21
 Read Command: 55
 Interpret: 0 = COOLING mode.
 1 = HEATING mode.
14. LOW SET RANGE
 Write Command: 22
 Read Command: 56
 Interpret: This is used to set the lowest temperature that the controller set point can be set to.
15. HIGH SET RANGE
 Write Command: 23
 Read Command: 57
 Interpret: This is used to set the highest temperature that the controller set point can be set to.
16. CONTROL SENSOR OFFSET
 Write Command: 24
 Read Command: 58
 Interpret: Value to offset control sensor in order to calibrate external sensor if desired.
17. ALARM 1 LOW SETTING
 Write Command: 25
 Read Command: 59
 Interpret: Temperature reference to compare against control sensor for high alarm output. Temperatures are in whole degree increments. To turn the low alarm OFF set the alarm temperature to -21_{10} ($ffeb_{16}$).
18. ALARM 1 HIGH SETTING
 Write Command: 26
 Read Command: 5a
 Interpret: Temperature reference to compare against control sensor for high alarm output. Temperatures are in whole degree increments. To turn the high alarm OFF set the alarm temperature to 200_{10} ($00c8_{16}$).

19. ALARM 2 LOW SETTING
Write Command: 28
Read Command: 5c
Interpret:

Temperature reference to compare against secondary sensor for high alarm output. Temperatures are in whole degree increments. To turn the low alarm OFF set the alarm temperature to -21 (ffeb₁₆).

20. ALARM 2 HIGH SETTING
Write Command: 29
Read Command: 5d
Interpret:

Temperature reference to compare against secondary sensor for high alarm output. Temperatures are in whole degree increments. To turn the high alarm OFF set the alarm temperature to 200 (00c8₁₆).

21. ALARM LATCH FUNCTION
Write Command: 2b
Read Command: 5f
Interpret:

0 = NO LATCHES
1 = ALARM 1 LATCH
2 = ALARM 2 LATCH
3 = ALARM 1&2 LATCH

22. TEMPERATURE 2 DISPLAY
Write Command: 2c
Read Command: 60
Interpret:

0 = OFF
1 = AUTOMATIC
2 = ON

23. ALARM 1 DEADBAND
Write Command: 2d
Read Command: 61
Interpret:

The span in temperature that the control sensor must move before the ALARM 1 output is toggled off.
For writing, multiply desired deadband by 10₁₀ then convert to hexadecimal. For reading, convert to decimal then divide by 10₁₀.
1 degree would be 10₁₀
20 degrees would be 200₁₀

24. ALARM 2 DEADBAND
Write Command: 2e
Read Command: 62
Interpret:

The span in temperature that the secondary sensor must move before the ALARM 2 output is toggled off.
For writing, multiply desired deadband by 10₁₀ then convert to hexadecimal. For reading, convert to decimal then divide by 10₁₀.
1 degree would be 10 decimal
20 degrees would be 200 decimal

25. ANALOG OUTPUT MULTIPLIER

Write Command: 2f

Read Command: 63

Interpret:

For writing, multiply desired analog output multiplier by 100_{10} then convert to hexadecimal. For reading, convert to decimal then divide by 100_{10} . Allowable range is 0 to 1.00_{10} .

1.00 multiplier is a value of 100_{10}

0.50 multiplier is a value of 50_{10}

0.00 multiplier is a value of 0

26. LATCH CLEAR

Write Command: 33

Read Command: NA

Interpret:

Send this command to reset alarm latches.

27. OUTPUT ENABLE

Write Command: 30

Read Command: 64

Interpret:

0 = OFF

1 = ON

28. EEPROM WRITE ENABLE

Write Command: 31

Read Command: 65

Interpret:

0 = OFF

1 = ON

NOTE: this command valid only for firmware versions H and higher. EEPROM WRITE ENABLE is automatically turned "ON" whenever the controller is turned on. Note: for the TC-48-20 only, regardless of the EEPROM WRITE ENABLE setting, changes made to parameters via keypad are automatically stored in the EEPROM. This feature can not be turned off.

27. REVISION LEVEL

Write Command: NA

Read Command: 05

Interpret:

08 = H

09 = I

10 = J

11 = K

12 = L

13 = M

14 = N

15 = O

16 = P

17 = Q

18 = R

19 = S

20 = T

21 = U

22 = V

23 = W

24 = X

25 = Y

26 = Z

V. ASCII Reference Table

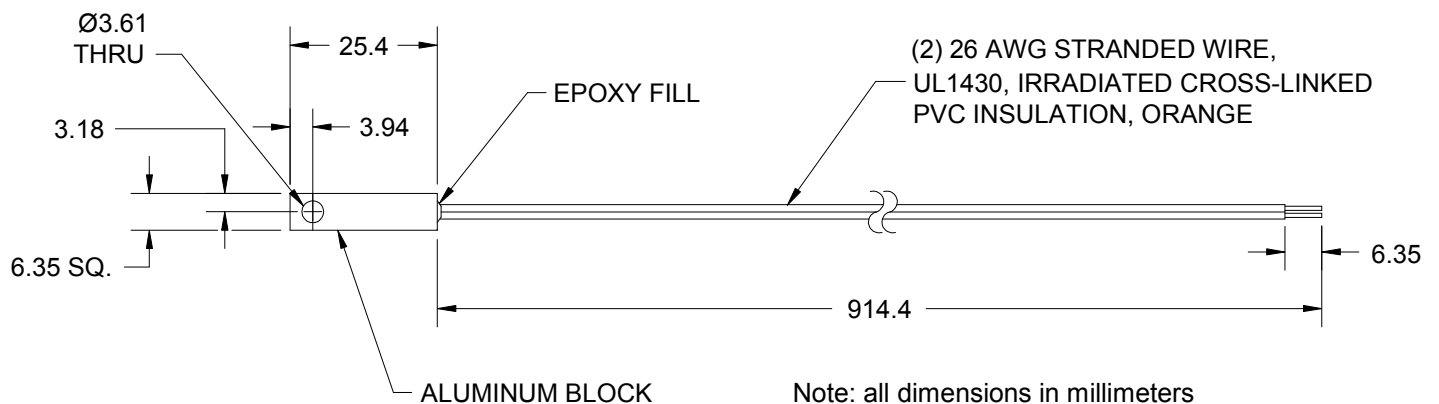
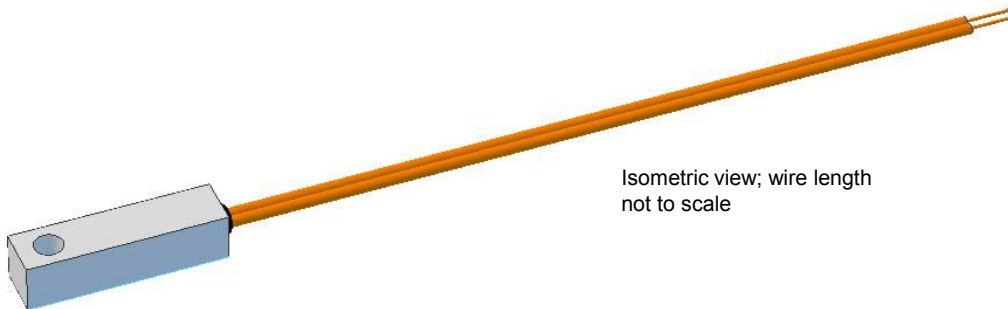
Dec	Oct	Hex	Binary	Description
000	000	00	00000000	^@ ^` NULL NUL null c-@ c-`
001	001	01	00000001	^A ^a SOH GTL c-A c-a start-of-heading
002	002	02	00000010	^B ^b STX c-B c-b start-of-text
003	003	03	00000011	^C ^c ETX c-C c-c end-of-text
004	004	04	00000100	^D ^d EOT SDC end-of-transmission c-D c-d ..._._
005	005	05	00000101	^E ^e ENQ PPC c-E c-e enquiry
006	006	06	00000110	^F ^f ACK c-F c-f acknowledge
007	007	07	00000111	^G ^g BELL BEL bell c-G c-g \a
008	010	08	00001000	^H ^h BS GET backspace c-H c-h \b
009	011	09	00001001	^I ^i TAB TCT HT tab c-I c-i \t
010	012	0A	00001010	^J ^j LF lf linefeed c-J c-j \n
011	013	0B	00001011	^K ^k VT vertical-tab c-K c-k \v
012	014	0C	00001100	^L ^l FF ff formfeed page \f c-L c-l
013	015	0D	00001101	^M ^m CR cr carriage-return c-M c-m \r
014	016	0E	00001110	^N ^n SO c-N c-n shift-out
015	017	0F	00001111	^O ^o SI c-O c-o shift-in
016	020	10	00010000	^P ^p DLE c-P c-p data-link-escape
017	021	11	00010001	^Q ^q DC1 LLO go XON xon c-Q c-Q
018	022	12	00010010	^R ^r DC2 c-R c-r
019	023	13	00010011	^S ^s DC3 stop XOFF xoff c-S c-s
020	024	14	00010100	^T ^t DC4 DCL c-T c-t
021	025	15	00010101	^U ^u NAK PPU negative-acknowledge c-U c-u
022	026	16	00010110	^V ^v SYN c-V c-v synchronous-idle
023	027	17	00010111	^W ^w ETB end-of-transmission-block c-W c-w
024	030	18	00011000	^X ^x CAN SPE c-X c-x cancel
025	031	19	00011001	^Y ^y EM SPD c-Y c-y end-of-medium
026	032	1A	00011010	^Z ^z SUB suspend c-Z c-z substitute
027	033	1B	00011011	^[^{ ESC escape c-[c-{ m-
028	034	1C	00011100	^\\ ^ FS field-separator c-\ c-
029	035	1D	00011101	^] ^} GS group-separator
030	036	1E	00011110	^^ ^~ RS record-separator c-^ c-~
031	037	1F	00011111	^_ ^DEL unit-separator US c-_ c-DEL
032	040	20	00100000	SPC space spc
033	041	21	00100001	! exclamation-point
034	042	22	00100010	" straight-double-quotation-mark
035	043	23	00100011	# number-sign
036	044	24	00100100	\$ @@ dollar-sign
037	045	25	00100101	% percent-sign
038	046	26	00100110	& ampersand
039	047	27	00100111	' apostrophe
040	050	28	00101000	(left-parenthesis
041	051	29	00101001) right-parenthesis
042	052	2A	00101010	* asterisk star
043	053	2B	00101011	+ addition-sign
044	054	2C	00101100	, comma
045	055	2D	00101101	- subtraction-sign minus hyphen negative dash
046	056	2E	00101110	. period dot decimal
047	057	2F	00101111	/ right-slash
048	060	30	00110000	0
049	061	31	00110001	1

050	062	32	00110010	2
051	063	33	00110011	3
052	064	34	00110100	4
053	065	35	00110101	5
054	066	36	00110110	6
055	067	37	00110111	7
056	070	38	00111000	8
057	071	39	00111001	9
058	072	3A	00111010	: colon
059	073	3B	00111011	; semicolon
060	074	3C	00111100	< less-than
061	075	3D	00111101	= equals
062	076	3E	00111110	> greater-than, right-chevron
063	077	3F	00111111	? question-mark, query
064	100	40	01000000	@ at-symbol, at-sign
065	101	41	01000001	A
066	102	42	01000010	B
067	103	43	01000011	C
068	104	44	01000100	D
069	105	45	01000101	E
070	106	46	01000110	F
071	107	47	01000111	G
072	110	48	01001000	H
073	111	49	01001001	I
074	112	4A	01001010	J
075	113	4B	01001011	K
076	114	4C	01001100	L
077	115	4D	01001101	M
078	116	4E	01001110	N
079	117	4F	01001111	O
080	120	50	01010000	P
081	121	51	01010001	Q
082	122	52	01010010	R
083	123	53	01010011	S
084	124	54	01010100	T
085	125	55	01010101	U
086	126	56	01010110	V
087	127	57	01010111	W
088	130	58	01011000	X
089	131	59	01011001	Y
090	132	5A	01011010	Z
091	133	5B	01011011	[left-bracket, open-square
092	134	5C	01011100	\ left-slash, backslash bash
093	135	5D	01011101] right-bracket, close-square
094	136	5E	01011110	^ hat, circumflex, caret, up-arrow
095	137	5F	01011111	_ UNT, underscore, underbar
096	140	60	01100000	` accent-grave, backprime, backquote
097	141	61	01100001	a
098	142	62	01100010	b
099	143	63	01100011	c
100	144	64	01100100	d
101	145	65	01100101	e
102	146	66	01100110	f
103	147	67	01100111	g

104	150	68	01101000	h
105	151	69	01101001	i
106	152	6A	01101010	j
107	153	6B	01101011	k
108	154	6C	01101100	l
109	155	6D	01101101	m
110	156	6E	01101110	n
111	157	6F	01101111	o
112	160	70	01110000	p
113	161	71	01110001	q
114	162	72	01110010	r
115	163	73	01110011	s
116	164	74	01110100	t
117	165	75	01110101	u
118	166	76	01110110	v
119	167	77	01110111	w
120	170	78	01111000	x
121	171	79	01111001	y
122	172	7A	01111010	z
123	173	7B	01111011	{ left-brace begin
124	174	7C	01111100	logical-or vertical-bar
125	175	7D	01111101	} right-brace end
126	176	7E	01111110	~ similar
127	177	7F	01111111	^? DEL rubout delete

MP-3193 Temperature Sensor

- NTC thermistor temperature sensor.
- Durable aluminum housing.
- Long wires eliminate the need for adding extension wires in most applications.
- Large contact area for accurate surface-temperature measurements (cold plates); can also be used for measuring air temperatures.



RoHS Compliant
Directive 2002/95/EC

TE TECHNOLOGY, INC.®

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Traverse City, MI 49696-8257
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email: cool@tetech.com

MP-3193 Temperature Sensor

Sensor resistance at 25 °C:	15,000±650 ohms
Sensor tolerance between 0 ° to 70 °C:	±1.0 °C
Operating range:	-20 °C to +100 °C
Weight:	8 grams

TEMPERATURE, °C	RESISTANCE, OHMS	TEMPERATURE, °C	RESISTANCE, OHMS	TEMPERATURE, °C	RESISTANCE, OHMS
-20	146735	21	17923	61	3590
-19	138447	22	17136	62	3464
-18	130677	23	16388	63	3343
-17	123390	24	15676	64	3227
-16	116554	25	15000	65	3115
-15	110138	26	14356	66	3008
-14	104113	27	13744	67	2905
-13	98454	28	13161	68	2806
-12	93137	29	12606	69	2711
-11	88138	30	12078	70	2620
-10	83438	31	11574	71	2532
-9	79016	32	11095	72	2448
-8	74855	33	10637	73	2367
-7	70938	34	10202	74	2288
-6	67249	35	9786	75	2213
-5	63773	36	9389	76	2141
-4	60498	37	9011	77	2072
-3	57410	38	8650	78	2005
-2	54498	39	8306	79	1940
-1	51750	40	7976	80	1878
0	49157	41	7662	81	1818
1	46709	42	7362	82	1761
2	44397	43	7075	83	1705
3	42213	44	6801	84	1652
4	40150	45	6539	85	1601
5	38199	46	6289	86	1551
6	36354	47	6049	87	1503
7	34608	48	5820	88	1457
8	32957	49	5600	89	1412
9	31394	50	5391	90	1369
10	29914	51	5190	91	1328
11	28512	52	4997	92	1288
12	27183	53	4813	93	1250
13	25925	54	4637	94	1212
14	24731	55	4467	95	1176
15	23600	56	4305	96	1142
16	22526	57	4150	97	1108
17	21508	58	4001	98	1076
18	20541	59	3858	99	1045
19	19623	60	3721	100	1014
20	18751				

Please review the product manual: *Thermoelectric Temperature Controller Sensor Attachment with Notes on Thermocouples*, FAQ's and related technical information, and ordering information posted on our web site before purchasing or using this product. When used in conjunction with a Peltier-Thermoelectric Cooler Assembly or Module, please review the *Thermoelectric Cooling Assembly (TCA) Instruction Manual* or *TEM (Thermoelectric Module) Mounting Procedure*. When used in conjunction with a temperature controller, please review the temperature controller manual. These manuals contain general information, guidelines, and precautions for thermoelectric cooling and control applications.

FINAL DETERMINATION OF THE SUITABILITY OF THE PRODUCT IS THE SOLE RESPONSIBILITY OF THE USER. TE TECHNOLOGY MAKES NO WARRANTY, REPRESENTATION OR GUARANTEE REGARDING THE SUITABILITY, NOR DOES TE TECHNOLOGY ASSUME ANY LIABILITY RESULTING FROM USE AND SPECIFICALLY DISCLAIMS ANY AND ALL LIABILITY, INCLUDING WITHOUT LIMITATION CONSEQUENTIAL OR INCIDENTAL DAMAGES.



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Hydro Series H75 Liquid CPU Cooler



Copper microfin coldplate

The coldplate draws heat from your CPU into the circulating liquid. Copper has outstanding thermal conductivity, and the microfin design provides fast and efficient heat transfer.

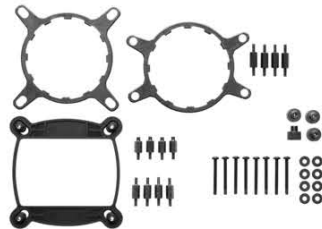
25mm x 120mm radiator

The 25mm thickness combines ample cooling surface area with a low-profile size that's ideal for smaller cases or any installation where space is at a premium.



Dual high-torque 120mm PWM fans

Dual fans mount on opposite sides of the radiator for high-speed push-pull airflow. You can connect them to the standard PWM fan headers on your motherboard for precise fan speed control, and select the exact level of cooling performance you need.



Tool free bracket installation

All mounting hardware is included. Installation is simpler and you don't need to go hunting for a screwdriver.



Contents and Specifications

Package contents

- > Hydro Series H75 Liquid CPU Cooler
- > Mounting Hardware
- > Dual SP120L 120mm PWM fans
- > User Installation Guide
- > Warranty Leaflet

Technical specifications

- > Radiator dimensions: 120mm x 152mm x 25mm
- > Fan dimensions: 120mm x 120mm x 25mm
- > Fan speed: 2000 RPM
- > Fan airflow: 54 CFM
- > Fan dBA: 31.4 dBA
- > Fan static pressure: 2.8 mm/H2O

Compatibility

- > Intel™ LGA 1150, 1151, 1155, 1156, 1366, and 2011
- > AMD™ sockets FM1, FM2, AM2, and AM3



GeminII M4

RR-GMM4-16PK-R1



GeminII M4 is a super low profile CPU cooler (59mm / 2.3in height) designed for a system with limited space, such as mini-ITX, HTPC, or any small desktop. With its 4 direct contact heat pipes and unique heat pipe layout, GeminII M4 not only keeps compact size but provides amazing cooling performance.

Features

- Super low profile cooler (59mm / 2.3in height) with 4 direct contact heat pipes.
- A base engineered to minimize CPU contact gaps provides excellent heat conduction.
- Suitable for limited space applications (e.g. HTPC or slim systems).
- Newly developed thin fan profile delivers uncompromised cooling performance in a compact package.
- Unique heat pipe layout combines two very effective cooling methods to increase cooling efficiency while maintaining a low profile heat sink

Package Information


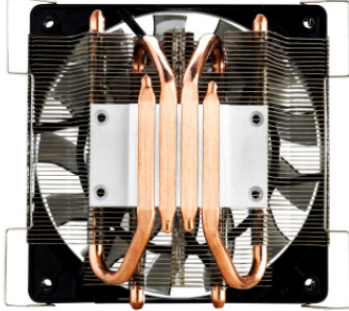
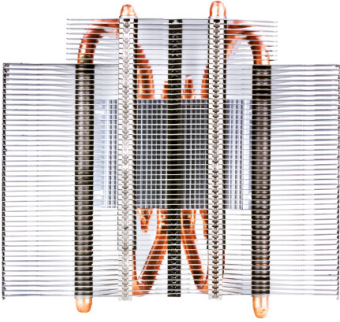
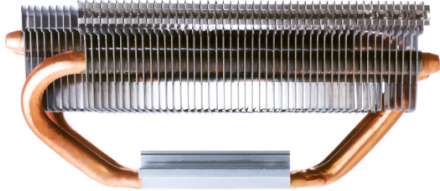


EAN Code	4719512032930
UPC Code	884102013140
Package Dimensions	152 x 93 x 175 mm (6.0 x 3.7 x 6.9 inch)
Carton Dimensions	403 x 322 x 383 mm (15.9 x 12.7 x 15.1 inch)
Unit / Carton	16
Carton / Pallet	45

Specifications

CPU Socket	Intel® LGA1366/1156/1155/775 AMD FM1/AM3+/AM3/AM2+/AM2
Dimensions	137 x 122 x 59mm (5.4 x 4.8 x 2.3 inch)
Heat Sink Dimensions	120x 118 x 44 mm (4.7 x 4.6 x 1.7 inch)
Heat Sink Material	4 Direct Contact Heat Pipes Aluminum Fins
Heat Sink Weight	210g (0.46 lb)
Heat Pipe Dimensions	Ø6mm
Fan Dimensions	120 x 120 x 15mm (4.7 x 4.7 x 0.6 inch)
Fan Speed	500 - 1600 RPM (PWM) ± 10%
Fan Air Flow	17.4 - 58.4 CFM ± 10%
Fan Air Pressure	0.18 - 1.76mm H ₂ O ± 10%
Fan Life Expectancy	40,000 hrs
Noise Level	8 - 30 dBA
Bearing Type	Long Life Sleeve Bearing
Connector	4-Pin
Fan Weight	79g (0.17 lb)
Weight	289g (0.64 lb)

Warranty

2 years

	
<p>CPU cooler with a super low profile (59mm / 2.3in attached fan)</p>	<p>Improved direct contact heat pipe base</p>
	
<p>Aluminum fins with 4 direct contact heat pipes</p>	<p>Unique heat pipe layout – combine "U-shape" and "C-shape" pipes</p>
	
<p>HTPC and slim system compatibility</p>	<p>New super slim fan with a thickness of only 15mm</p>

Note: Photos may differ slightly from the final product.

Grounding Screw Specifications (as published by Fastenal®)

Part #10-32 x 3/8" Slotted Head Green Die Finish Grounding Screw



Wholesale: \$12.75 / package

Unit Price: \$0.1275 / each

Units / package: 100

Specifications

Diameter	#10
Drive	Slotted
Finish	Green
Head	Hex Washer
Length	3"
Material	Steel
Thread	Fine
Thread Size	32
Type	Grounding Screw
Product Weight	61 lbs. (per package)

Notes:

- Thread-forming
- Hole-finding tip combination hex, Phillips, slotted & Robertson head
- Will ground each of the sheet metal assemblies

Fastener Specifications (as published by PennEngineering®)

Part # SKC-F1.5, KEYHOLE® Sheet Joining Fasteners Type SKC-F™ - Unified



Specifications

Panel 1 (Bottom) Sheet Thickness Min.	.039 in
Panel 1 (Bottom) Mounting Hole B +.003 -.000	.213 in
Panel 2 (Top) Thickness Range	.057 to .064 in
Panel 2 (Top) Mounting Hole A1 Nom. *	.059 in
Panel 2 (Top) Mounting Hole A2 ± .003 *	.118 in
Panel 2 (Top) Mounting Hole A3 ± .003 *	.197 in
Panel 2 (Top) Mounting Hole A4 Min. *	.148 in
Panel 1 (Bottom) Sheet Harness Max. ¹	HRB 70 / HB 125
Panel 2 (Top) Material	Any
A Max. **	.039 in
B ± .003 **	.177 in
C Max. **	.212 in
D Anvil Hole +.003 -.000 **	.184 in
H Nom. **	.237 in
M Max. **	.108 in
N ± .003 **	.099 in
S ± .003 **	.068 in
Panel 1 (Bottom) Edge Distance C1 Min. ***	.150 in
Panel 1 (Bottom) Location Tolerance Max. ***	± .005 in
Panel 2 (Top) Edge Distance C2 Min. ***	.160 in
Standard Material	300 Series stainless steel
Standard Finish	Passivated and/or tested per ASTM A380
CAD Supplier	PennEngineering® (PEM®)

* Refer to layout diagram as shown in Figure 1.1.

** Refer to layout diagram as shown in Figure 1.2.

*** Refer to layout diagram as shown in Figure 1.3.

Fastener Specifications (as published by PennEngineering®)

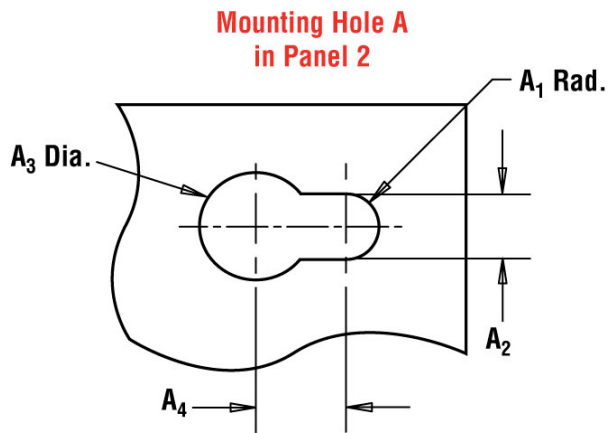


Figure 1.1. Mounting Hole Layout on Panel 2 (Top).

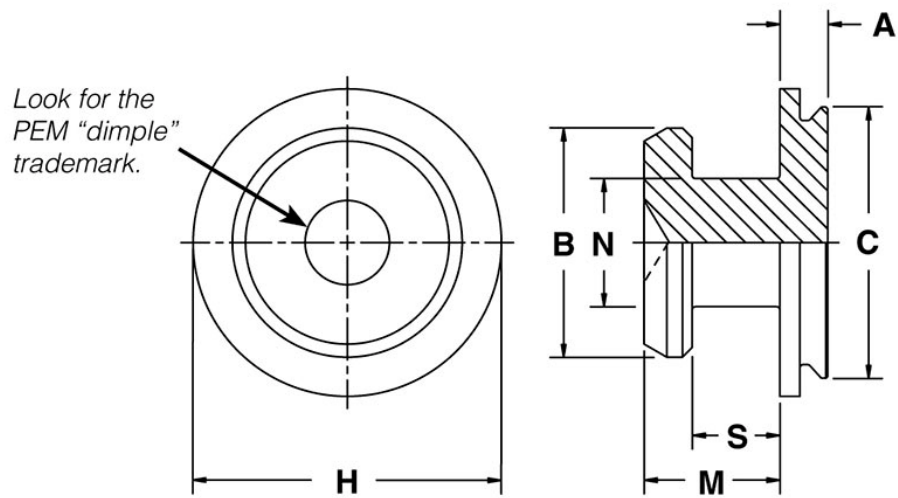


Figure 1.2. Dimensions for SKC-F1.5 KEYHOLE® Sheet Joining Fastener.

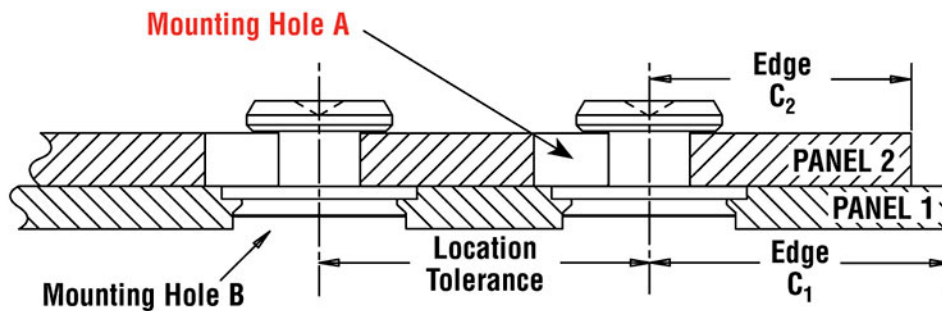


Figure 1.3. Locations and Tolerances for SKC-F1.5 KEYHOLE® Sheet Joining Fastener.

Fastener Specifications (as published by PennEngineering®)

Part # PF51-440-0 CN, Captive Panel Screw-Low Profile Knob, Spring-loaded - Unified PF50/PF60 Series



Specifications

Thread Size	.112-40 (#4-40)
Type	Knurled Cap – PF51
Thread Code	440
Screw Length Code	0
A (Shank) Max. *	.038 in
Min. Sheet Thickness	.040 in
Hole Size in Sheet +.003 -.000	.203 in
C Max. *	.202 in
E +.015 -.005 *	.406 in
N ± .025 *	.230 in
H ± .008 *	.207 in
P ± .025 *	.000 in
T1 Max. *	.340 in
T2 Nom. *	.520 in
Driver Size	#1 Phillips
Min. Dist. Hole C/L to Edge	.260 in
Thread Specification ¹	ANSI B1.1, 2A
Material Knob	Carbon Steel
Material Retainer	Carbon Steel
Material Screw	Carbon Steel
Material Spring	300 Series stainless steel
Finish Knob	Bright nickel over copper flash per ASTM B689
Finish Retainer	(same as above)
Finish Screw	(same as above)
Finish Spring	Natural Finish
For Use in Sheet Hardness	HRB 60 / HB107 or Less
CAD View	Unfastened
CAD Supplier	PennEngineering® (PEM®)

* Refer to layout diagram as shown in Figure 2.1.

** Refer to layout diagram as shown in Figure 2.2.

Fastener Specifications (as published by PennEngineering®)

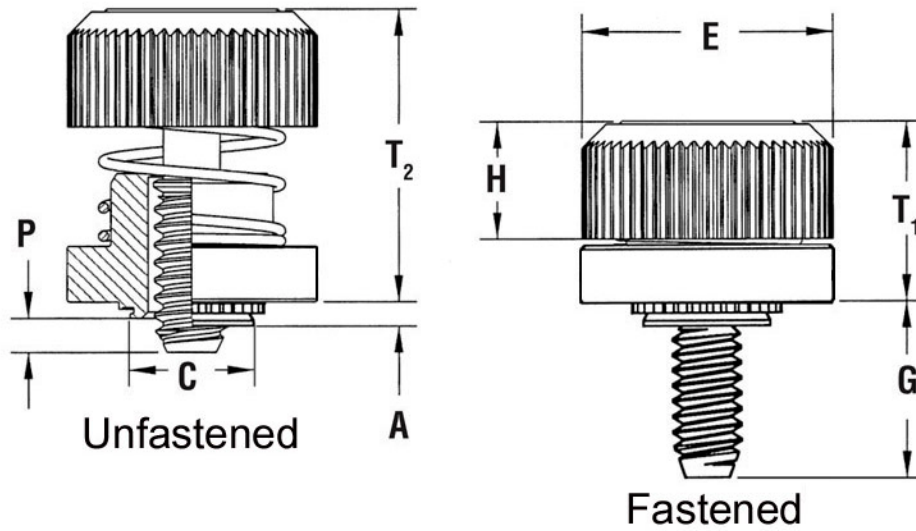


Figure 2.1. Dimensions for PF51-440-0 CN.

Four dimples on head designate metric thread.

Phillips driver size.
(See chart)

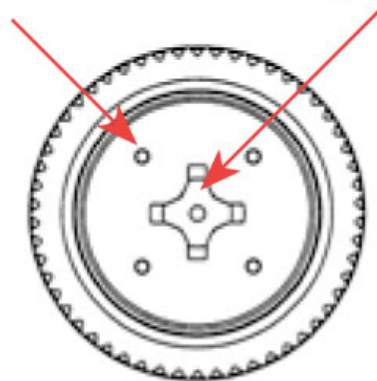


Figure 2.2. PF51-440-0 CN – top view (Phillips head).

Fastener Specifications (as published by PennEngineering®)

Part # SP-0420-2, Self-Clinching Nuts – Types, SS, CLS, CLSS, SP - Unified

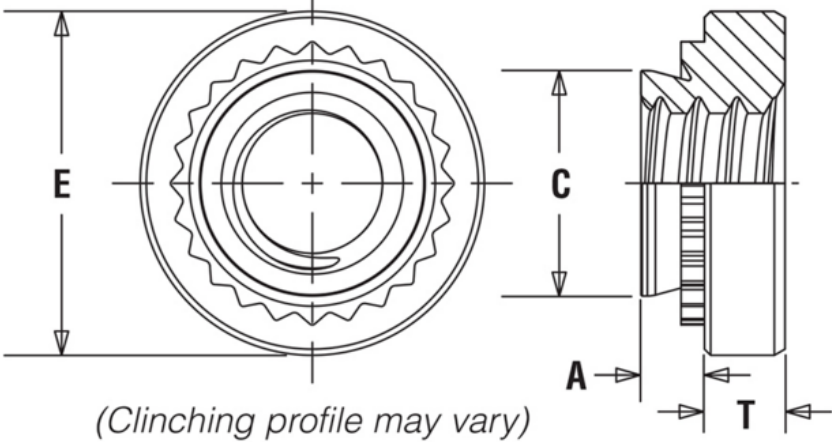


Specifications

Thread Size	.250-20 (1/4-20)
Thread Code	0420
Shank Code	2
A (Shank) Max. *	.038 in
Rec. Min. Sheet Thickness ¹	.040 in
Hole Size in Sheet +.003 -.000	.203 in
C Max. *	.202 in
E ± .010 *	.406 in
T ± .010 *	.230 in
Min. Dist. Hole C/L to Edge * ²	.260 in
For Use in Sheet Hardness ³	HRB 60 / HB 185 or Less
Thread Specification ¹	Internal ANSI B1.1, 2B
Fastener Material	Aged Hardened 286 A286 Stainless Steel
Standard Finish	Passivated and/or tested per ASTM A380
CAD Supplier	PennEngineering® (PEM®)

* Refer to layout diagram as shown in Figure 3.1.

Fastener Specifications (as published by PennEngineering®)



*(Clinching profile may vary)
Due to manufacturing procedure, parts
may have a counterbore at shank end.*

Figure 3.1. Dimensions for SP-0420-2, Self-Clinching Nut.

Fastener Specifications (as published by PennEngineering®)

Uses:

All fasteners will be press fitted onto the locations specified in the sheet layout drawings. Refer to *Figure 4.1* below to see how they will be press-fitted.

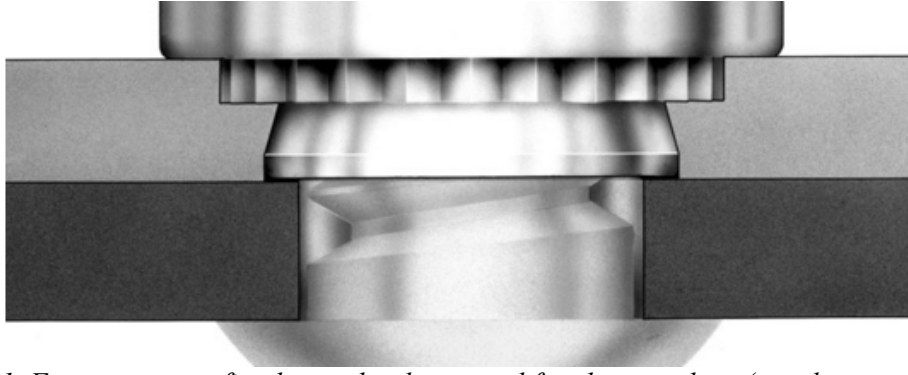


Figure 4.1. Fasteners press fitted onto the sheet metal for sheet-to-sheet (panel-to-panel) assembly.

Socket Button Head Size Chart

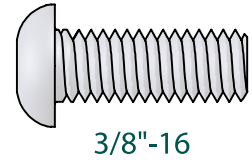
www.boltdepot.com/tools



#2-56



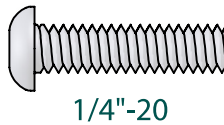
#12-24



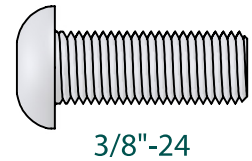
3/8"-16



#4-40



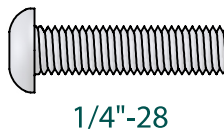
1/4"-20



3/8"-24



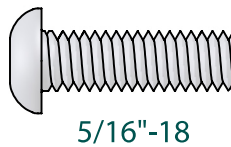
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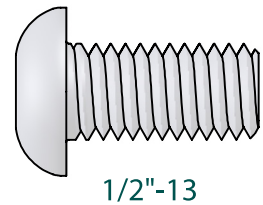
1/4"-28



#8-32



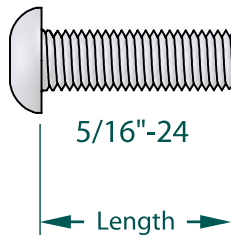
5/16"-18



1/2"-13

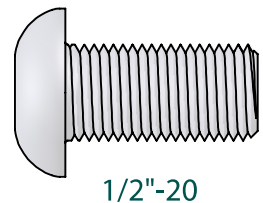


#10-24



5/16"-24

← Length →



1/2"-20



#10-32

Fastener length is measured from where the material surface is assumed to be, to the end of the fastener.

IMPORTANT: Make sure to print this chart to **Actual Size** (no scaling).
After printing, measure the scale check below to ensure correct scale. See boltdepot.com/tools for more details.



Appendix E Detailed Supporting Analysis

Cooling Load Calculations

Determining cooling load required to cool 48 50ml vials from room temperature down to the target temperature of 5 °C.

Assumptions:

- Vials filled to the maximum vial capacity
- Specific heat and density of the allergen solutions resemble the specific heat of water
- Efficiency is estimated, taking thermal resistance of the glass vial into consideration

Volume, $V_{vial} = 50 \text{ ml}$

Specific Heat, $c = 4.18 \text{ kJ/kg-K}$

Density, $\rho = 1000 \text{ kg/m}^3$

Ambient Temperature, $T_{amb} = 25^\circ\text{C}$

Target Temperature, $T_{target} = 5^\circ\text{C}$

Desired Cooling Time, $\Delta t = 1 \text{ hr}$

Cooling Efficiency, $\eta = 90\%$

Number of vials cooled = 48 vials

Individual Vials:

$$\dot{Q}_{indiv} = \frac{c\rho V_{vial}\Delta T}{\Delta t} = \frac{c\rho V_{vial}(T_{amb} - T_{target})}{\Delta t}$$

$$\dot{Q}_{indiv} = \frac{\left(1000 \frac{\text{kg}}{\text{m}^3}\right) (50 \text{ ml}) \left(\frac{1 \text{ m}^3}{10^6 \text{ ml}}\right) \left(4.18 \frac{\text{kJ}}{\text{kgK}}\right) (25 - 5) \text{K}}{1 \text{ hr} \left(\frac{3600 \text{ s}}{1 \text{ hr}}\right)}$$

$$\dot{Q}_{indiv} = 1.16 \text{ W per vial}$$

Total Load:

$$\dot{Q}_{total} = 48\dot{Q}_{indiv}$$

$$\dot{Q}_{total} = 48 (1.16 \text{ W})$$

$$\dot{Q}_{total} = 55.73 \text{ W}$$

$$\dot{Q}_{design} = \frac{\dot{Q}_{total}}{\eta}$$

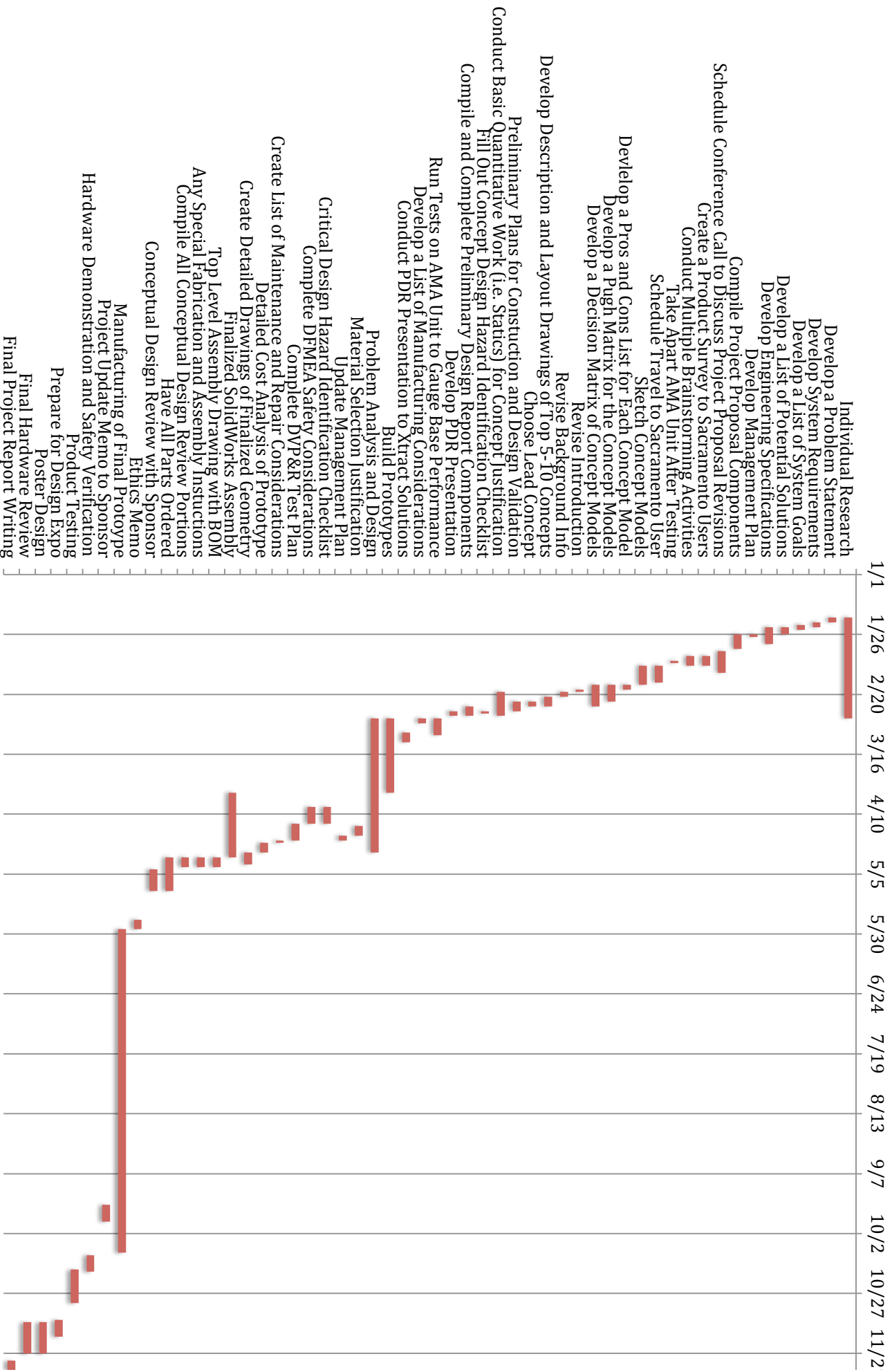
$$\dot{Q}_{design} = \frac{55.73 \text{ W}}{0.90}$$

$$\dot{Q}_{design} = 61.92 \text{ W}$$

Appendix E Gantt Chart

Task Name	Start	End	Duration (days)
Individual Research	1/19/16	3/1/16	42
Develop a Problem Statement	1/19/16	1/21/16	2
Develop System Requirements	1/21/16	1/23/16	2
Develop a List of System Goals	1/22/16	1/24/16	2
Develop a List of Potential Solutions	1/23/16	1/26/16	3
Develop Engineering Specifications	1/23/16	1/30/16	7
Develop Management Plan	1/26/16	1/27/16	1
Compile Project Proposal Components	1/26/16	2/1/16	6
Schedule Conference Call to Discuss Project Proposal Revisions	2/2/16	2/11/16	9
Create a Product Survey to Sacramento Users	2/4/16	2/8/16	4
Conduct Multiple Brainstorming Activities	2/4/16	2/8/16	4
Take Apart AMA Unit After Testing	2/6/16	2/7/16	1
Schedule Travel to Sacramento User	2/8/16	2/15/16	7
Sketch Concept Models	2/8/16	2/16/16	8
Develop a Pros and Cons List for Each Concept Model	2/16/16	2/18/16	2
Develop a Pugh Matrix for the Concept Models	2/16/16	2/23/16	7
Develop a Decision Matrix of Concept Models	2/16/16	2/25/16	9
Revise Introduction to include Project Definition, Justification and Motivation	2/18/16	2/19/16	1
Revise Background Info to Include Competitor Info, Similar Systems, Standard Testing/Validation Regimes, Literature, etc	2/19/16	2/21/16	2
Develop Description and Layout Drawings of Top 5-10 Concepts	2/21/16	2/25/16	4
Choose Lead Concept	2/23/16	2/25/16	2
Preliminary Plans for Constuction and Design Validation	2/23/16	2/27/16	4
Conduct Basic Quantitative Work (i.e. Statics) for Concept Justification	2/19/16	2/29/16	10
Fill Out Concept Design Hazard Identification Checklist	2/27/16	2/28/16	1
Compile and Complete Preliminary Design Report Components	2/25/16	2/29/16	4
Develop PDR Presentation	2/27/16	2/29/16	2
Run Tests on AMA Unit to Gauge Base Performance	3/1/16	3/8/16	7
Develop a List of Manufacturing Considerations	3/1/16	3/3/16	2
Conduct PDR Presentation to Xtract Solutions	3/7/16	3/11/16	4
Build Prototypes	3/1/16	4/1/16	31
Problem Analysis and Design	3/1/16	4/26/16	56
Material Selection Justification	4/15/16	4/19/16	4
Update Management Plan	4/19/16	4/21/16	2
Critical Design Hazard Identification Checklist	4/7/16	4/14/16	7
Complete DFMEA Safety Considerations	4/7/16	4/14/16	7
Complete DVP&R Test Plan	4/14/16	4/21/16	7
Create List of Maintenance and Repair Considerations	4/21/16	4/22/16	1
Detailed Cost Analysis of Prototype	4/22/16	4/26/16	4
Create Detailed Drawings of Finalized Geometry	4/26/16	5/1/16	5
Finalized SolidWorks Assembly	4/1/16	4/28/16	27
Top Level Assembly Drawing with BOM	4/28/16	5/2/16	4
Any Special Fabrication and Assembly Instuctions	4/28/16	5/2/16	4
Compile All Conceptual Design Review Portions	4/28/16	5/2/16	4
Have All Parts Ordered	4/28/16	5/12/16	14
Conceptual Design Review with Sponsor	5/3/16	5/12/16	9
Ethics Memo	5/24/16	5/28/16	4
Manufacturing of Final Prototype	5/28/16	10/10/16	135
Project Update Memo to Sponsor	9/20/16	9/27/16	7
Hardware Demonstration and Safety Verification	10/11/16	10/18/16	7
Product Testing	10/17/16	10/31/16	14
Prepare for Design Expo	11/7/16	11/14/16	7
Poster Design	11/8/16	11/21/16	13
Final Hardware Review	11/8/16	11/21/16	13
Final Project Report Writing	11/24/16	12/1/16	7

Xtract Solutions AMA Refrigeration Redesign Gantt Chart



Appendix G

ME428/429/430 Senior Design Project

2015-2016

SENIOR PROJECT CONCEPT DESIGN HAZARD IDENTIFICATION CHECKLIST

Team: _____ Advisor: _____

Y N

- Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and shear points?
- Can any part of the design undergo high accelerations/decelerations?
- Will the system have any large moving masses or large forces?
- Will the system produce a projectile?
- Would it be possible for the system to fall under gravity creating injury?
- Will a user be exposed to overhanging weights as part of the design?
- Will the system have any sharp edges?
- Will any part of the electrical systems not be grounded?
- Will there be any large batteries or electrical voltage in the system above 40 V either AC or DC?
- Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
- Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
- Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
- Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
- Can the system generate high levels of noise?
- Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
- Is it possible for the system to be used in an unsafe manner?
- Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any "Y" responses, add a complete description, list of corrective actions to be taken, and dates to be completed on the reverse side.

**Potential
Failure Mode and Effect Analysis
(Design FMEA)**

Design Responsibility:
Mitchell and Michael

FMEA Number: 1

Page 1 of 1

Key Date:

N/A

Prepared By:

Mitchell Par

Model Year(s)/Vehicle(s): AMA Unit

FMEA Date (Orig.)

(Rev.)

Core Team:

Action Results											
Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	S _e	Potential Cause(s) / Mechanism(s) of Failure	O _c	C _r	Recommended Action(s)	Responsibility & Target Completion Date	Actions Taken	S _e	O _c
1	Exposed electrical current	Electric shock due to 24V DC voltage and associated current	6	Vibration from fans may loosen nut/bolt, which grounds the electrical components	3	8	Ensure the all metal housing is grounded Include a hole in the sheet metal body to bolt on the GND wire. Include a lock or spring washer	Mitchell and Michael - Order securing washers when all parts are ordered	Mitchell and Michael - Holes for ground wire have been incorporated into SolidWorks models	N/A	N/A
2	Finger pinch point while rotating the head	Pinched or jammed fingers	3	Positioning fingers straight down, while grabbing and rotating the head handhold mechanism	6	5	Grasp onto the hand hold firmly without dangling your fingers. Place a warning label near the hand holds and in the AMA unit manual	Mitchell and Michael - Warning label added to design after fabrication of final prototype	Head is raised just over an inch above the body to allow more clearance in the design	N/A	N/A
3	Leaking liquid from hot side CPU cooler	Combination of electricity and water will ruin the electrical components and create potential for electric shock	8	Puncturing of CPU cooler tubes, or	1	2	Position electrical components far away from potential places of leakage. Keep wires enclosed in body so there is no potential to touch them while the machine is on.	Mitchell and Michael - Take into consideration when placing components	Fix wires with to the top of the underside of the body. Electrical components are either placed far away from the design or have a protective housing. Using a potted TEC to wick out moisture.	N/A	N/A

Appendix H Cost Breakdown

Unit	Details		Quantity	Estimated Cost	Estimated Total
Cooling System					
1	Thermoelectric cooler	HP-199-1.4-0.8	1	\$39.10	\$39.10
2	CPU cooler (Top)	GeminII M4	1	\$37.99	\$37.99
3	CPU liquid cooler (Bottom)	Hydro Series H75	1	\$99.99	\$99.99
4	Thermal Compound	Xtract has some already	0	\$16.19	\$0.00
				Subtotal	\$177.08
Control System					
5	Sensors**	Cost of one extra (MP-3193)	1	\$24.00	\$24.00
6	Controller	TC-48-20 OEM	1	\$189.00	\$189.00
7	Computer Cable (optional)	MP-3023 RS232 Cable	0	\$15.00	\$0.00
8	Wiring	10 ft of 12 gauge wire (20A max)	1	\$12.99	\$12.99
9	Wire Connectors Pack	Used throughout electrical connections of design	3	\$3.28	\$9.84
10	LCD Display	Xiamen Ocular GDM1602K	1	\$9.29	\$9.29
				Subtotal	\$245.12
Power Components					
11	AC to DC converter	PS-24-12.5	1	\$119.00	\$119.00
12	Fuse Holder	Provided by Xtract Solution's current design	1	\$8.00	\$8.00
13	Button	Provided by Xtract Solution's current design	1	\$40.00	\$40.00
14	Power Supply Box Build	Estimated using current design cost	1	\$134.59	\$134.59
				Subtotal	\$301.59
Structural Components					
15	Sheet metal	Not factored into \$500 - \$1500 target cost range	0	N/A	\$0.00
16	Fasteners**		1	\$5.59	\$5.59
17	Insulation	Deemed unnecessary unless testing proves otherwise	0	N/A	\$0.00
				Subtotal	\$5.59
Miscellaneous Components					
18	Electrical tape	Secures wires together and color coordinate wires	1	\$6.02	\$6.02
19	Wire clamps	Pack of 6, used to secure wires to the sheet metal	1	\$3.28	\$3.28
				Subtotal	\$9.30
				Total Cost	\$738.68

Fastener BOM

Unit #	Part Description	Size/name	Price per Unit	Quantity	Estimated Total
16a	Socket Button Head	#10-24	\$0.17	4	\$0.68
16b	Flat Washers	#10	\$0.05	4	\$0.20
16c	Sheet Joining Fasteners***	SKC-F1.5	\$0.10	2	\$0.20
16d	Captive Panel Screw***	PF51-440-0 CN	\$1.25	3	\$3.75
16e	Grounding Screw	#10-32 x 3/8"	\$0.13	2	\$0.26
16f	Self-clinching nuts***	SP-0420	\$0.25	2	\$0.50
				Total	\$5.59

* One thermistor already included with the Controller

** See Fastener BOM

***Price per unit was estimated

Unit	Website
1	http://totech.com/product/hp-199-1-4-0-8/
2	http://www.coolermaster.com/cooling/cpu-air-cooler/geminii-m4/
3	http://www.corsair.com/en-us/hydro-series-h75-liquid-cpu-cooler
4	http://www.amazon.com/Arctic-Silver-High-Density-Polysynthetic-ASS-12GRFB/dp/B001JVFYFLY
5	http://totech.com/product/mp-3193/
6	http://totech.com/product/tc-48-20-oem/
7	http://totech.com/product/mp-3023-rs232-cable/
8	http://www.amazon.com/12-Gauge-Silicone-Wire-Feed/dp/B0070RZXLW
9	http://www.lowes.com/pd/136010-12704-770310_1z0Yr4o_?productId=3363058&pl=1
10	http://www.datasheetspdf.com/datasheet/GDM1602K.html
11	http://totech.com/product/ps-24-12-5/
16a	https://www.boltdepot.com/Product-Details.aspx?product=4398
16b	https://www.boltdepot.com/Product-Details.aspx?product=2946
16c	http://catalog.pennnet.com/item/panel-to-panel-keyhole-style-type-sk-c-f/keyhole-sheet-joining-fasteners-type-sk-c-f-unifi-2/sk-f1-5-2
16d	http://catalog.pennnet.com/item/low-profile-knob-spring-loaded-types-pf50-pt60/panel-screw-low-profile-knob-spring-loaded-unified/pf51-440-0-cn
16e	https://www.fastenal.com/products/details/0700644
16f	http://catalog.pennnet.com/item/ts-all-for-installing-into-stainless-steel-type-sp/s-class-cla-sp-self-clinching-nuts-types-sp-unified/sp-0420-2
18	http://www.amazon.com/3M-Scotch-Electrical-Value-10457NA/dp/B001B19FDK/ref=sr_1_4/186-9233714-2803914?si=industrial&ie=UTF8&qid=1461983197&sr=1-4
19	http://www.homedepot.com/p/Gardner-Bender-3-8-in-Plastic-Kwik-Clips-6-Pack-GKK-1538/100161019