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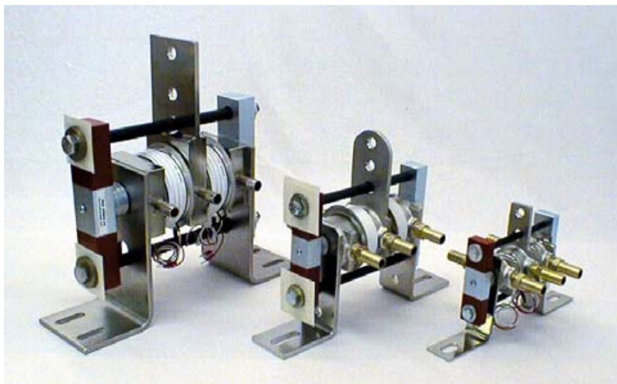
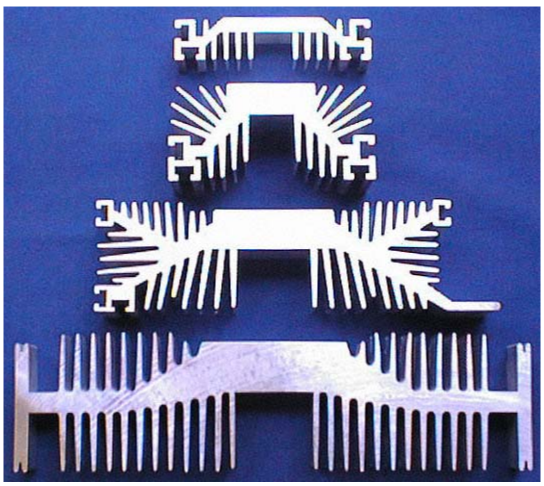
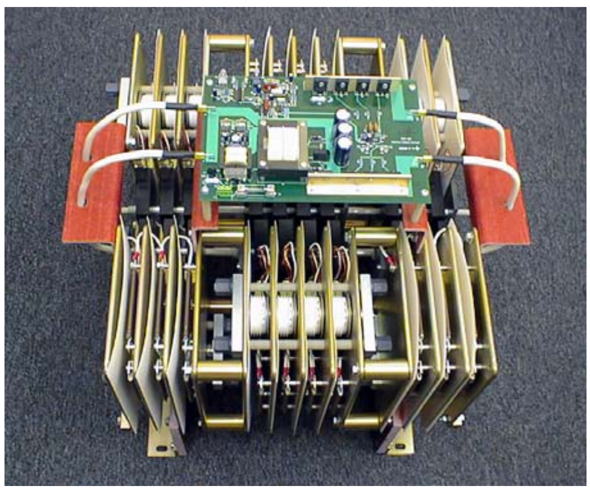
Applied Power Systems, Inc.

Precision Clamps and Heatsink Assemblies for High Power Semiconductors







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Introduction

Clamping Systems for Large Area Semiconductors

The mounting of high power semiconductors requires clamp that is capable of exerting a minimum force, given by the semiconductor manufacturer. The force applied by the clamp minimizes both electrical and thermal resistance by insuring the semiconductor is in intimate contact with the heatsink and bus bars, allowing your circuit to operate as designed. The clamps that Applied Power Systems, Inc. (APS) offers have been specially designed to meet the requirements of all semiconductor manufacturers and get maximum performance from the devices. APS also has a complete line of air-cooled and liquid-cooled heatsinks available off-the-shelf. In addition, APS offers complete line of standard assemblies in many circuit configurations for quick delivery.

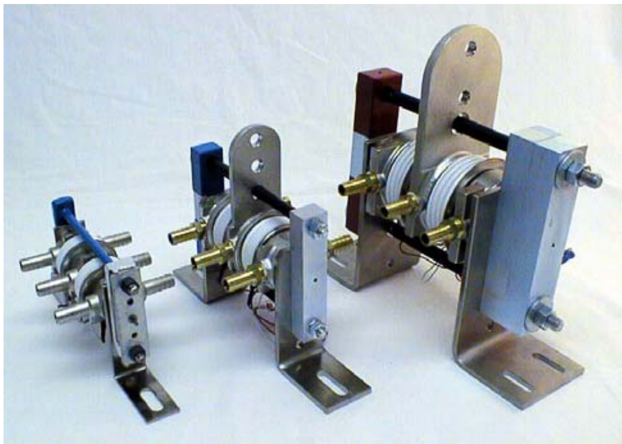


Figure 1: Typical liquid-cooled assemblies

Advantages of APS clamps:

- **Accurate and rugged force gauge to properly load press pack semiconductors.**
- **Center loaded force application.**
- **Complete range of force levels from 1000 pounds to over 20,000 pounds to allow for semiconductors of 100 mm or greater in diameter.**
- **A full line of standard air and liquid cooled heatsinks.**
- **Design facilities available for special requirements.**

The most efficient way to remove heat from a large area semiconductor (>23mm silicon diameter) is to package it into a flat circular package that allows heat and current to be removed or passed from both the anode and cathode of the device with as little thermal and electrical resistance as possible. This type of package is called by many names, hockey puck, press pack, flat pack and disc. From a user's point of view, it is the most difficult package to use since it not only requires two heat sinks (anode and cathode) but also requires a clamp that holds the assembly together and applies sufficient force to minimize the thermal and electrical resistance. The clamping force makes the electrical and thermal connections to the device. In addition, the method used to tighten and accurately gauge the applied force is not immediately apparent or trivial. Over tightening, under tightening and/or not maintaining a parallel force on the pole face of the device being clamped usually leads to premature failure. This new series of clamps available from Applied Power Systems, Inc. can minimize or eliminate many of these problems.

The clamping force applied to the semiconductor pole faces is critical and must be in accordance with the specified force from the semiconductor manufacturer. It is also necessary that the force be applied evenly across the entire surface of both pole faces and normal to the pole face plane of the devices being assembled. The clamp must apply the force evenly across the pole faces and not cause mechanical stress to be transferred to the semiconductor element over the entire temperature range to which the assembly will be exposed. Stress caused by non-perpendicular application of the clamp can cause a number of problems including cracking the semiconductor element, current crowding causing the semiconductor to have excessive hot spots, poor thermal conduction causing overheating of the semiconductor element, etc. When installed properly, disc clamps will provide good electrical contact and a low thermal resistance to insure proper heat removal.

FUNCTIONAL DESCRIPTION OF APS LARGE AREA DISK CLAMPS

The APS series of clamps are comprised of four main components (see **Figure 2**): Spring bar, Load Spreader, Bolts with Nuts and Washers along with an Insulating System. The spring bar is made from high strength, cold drawn steel bar stock. Mounted in the center of the bar is the captive Belleville washer stack assembly. The machine screw head that is flush with the top of the spring bar has a dual function. It is used as the force measuring indicator as well as the Belleville spring washer capturing mechanism.

The spring bar is epoxy powder coated to maintain electrical isolation from the bolts and load spreader bar. The spring bar is selectively powder coated on the ends of the bar only, the center portion is uncoated. All epoxy powder coat systems are temperature limited to approximately 130°C. Using the APS system, the spring bar is never in direct contact with the heat sink. Thus, the heat sink temperature will not affect the integrity of the epoxy coating. By not coating the center section of the spring bar, we reduce the potential of fracturing the epoxy coating during the application of load forces and deflection of the spring bar.

The load-spreading bar is made from the same high strength steel as the spring bar. There is no need for the Belleville washer assembly on this side of the clamp for standard designs. The load-spreading bar is used to reinforce, and provide strength on the side opposite the spring bar assembly for both air and water-cooled assemblies.

The bolts used in the clamp are zinc plated high carbon steel Grade 5. These bolts are resistant to both stretch and corrosion. In special applications, when the assembly is in a strong magnetic field, stainless steel bolts are provided to break the magnetic force and prevent eddy currents from heating the bolts and clamp.

These clamps were designed to reduce the possibility of corona discharges from destroying the assembly insulation over time. The clamps have been checked for inception and extinction voltages to insure the corona voltages are higher then normally encountered at line voltages up to 600 Volts AC. If the application will see higher voltages, consult APS.

APS clamps come in standard forces of 1,000 pounds (4.5kN), 2,000 pounds (8.9kN), 3,000 pounds (13.4kN), 5,000 pounds (22.2kN), 10,000 pounds (44.5kN) and 20,000 pounds (89kN). Special clamps can be designed for special or unique applications including high voltage, low or zero corona, low profile, etc.

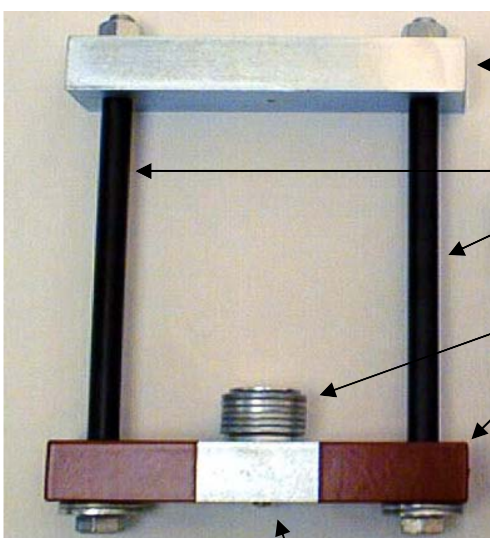


Figure 2: Typical components of an APS clamp. This is a 5,000-pound clamp used with devices that have a pole face between 38mm and 50mm in diameter.

Clamp Numbering System

The clamp part number consists of two components; the first component is the maximum force applied to the system; the second component is the bolt length, which determines the maximum height of the system to be clamped. In standard clamps, the range of forces is between 3,000 pounds or 13.4 kilo-Newton (kN) to 20,000 pounds or 89kN. The bolt length is a two-digit number that represents the range of heights that can be clamped.

Figure 3 below, is a drawing of a typical clamp. The dimensions for each size are listed in the tables on this page. The part numbering system is also shown.

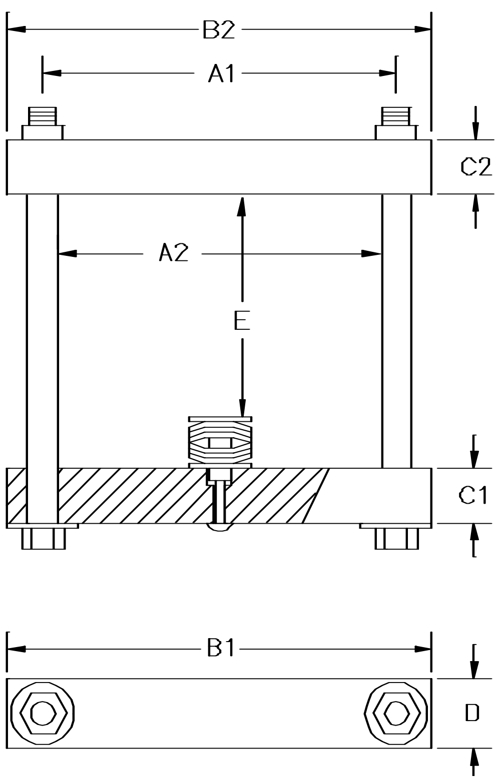


Figure 3: Clamp dimension nomenclature

Ordering Information		
Clamp Type	**Typical Force**	**Throat or "E" Dim. Range**
APS	**XX k**	**YY**
APS	3k, 5k, 10k or 20k	01 to 10 (Dim. "E" in tables)

3,000 LB Clamp Distances and Dimensions

Bolt Length	Allowable "E" Dim.	XX
6.00	3.00 - 3.75	01
6.50	3.50 - 4.25	02
7.00	4.00 - 4.75	03
7.50	4.50 - 5.25	04
8.00	5.00 - 5.75	05
8.50	5.50 - 6.25	06
9.00	6.00 - 6.75	07
9.50	6.50 - 7.25	08
10.00	7.00 - 7.75	09

Dimensions		
Dim.	**Inches**	**mm**
A1	2.75	69.8
A2	2.37	60.2
B1	3.77	95.8
B2	3.75	95.3
C1	0.52	13.2
C2	0.50	12.7
D	1.02	25.9

5,000 LB Clamp Distances and Dimensions

Bolt Length	Allowable "E" Dim.	XX
6.00	2.75 - 3.50	01
6.50	3.25 - 4.00	02
7.00	3.75 - 4.50	03
7.50	4.25 - 5.00	04
8.00	4.75 - 5.50	05
8.50	5.25 - 6.00	06
9.00	5.75 - 6.50	07
9.50	6.25 - 7.00	08
10.00	6.75 - 7.50	09

Dimensions		
Dim.	**Inches**	**mm**
A1	4.00	101.6
A2	3.50	88.9
B1	5.02	127.5
B2	5.00	127.0
C1	0.77	19.6
C2	0.75	19.1
D	1.02	25.9

10,000 LB Distances and Clamp Dimensions

Bolt Length	Allowable "E" Dim.	XX
7.00	2.25 - 3.25	01
8.00	3.25 - 4.25	02
9.00	4.25 - 5.25	03
10.00	5.25 - 6.25	04
11.00	6.25 - 7.25	05
12.00	7.25 - 8.25	06
13.00	8.25 - 9.25	07
14.00	9.25 - 10.25	08
15.00	10.25 - 11.25	09
16.00	11.25 - 12.25	10

Dimensions		
Dim.	**Inches**	**mm**
A1	5.50	139.7
A2	4.94	125.5
B1	7.04	178.8
B2	7.00	177.8
C1	1.04	26.4
C2	1.00	25.4
D	1.54	39.1

20,000 LB Clamp Distances and Dimensions

Bolt Length	Allowable "E" Dim.	XX
9.00	2.75 -3.75	01
10.00	3.75 - 4.75	02
11.00	4.75 - 5.75	03
12.00	5.75 - 6.75	04
13.00	6.75 - 7.75	05
14.00	7.75 - 8.75	06
15.00	8.75 - 9.75	07
16.00	9.75 - 10.75	08
17.00	10.75 - 11.75	09
18.00	11.75 - 12.75	10

Dimensions		
Dim.	**Inches**	**mm**
A1	7.50	190.5
A2	6.81	173.0
B1	9.54	242.3
B2	9.50	241.3
C1	1.54	39.1
C2	1.50	38.1
D	2.04	51.8

Example 1: If the requirement is for a 5,000# clamp with a throat (the “E” dimension) of 5.50”, the part number is the APS5k06. It is important to know the measurements of each of the elements to be clamped, i.e. the height and quantity of heatsink(s), the height and quantity of the semiconductor(s) and thickness and quantity of bus bar(s). This total “E” dimension must be within the clamping range of the bolt being used.

Example 2: A pair of 67mm devices is being used in an AC switch configuration. The height of the two devices, the three liquid cooled heatsinks and two bus bars is 8.0”. What clamp would be chosen? Answer: most 67mm devices use 9,000 to 11,000 pounds of force (40kN). Therefore, the part number would be APS10k06.

BAR CLAMP TIGHTENING PROCEDURE

- Apply thin coating of Alcoa #2 EJC Electrical Joint Compound to the device(s) pole face(s).
- Install device(s) onto base heatsink. Align device-centering indents with locating pins in heatsink.
- Rotate the device(s) to spread the compound and to seat the device(s).
- Check the polarity of the device(s) to insure proper orientation.
- Place top heatsinks onto device(s), aligning the heatsink locating pins with the device centering indents.
- Install Bar Clamp in assembly, insuring washer stack of Spring Bar is in contact with heatsink surface.
- Coat bolt threads with Anti-Seize Compound before installing nuts.
- Advance both bolts down equally to obtain finger tight fit (2 to 4 inch pounds) before tightening with a wrench.
- Insure that spring bar is parallel with the heatsink before tightening bolts.
- Tighten each bolt, alternating 1/4-turn increments on each bolt, until the proper gauge displacement is obtained, measured between the base of the washer stack screw head and the heatsink surface. Refer to the chart and diagram below.

- The diagram in **Figure 4** below shows the gap setting for a 10,000 lb. clamp. A feeler gauge is used to measure the minimum gap required to insure proper mounting force (the .945 REF dimension). Refer to the table below to determine the gap required for the entire series of clamps.

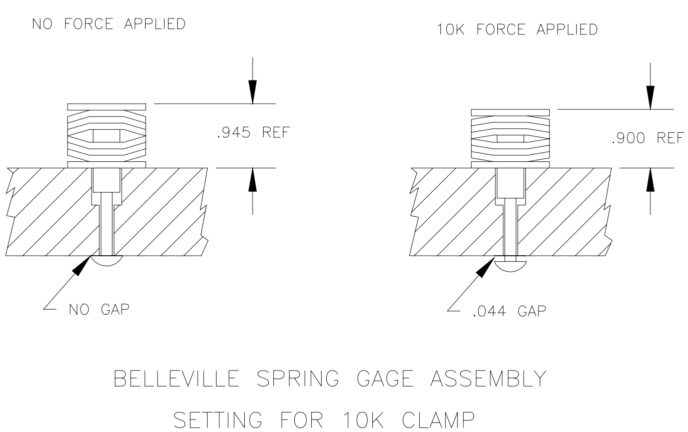


Figure 4: Close view of gap setting of force gauge for a 10,000-pound clamp

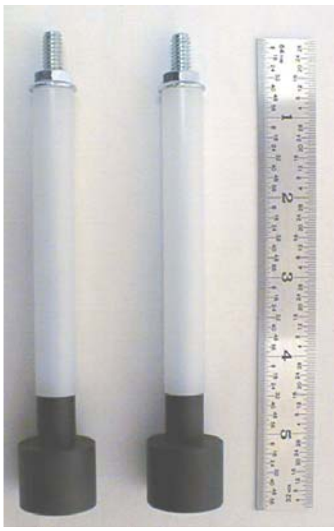
Clamp Size (Force)	Force Gauge Displacement
3,000-pound	0.024”
5,000-pound	0.027”
10,000-pound	0.044”
20,000-pound	0.035”

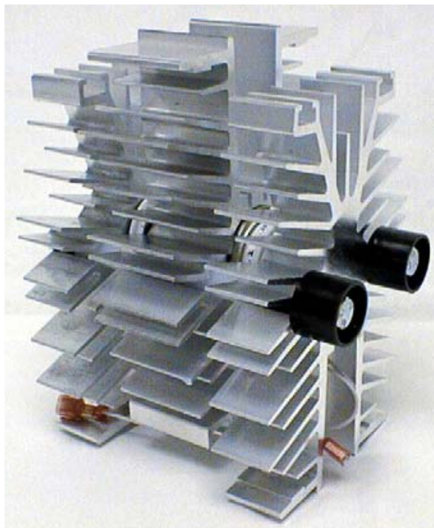
Table 1: Force Gauge settings for standard APS clamps

The APS Post Clamp

The APS Post Clamp is an economical method of clamping devices and heatsinks that require up to 2,000 pound of force. The clamp consists of two sets of grade 5 steel nuts and bolts, glass reinforced insulating cups and insulating sleeving. Assemblies using this type of clamp should be assembled at the factory using a calibrated press. It is the only method to tighten the clamp accurately.

From a practice standpoint however, field repair may be required. For that purpose, we present the following tightening procedure for emergency purposes only. It is not recommended for routine assembly.





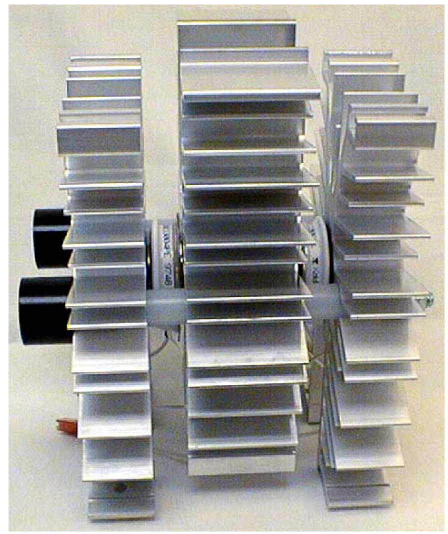


Figure 5: Left: Post clamp; Center: Post clamp shown in application of dual SCR assembly; Right: Same assembly, different view.

POST CLAMP TIGHTENING PROCEDURE

- Apply thin coating of Alcoa #2 EJC electrical joint compound to device pole face(s).
- Install device(s) onto base heatsink. Align device-centering indents with locating pins in heatsink.
- Rotate the device(s) to spread the compound and to seat the device(s).
- Check the polarity of the device(s) to insure proper orientation.
- Place top heatsinks onto device(s), aligning the heatsink locating pins with the device centering indents.
- Install Post Clamps in assembly and coat threads with Anti-Seize Compound before installing nuts.
- Advance both bolts down equally to obtain finger tight fit (2 to 4 inch pounds) before tightening with a wrench.
- Tighten each bolt 1-1/4 turns, in alternating 1/4-turn increments on each bolt.

General Mounting Tips for Clamping

Mounting Tips for Stud Devices

Mount studs to a heat sink through a clearance hole by means of one of the following methods:

1. Hex nut and a lockwasher or pal nut or
2. Hex nut-Belleville washer combination or
3. Hex nut and Tenz nut.

The diameter of the mounting clearance hole should not exceed the stud by more than 1/64" (0.0156") and should be accurately drilled perpendicular to the mounting surface. Remove projections from mounting clearance hole. Punched and drilled holes should be carefully de-burred with a chamfer not exceeding .01" radius. Avoid drilling and tapping holes for stud devices. Thermal ratcheting which tends to unscrew the stud from the hole can occur. In addition, the 0.10º perpendicularity tolerance necessary between the hole and mounting surface must be maintained and is difficult to achieve.

Apply appropriate thermal interface compound in a very thin film to the mounting interface area of the device and the mounting area of the heat sink only. Rotate the stud device on the heat sink to spread the compound and to seat the device. The threads of the stud and nut must not be lubricated, as this will drastically alter the recommended mounting torque and cause undue stress on the stud device.

Always use a torque wrench when mounting stud devices. Refer to the individual device data sheet for the correct torque to be used. A good quality torque wrench, accurate in the specified range, should always be used. The torque should always be applied on the hex nut while holding the semiconductor stationary. Do not exceed maximum recommended torque limits. Application of excessive torque is a major cause of stud device mounting problems. Semiconductors can be mechanically damaged by too much torque or thermally damaged by too little torque.

Mounting Tips for Disc Devices

Machine or spot face the heat sink mounting surface areas to a diameter slightly larger than that of the disc pole face to be mounted. Keep spot face shallow to prevent interference with other parts of the disc package.

Use locating pins (or alternative method) to center the disc for optimum load distribution. Pre-assemble locating pins with a light hammer into center dowel hole in each heat sink. A gauge block is useful to prevent excessive pin length. Improperly mounting disc off center or using a locating pin too long and/or wrong diameter, resulting in improper device seating and possible fracturing of the silicon element, are major causes of device mounting problems.

Apply appropriate thermal interface compound in a very thin film to the mounting surfaces of the device, as well as to the mounting surfaces of the heat sinks. Rotate the disc to spread the compound and to seat the devices.

Check the polarity of the device prior to assembly to insure the device is installed in the desired direction. Also, position the SCR gate leads, etc. prior to assembly.

Follow Clamping Tips:

1. Use self-leveling type mounting clamp to assure parallelism and even distribution of force on the semiconductor. All APS clamps, except the Post Clamp, utilize this clamping action.
2. Select the proper size clamp; be aware of clamp insulation, the temperature limitation is less than 130°C for most clamps. If higher temperature limits are required, please contact APS.
3. Coat clamp threads for large area discs with Never-Seez® or equivalent type compound, in order to prevent nut and clamp thread binding when high clamping forces are being applied.
4. Take necessary safety precautions to prevent bodily harm as high load forces can result in clamp breakage resulting in the broken bolt becoming a flying projectile.
5. Pre-stressing the clamp to its rated force prior to actual use in the application can help to seat clamp springs.
6. Insure the availability of proper feeler gauge to insure correct force. All APS clamps have captive spring hardware and are calibrated to the rated load force.

7. Apply clamping force smoothly, evenly and perpendicularly to the disc.
8. Advance nuts onto clamp bolts equal length and finger tight before tightening with a wrench.
9. Apply the correct force as described on the device data sheet. Should too much force be applied to the clamp, do not attempt to back down to correct force – start the clamping procedure all over again.
   a. Manual method - using an appropriate wrench, alternately advance nuts 1/4 turn each until the correct thickness feeler gauge can be inserted between the load bar and bottom of the bolt head in the center of the clamp. See diagram on page 5 of this brochure.
   b. Hydraulic press method - apply the calibrated force to the assembly with press. Using a good quality torque wrench, torque each nut 1/4 turn alternately to 10 ft. lbs. torque. Release press.
10. Install disc assemblies in such a way that the clamping force will always be centered on the semiconductor so as not to be affected by electrical connections or supports. Only one of the two heat sinks may be rigidly attached to a bus bar or a mounting bracket; cable and bus bar connections that tie to other heat sinks must be flexible or have stress relief built in.
11. Develop a through disc mounting procedure. Attention to each and every detail in mounting a disc is much more critical than mounting a stud device. Successful and reliable device operation depends on it!

Forced Air and Natural Convection Heatsinks for Thermal Management

There is a wide variety of heatsink profiles available from APS. They fall into three categories, i.e. profiles for hockey pucks (or Press-Packs), profiles for modules and profiles for stud devices. Below is a selection of our most popular extrusions and assemblies. The first selections are for hockey puck devices.

A4 HEATSINK OUTLINE

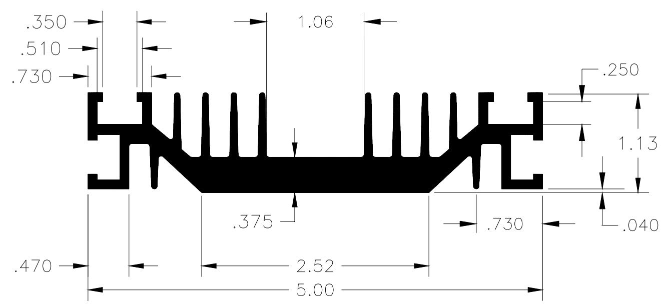


Figure 6: Type A4 heatsink, small, low power applications. Can mount an SCR or diode with a pole face up to 67mm.

PERIMETER 31.40 IN.
AREA XX.XX SQ.IN.
WEIGHT 2.95 LB/FT
THERMAL RES. 2.2 °C/W/3"

A6 HEATSINK OUTLINE

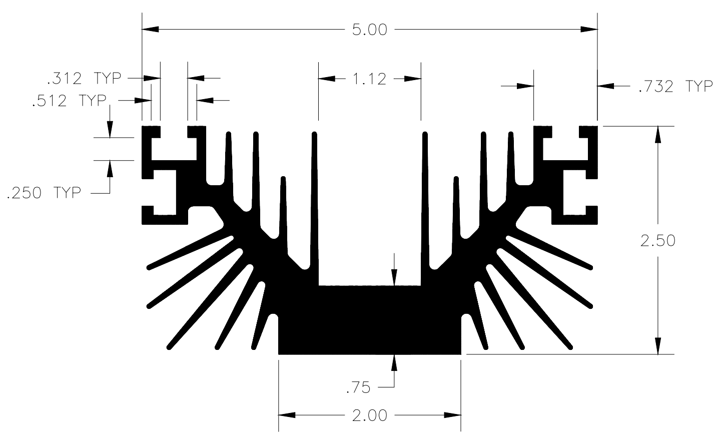


Figure 7: Type A6 heatsink for moderate power applications (1600A DC from a 3-phase bridge). Can mount SCR or diode with a pole face up to 50mm.

PERIMETER 55.87 IN.
AREA 4.62 SQ.IN.
WEIGHT 5.56 LB/FT
THERMAL RES. 1.38° C/W/3"

Standard Air Cooled Assembly Circuits

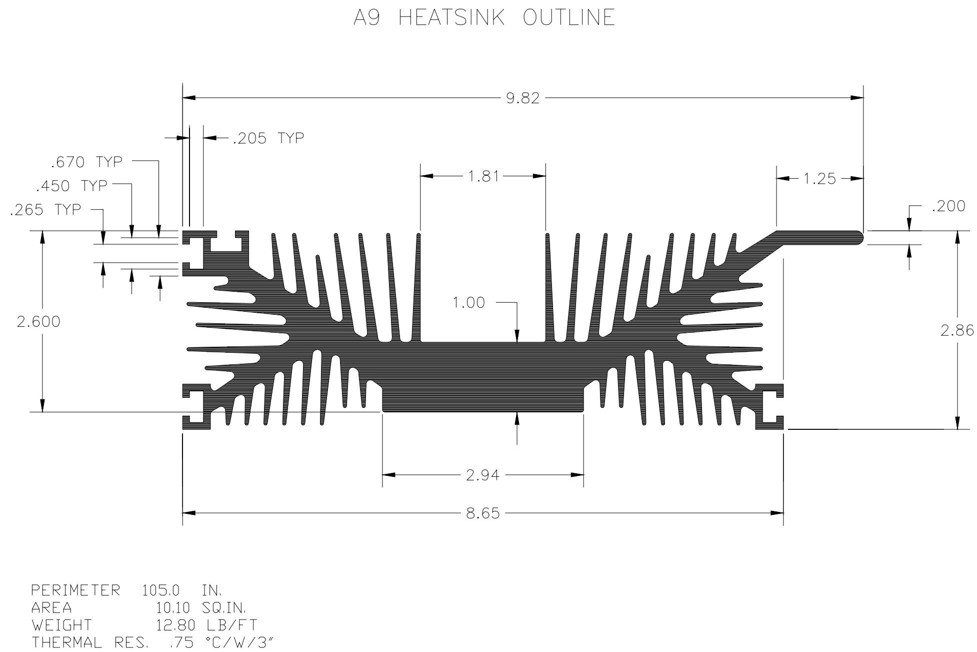


Figure 8: Type A9 heatsink for moderate to high currents. Can accept devices with up to a 74mm pole face.

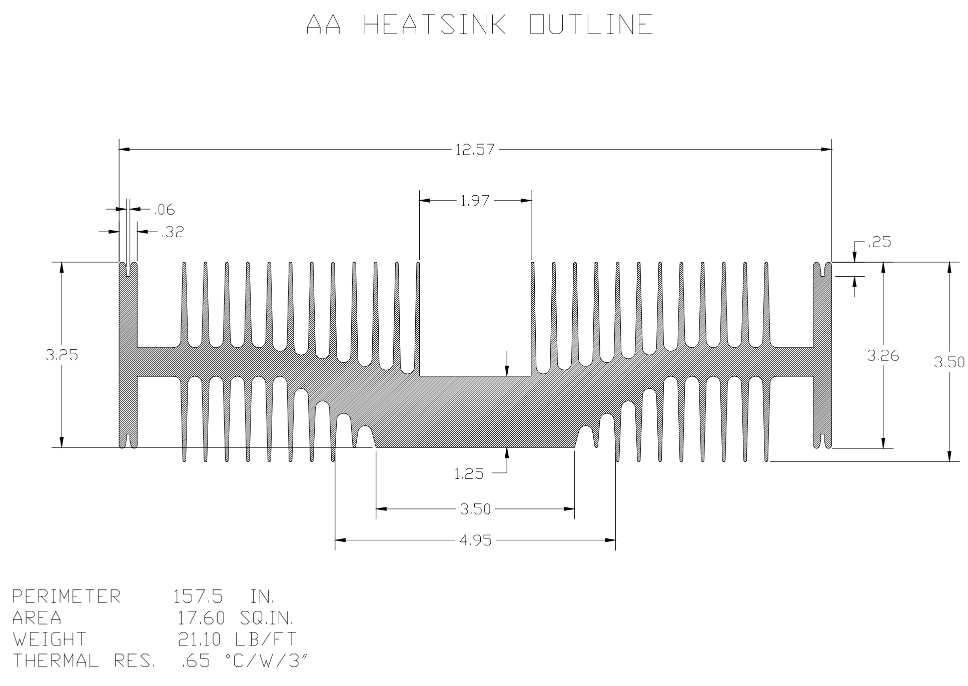


Figure 9: Type AA heatsink for high current applications. Can accept devices with a pole face up to 88mm.

The heatsink profiles above plus many others are used to manufacture a complete series of assemblies using diodes and SCRs. These assemblies can be made into full bridges, three-phase bridges, AC controllers, converters and a multitude of other standard and custom circuits. We also offer an extensive selection of driver boards for these devices. Below are just a few examples of assemblies APS have manufactured for companies like yours.

Assemblies for Natural Convection and Forced Air Cooling

From the heatsinks above we can supply a multitude of applications with off-the-shelf speed. Below are examples of our standard assemblies.

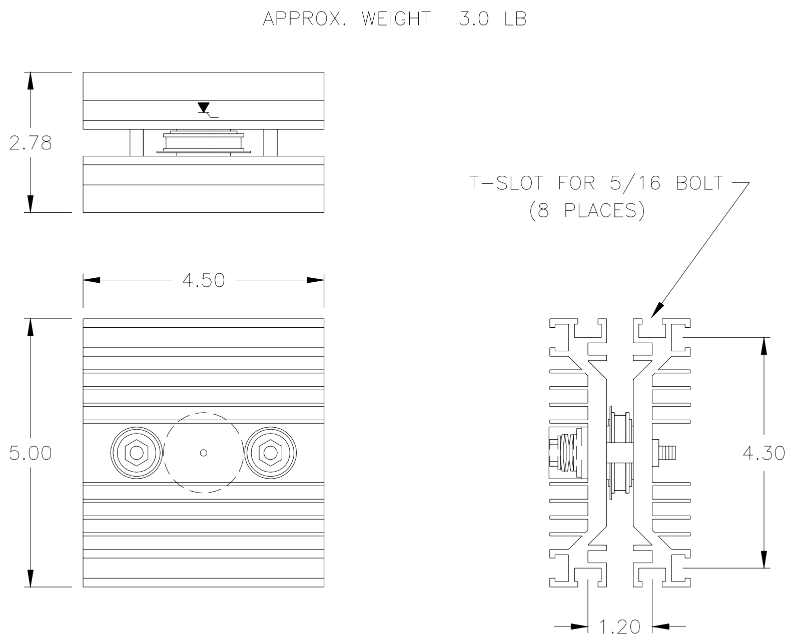


Figure 10: Typical single device assembly using the A4 heatsink. The pole face of the device drawn is 32mm. Can be used in many applications.

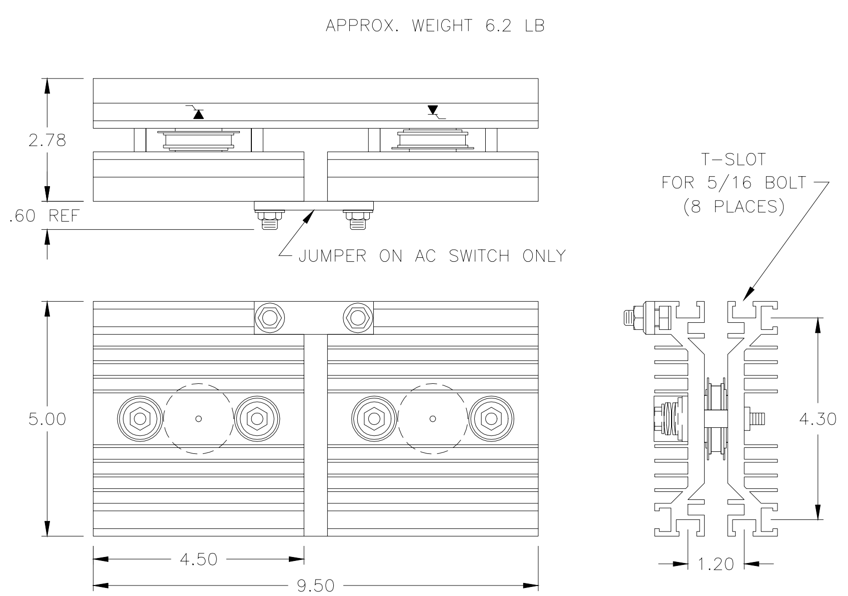


Figure 11: Typical "doubler" assembly using the A4 heatsink. Two devices can be connected as a phase leg for full bridges (two assemblies needed) or three-phase bridges (three assemblies needed). Can also be used in AC controller applications.

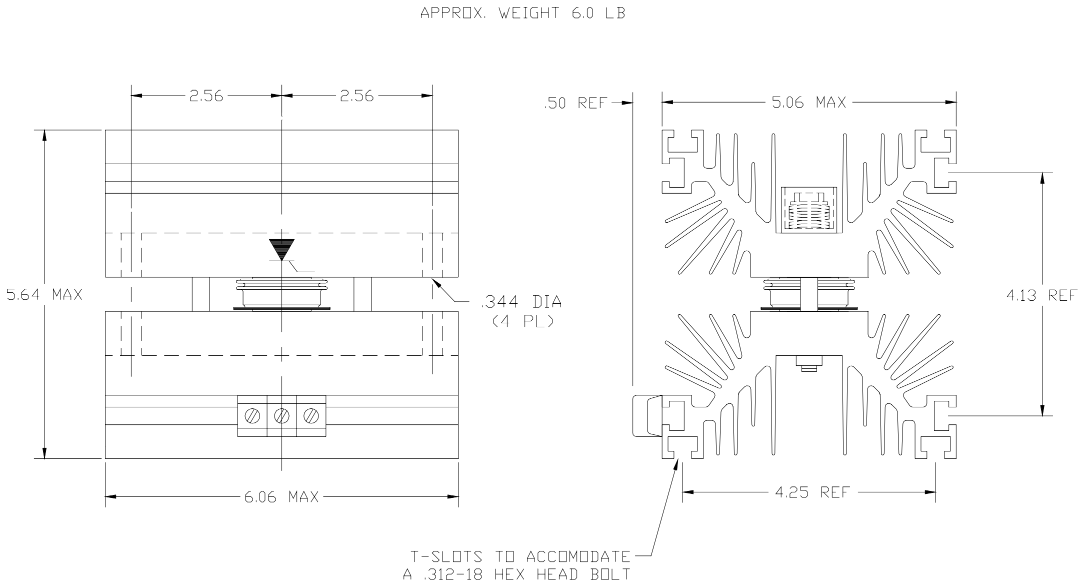


Figure 12: Typical single device assembly using the A6 heatsink, shown with a 30mm pole face device. Can be used in many applications.

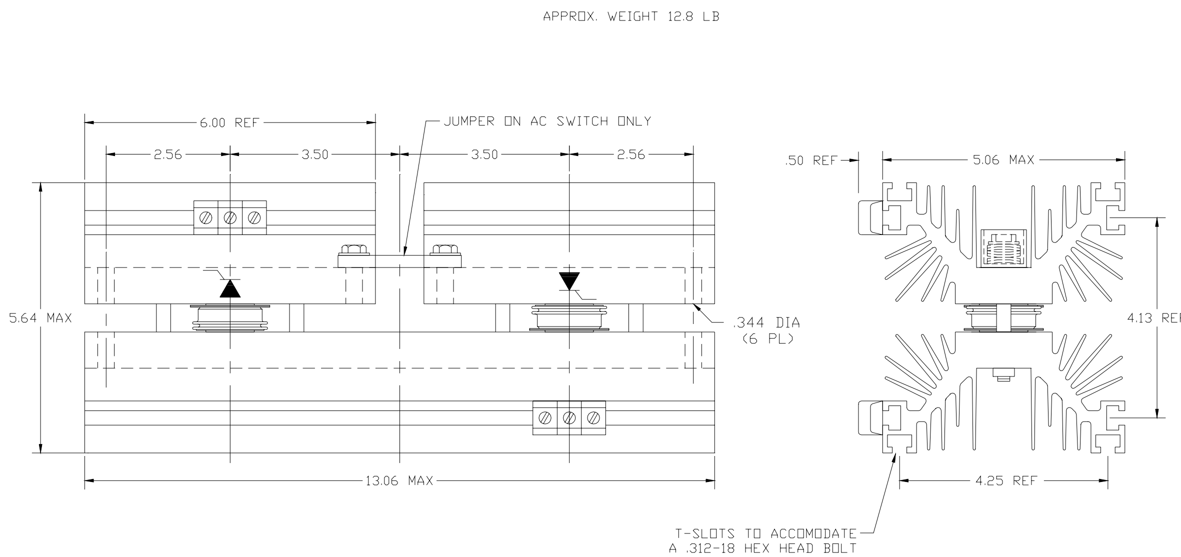


Figure 13: Typical "doubler" assembly using the A6 heatsink. Two devices can be connected as a phase leg for full bridges (two assemblies needed) or three-phase bridges (three assemblies needed). Can also be used in AC controller applications. Device drawn is a 30mm rectifier.

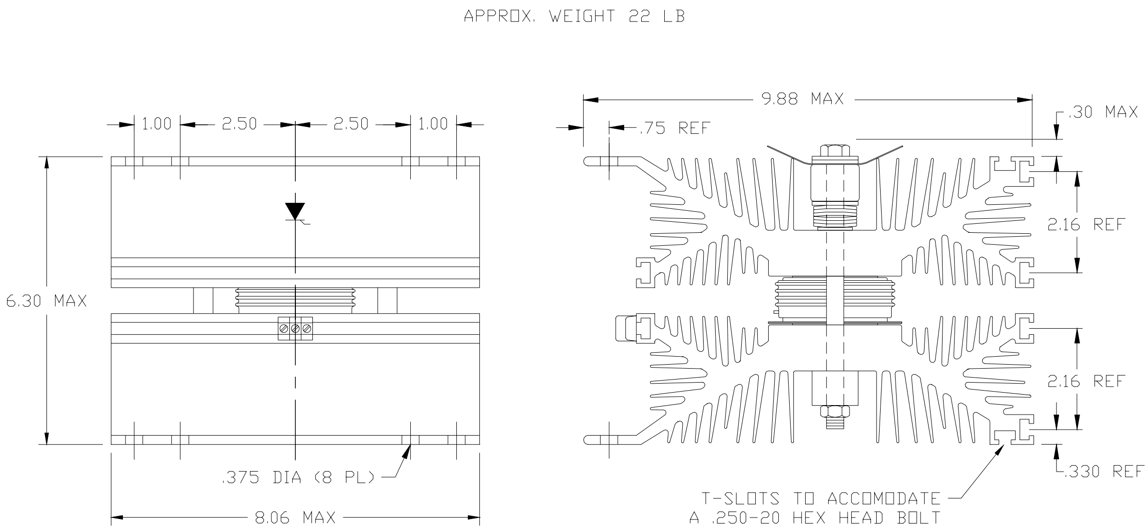


Figure 14: Typical single device assembly using the A9 heatsink and a device with a 50mm pole face. Can be used in many applications.

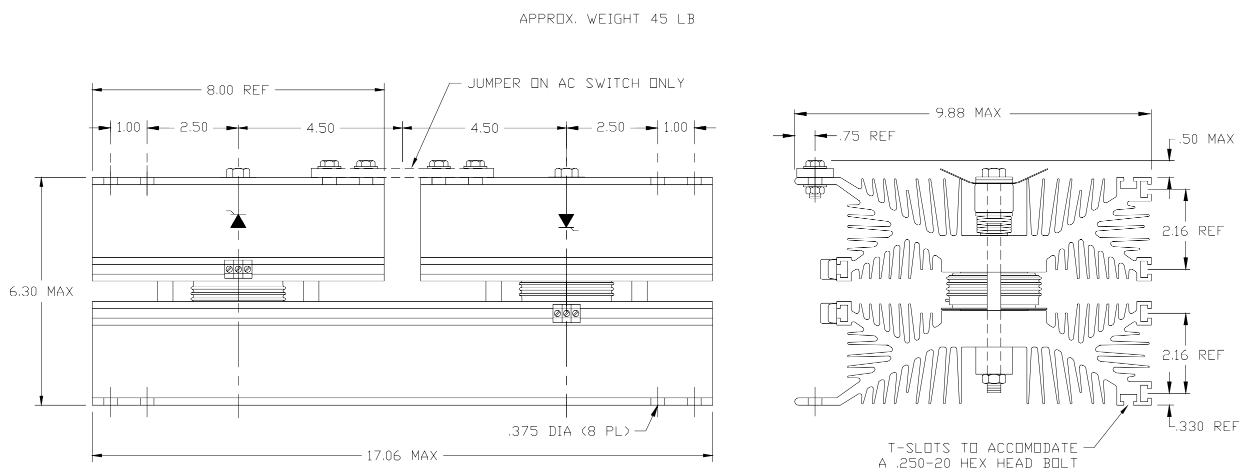


Figure 15: Typical "doubler" assembly using the A9 heatsink. Two devices can be connected as a phase leg for full bridges (two assemblies needed) or three-phase bridges (three assemblies needed). Can also be used in AC controller applications. Device drawn is a rectifier with a 50mm pole face.

Standard Air Cooled Assembly Circuits

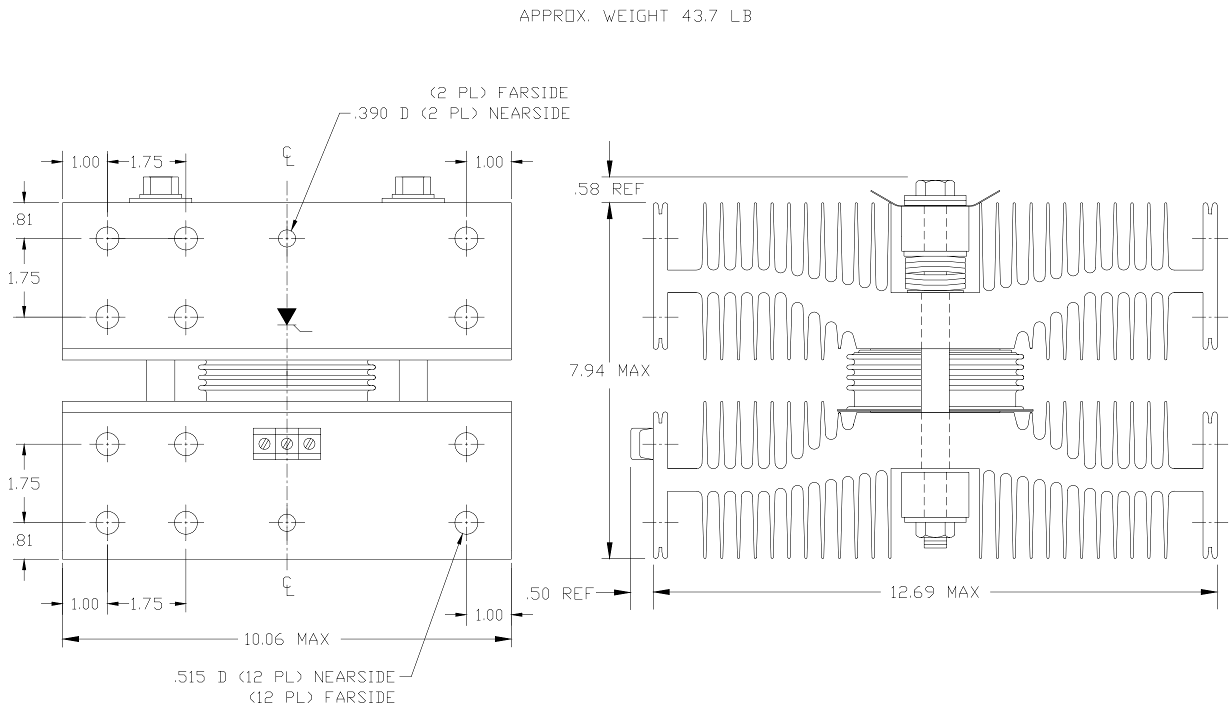


Figure 16: Typical single device assembly using the AA heatsink and a device with a 65mm pole face. Can be used in many applications.

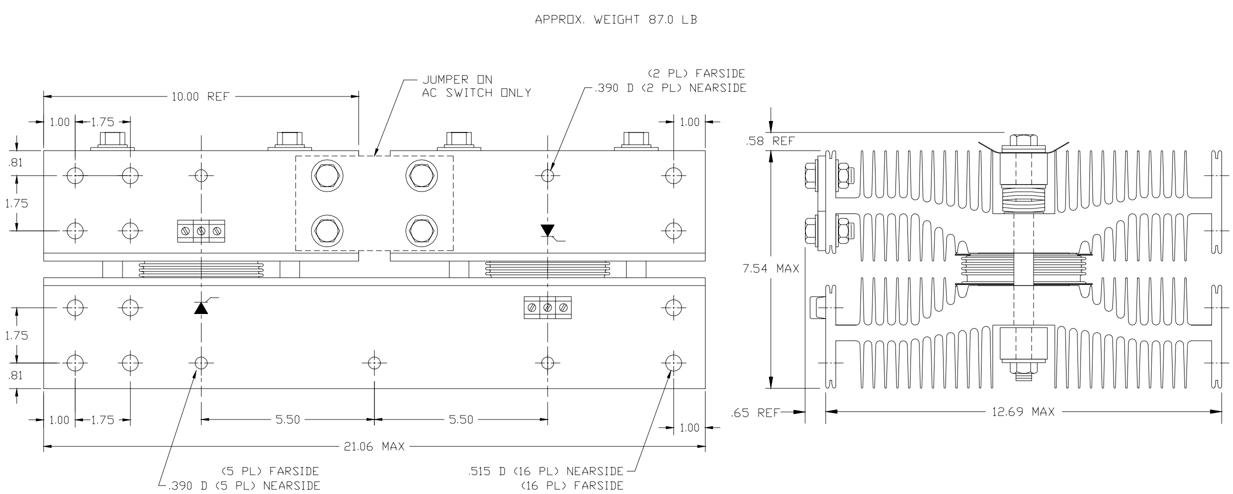
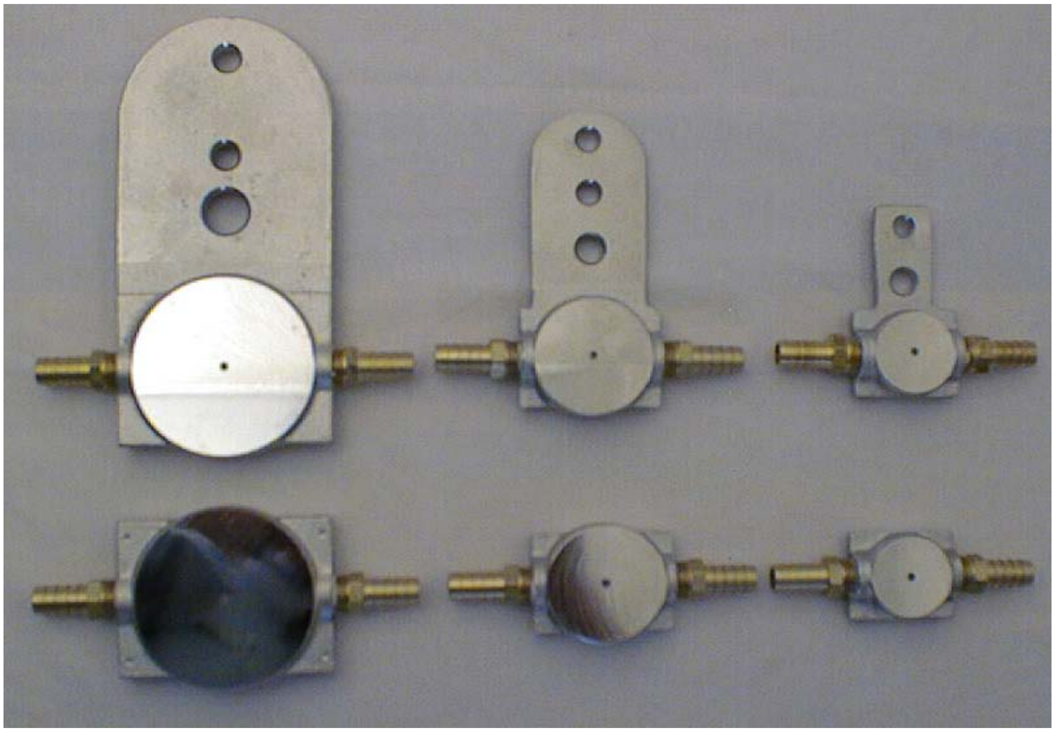
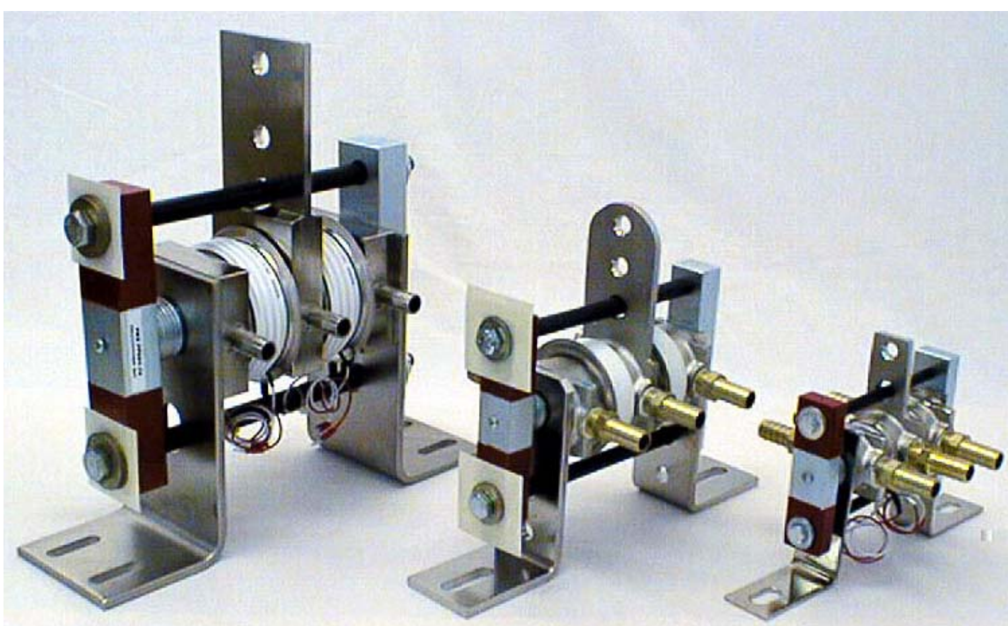


Figure 17: Typical "doubler" assembly using the AA heatsink. These assemblies can be connected as phase legs for full bridges (two assemblies needed) or three-phase bridges (three assemblies needed). Can also be used in AC controller applications. Device drawn is a rectifier with a 73mm pole face.

Heatsinks for Liquid Cooled Assemblies





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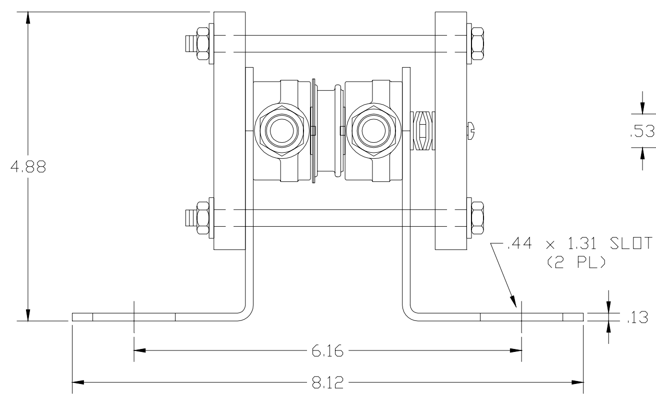
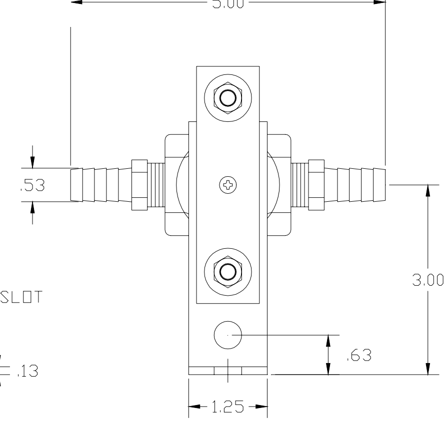
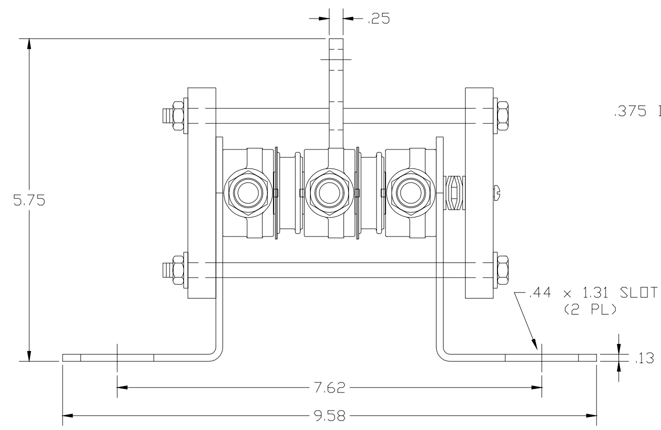
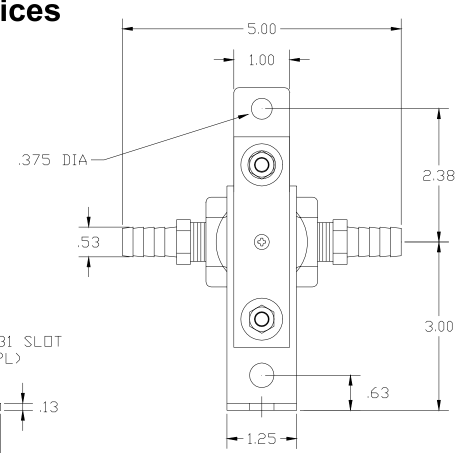
W6 Single for 23mm Devices



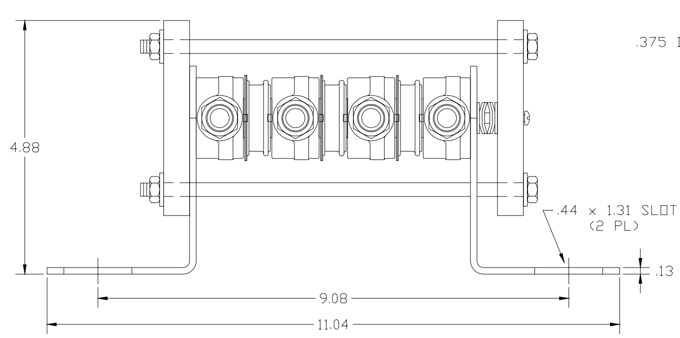


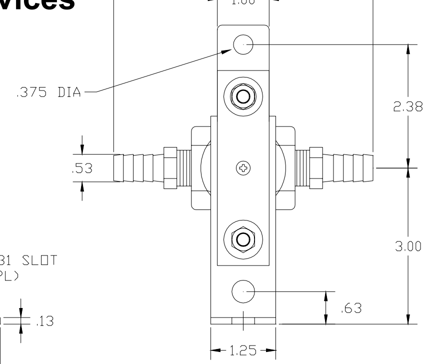
W6 Doubler for 23mm Devices





W6 Triple-Series String for 23mm Devices





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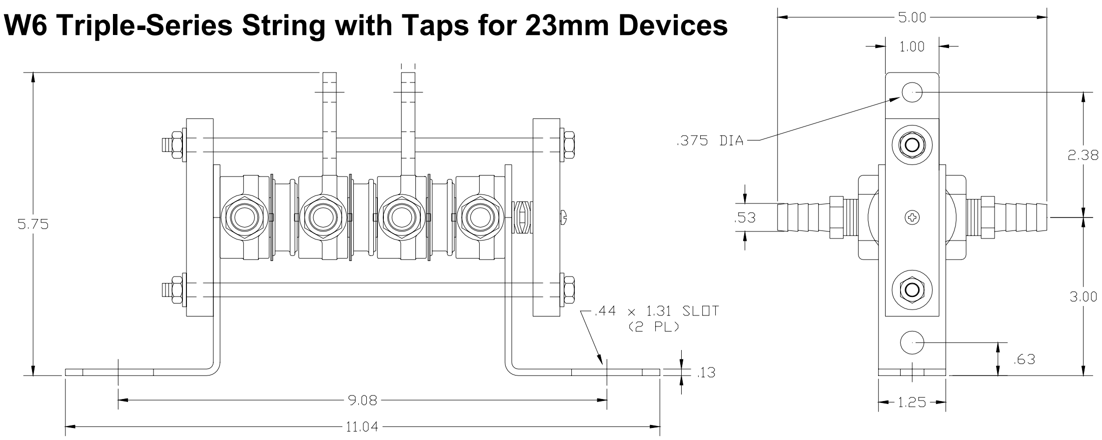
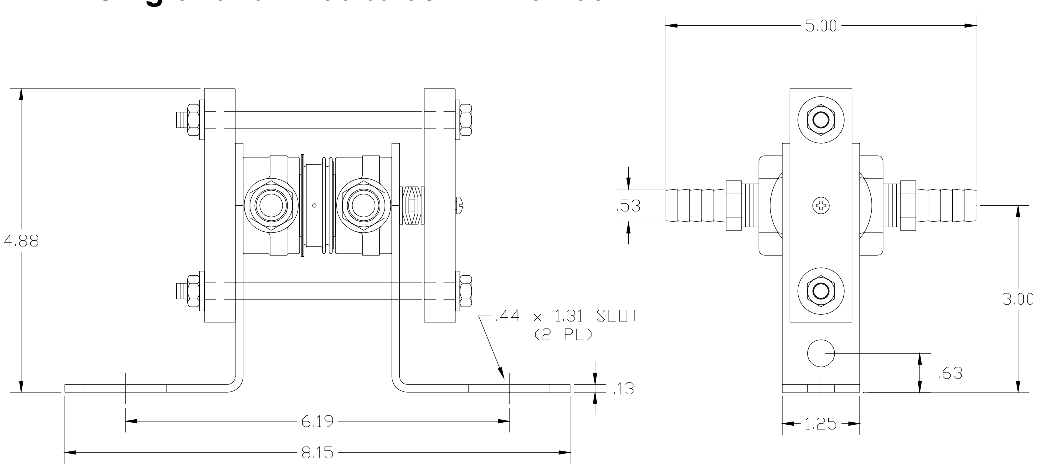
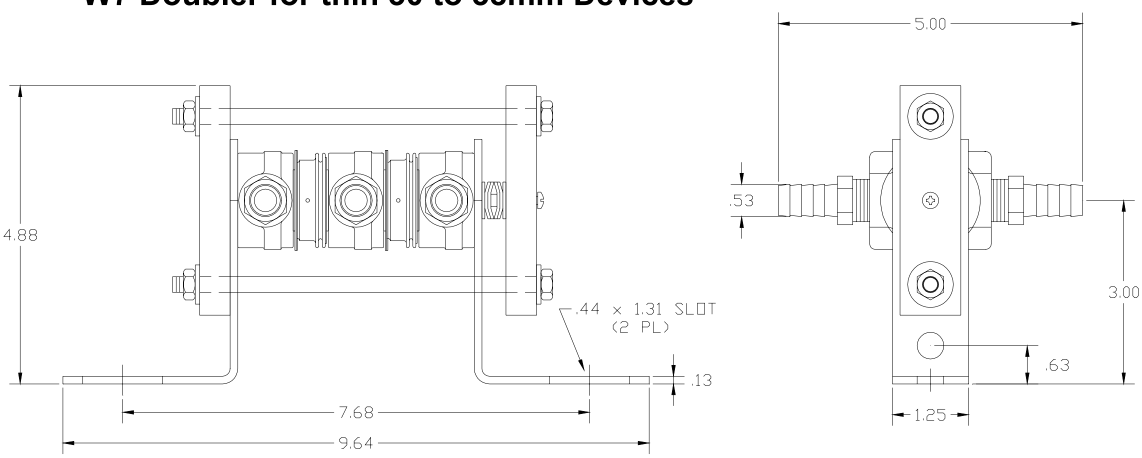
W6 Triple-Series String with Taps for 23mm Devices



W7 Single for thin 30 to 38mm Device



W7 Doubler for thin 30 to 38mm Devices



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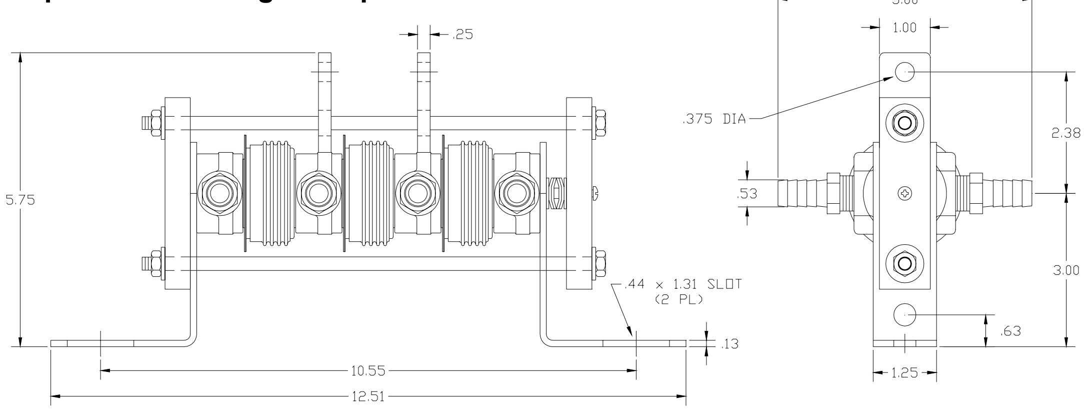
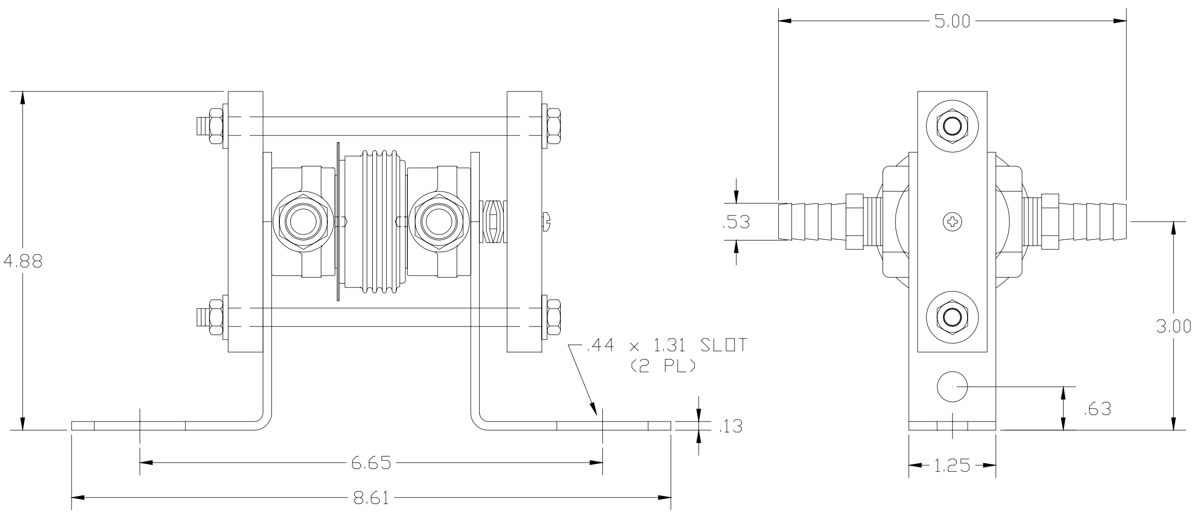
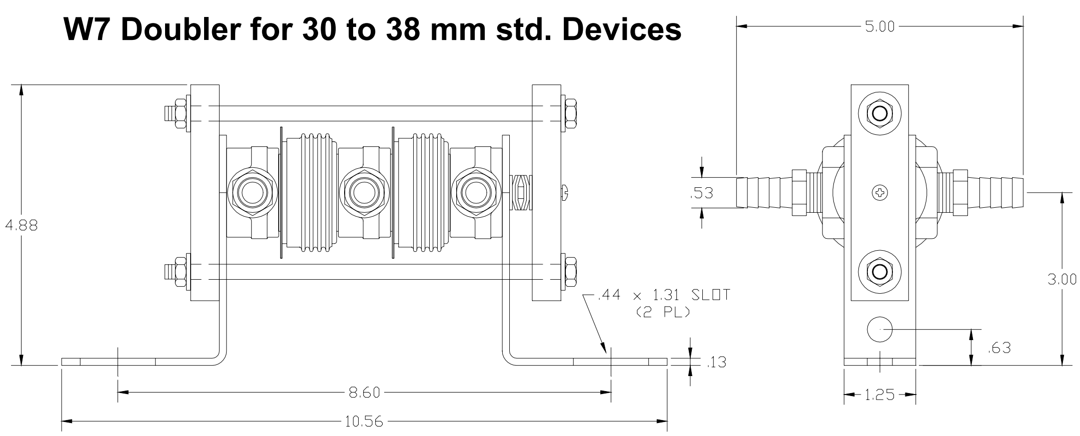
W7 Triple- Series String for Taps 30 to 38mm std. devices



W7 Single device for 30 to 38 mm std. Devices



W7 Doubler for 30 to 38 mm std. Devices



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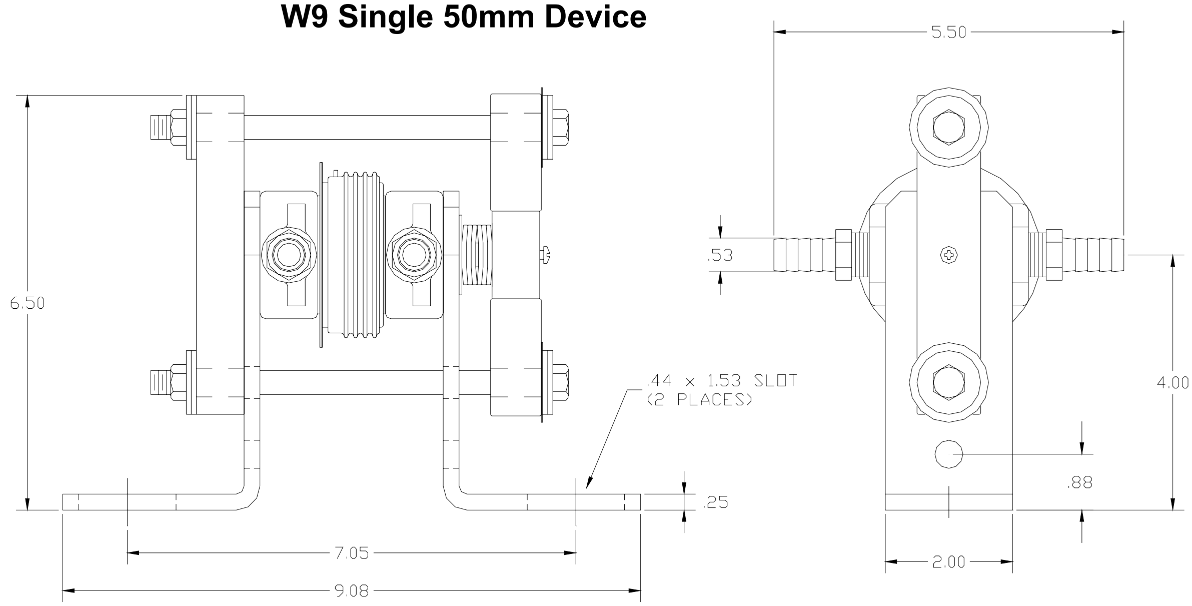
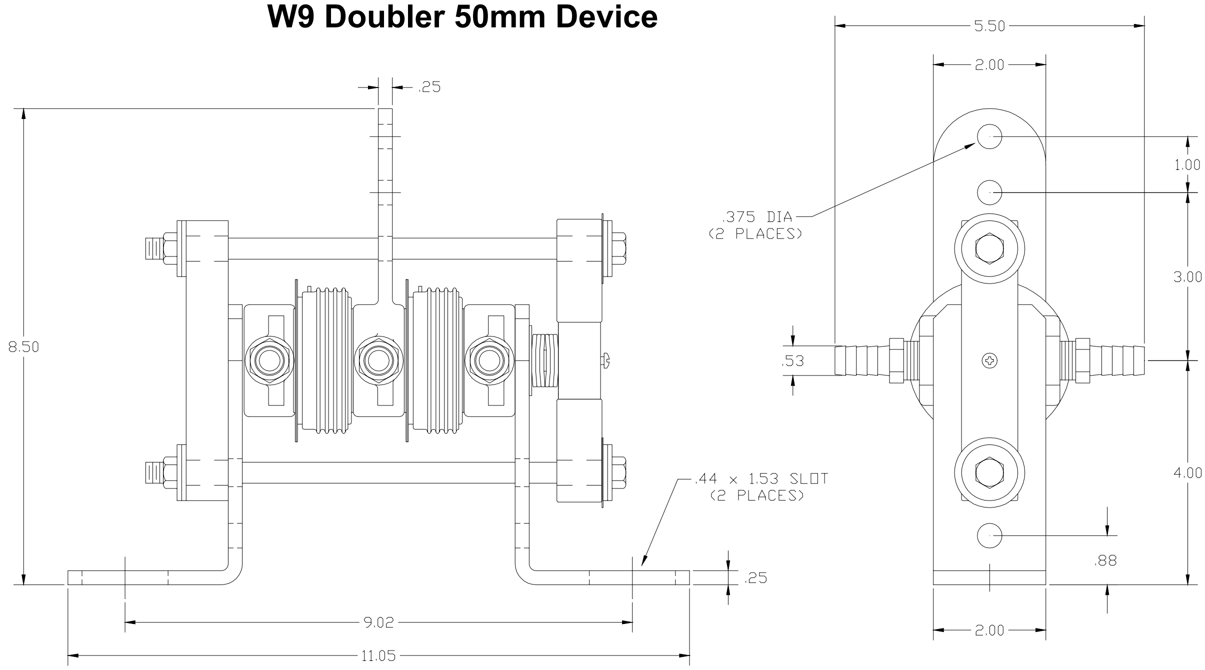
W9 Single 50mm Device



W9 Doubler 50mm Device



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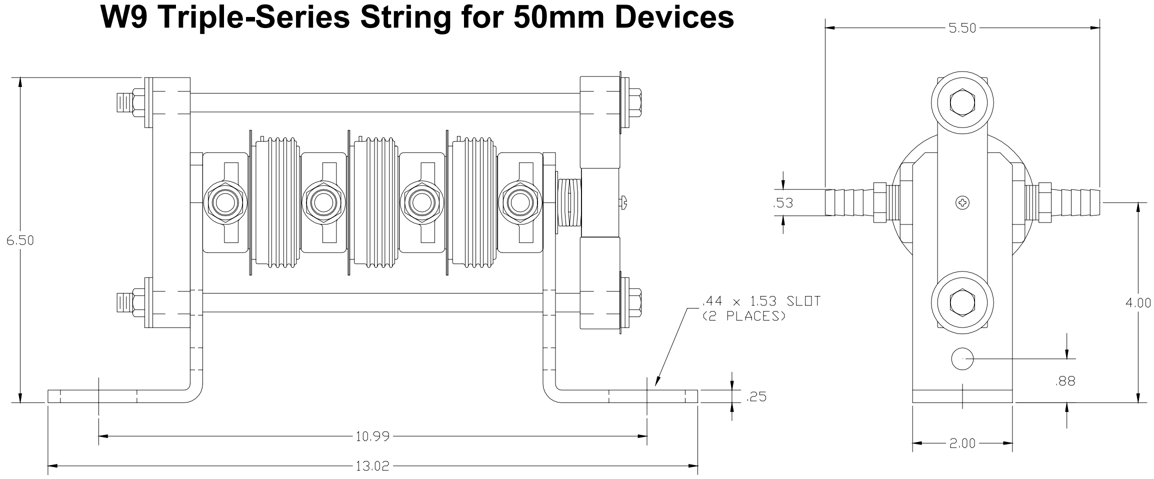
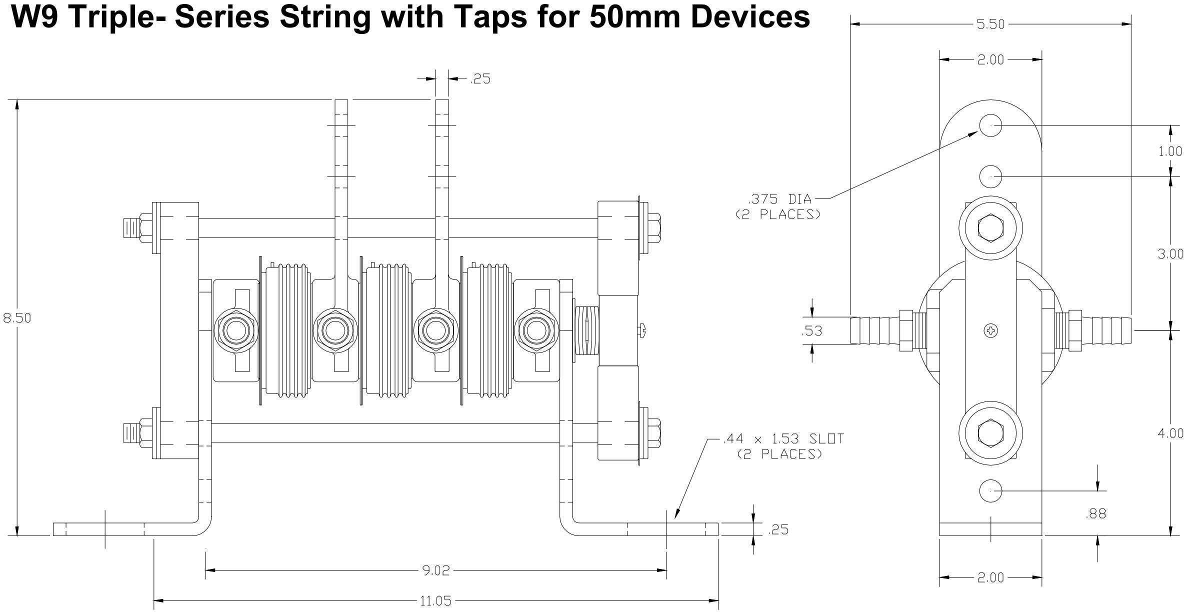
W9 Triple-Series String for 50mm Devices



W9 Triple- Series String with Taps for 50mm Devices



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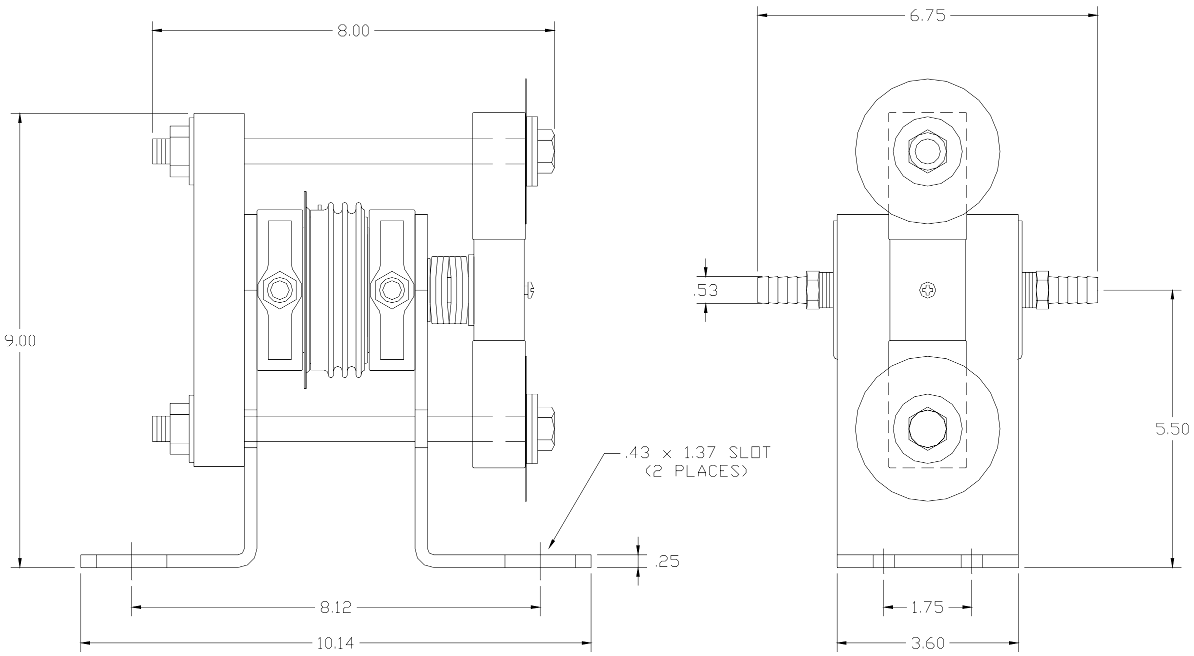
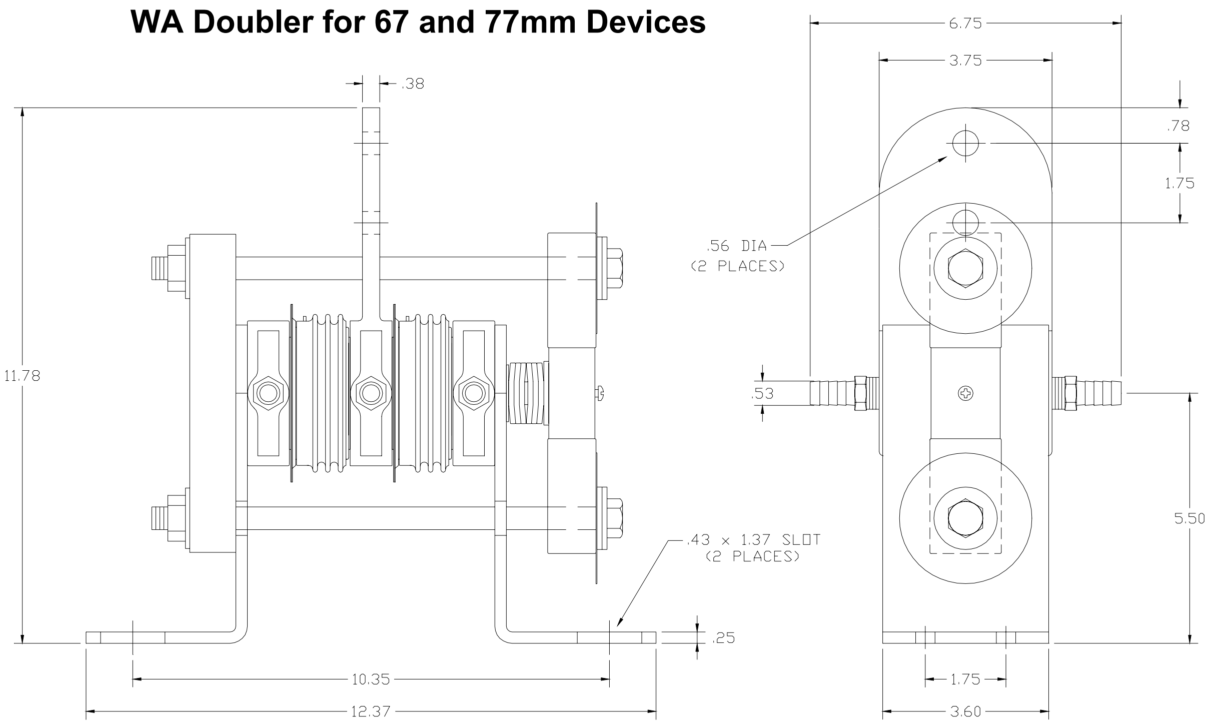
WA Single Device for 67 and 77mm Devices



WA Doubler for 67 and 77mm Devices



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Please feel free to contact us with your application and see what we can do for you!