HEAT SINKS

1. HEAT TRANSFER

<u>Conduction:</u> heat transfer through and by means of matter not involving motion of the matter. . The amount of heat transfer depends on the thermal conductivity of the material, its cross-section area normal to the direction of the heat flow and the temperature gradient or differential.

<u>Convection:</u> heat tranfer by moving matter. The fluid used for convection absorbs the heat by conduction and then moves away carrying the heat within it.

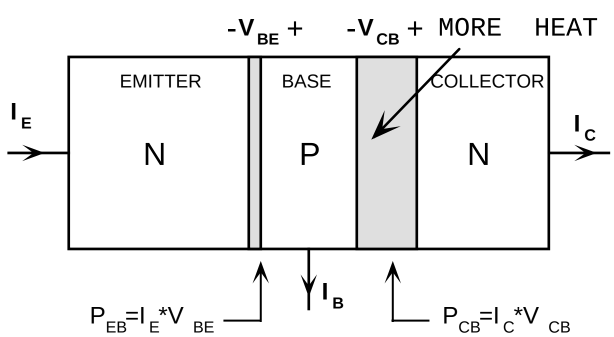
Natural convection occurs when the fluid being heated becomes less dense and is pushed away by the cooler fluid which is more dense, and thus produces a natural or unaided flow.

Forced convection is accomplished using a fan (air flow) or a pump (liquid flow) and is more efficient than natural convection. Efficiency is proportional to the flow rate (litres/sec or m^3/s) of the cooling fluid.

<u>Radiation:</u> heat transfer not involving a transport medium or matter. The rate at which a body emits heat in the form of electromagnetic radiation is a function of its temperature and its thermal emissivity.

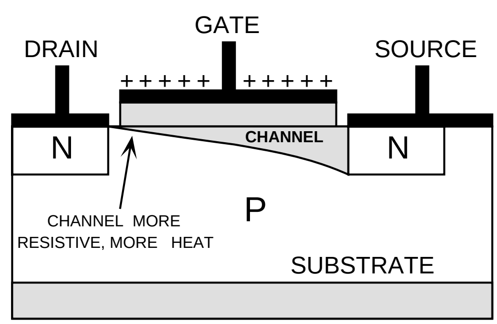
2. HEAT DISSIPATION IN A TRANSISTOR

BIPOLAR TRANSISTOR



$P_{TOTAL} = I_E V_{BE} + I_C V_{CB} \approx I_E (V_{BE} + V_{CB}) = I_E V_{CE}$

MOSFET TRANSISTOR



$P = V_{DS} * I_D$

In a bipolar transistor most of the heat is generated at the CB junction where the voltage drop is higher. Therefore the collector usually makes a physical contact with the transistor case for better heat transfer to the ambiant air surrounding the case - the metal case is a good heat conductor.

In the MOSFET the heat is generated in the channel where the electronic current flows and the majority of that heat will be dissipated near the drain where the channel is pinched and therefore channel resistance at its highest. The drain therefore makes physical contact with the metal case for a more efficient heat transfer to the outside ambient air.

3. THERMAL-ELECTRICAL EQUIVALENTS

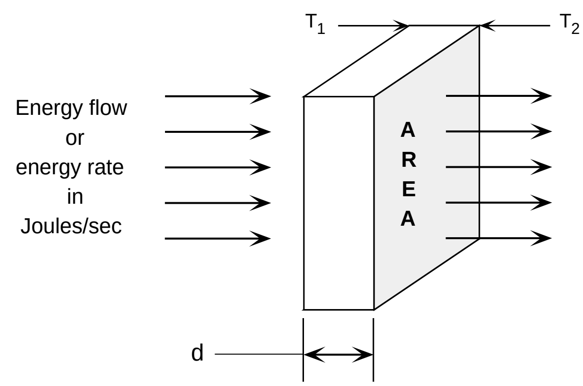
Electrical		Thermal	
current source	ampere (A)	heat source P	watt (W)
current	ampere (A)	power P	watt (W)
voltage	volt (V)	temperature T	degree celsius (°C)
resistance	ohm (Ω)	resistance θ	(°C/W)
capacitance	farad (F)	capacitance C_T	(J/°C)
impedance	ohm (Ω)	transient impedance $\theta(t)$	(°C/W)

<u>Thermal resistance:</u> a quantity that represents the amount of opposition to the flow of heat.

Thermal resistance is given by:

$$\theta = \frac{d}{kA} = \frac{\Delta T}{P} = \frac{T_2 - T_1}{P}$$

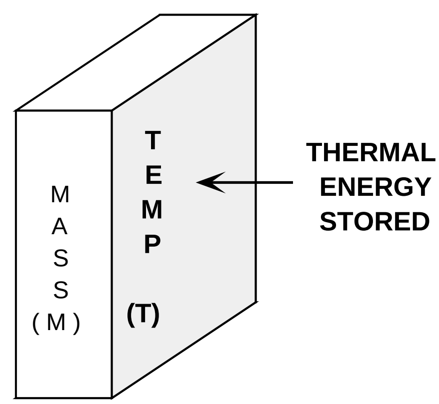
where d = thickness, A = area, k = thermal conductivity of material, ΔT = temperature change across two planes normal to direction of heat flow, P = power representing the rate of flow of thermal energy (or heat) in Watts or Joules/sec.



<u>Thermal capacitance:</u> a quantity that represents the capacity to store heat. Thermal capacitance is given by:

$$C_T = H \times M = \frac{\Delta E}{\Delta T}$$

where ΔE is the quantity of heat absorbed in Joules for a temperature rise ΔT, after temperature has stabilised, M = mass of sample material, H = specific heat of material, that is the quantity of thermal energy required to raise the temperature of one gram of material by 1°C. The unit of H is usually in Cal/(gr-°C).

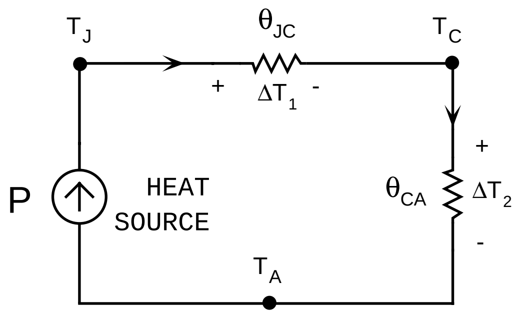


Typical specifications for popular JEDEC metal cases

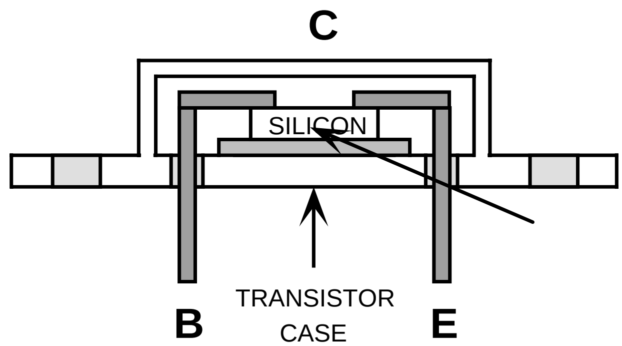
CASE #	TO-3	TO-5	TO-8	TO-18	TO-36	TO-66	TO-220
thermal resistance(°C/W)	30	150	75	300	25	60	60
thermal capacitance (J/°C)	6,8	0,58	1,84	-	-	2,56	-
thermal time constant (sec)	204	87	138	-	-	154	-

4. THERMAL EQUIVALENT CIRCUIT - THERMAL OHM'S LAW

Thermal equivalent circuit



Power transistor



If the power dissipation of an electronic component is constant, it will heat up and reach thermal equilibrium, that is the silicon and case temperatures will reach constant levels. Under those conditions, we can use thermal Ohm's law to calculate the steady-state temperatures.

Thermal Ohm's law: $\Delta T = T_J - T_A = P \times \theta_{tot} = P \times (\theta_{JC} + \theta_{CA})$ $\quad T_J - T_C = \Delta T_1 = P \times \theta_{JC}$

where
- T_J is the junction or silicon chip temperature
- T_A is the ambiant air temperature
- T_C is the case temperature
- P is the power dissipation
- θ is the thermal resistance

EXAMPLE-1 2N3773 NPN Power Transistor Without a Heat Sink

Rating	Symbol	Value	Unit
Collector Emitter Voltage	V_{CEO}	140	Vdc
Collector–Emitter Voltage	V_{CEX}	160	Vdc
Collector–Base Voltage	V_{CBO}	160	Vdc
Emitter–Base Voltage	V_{EBO}	7	Vdc
Collector Current — Continuous — Peak (1)	I_C	16 30	Adc
Base Current — Continuous — Peak (1)	I_B	4 15	Adc
Total Power Dissipation @ T_C = 25_C Derate above 25_C	P_D	150 0.855	Watts W/_C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–65 to +200	_C

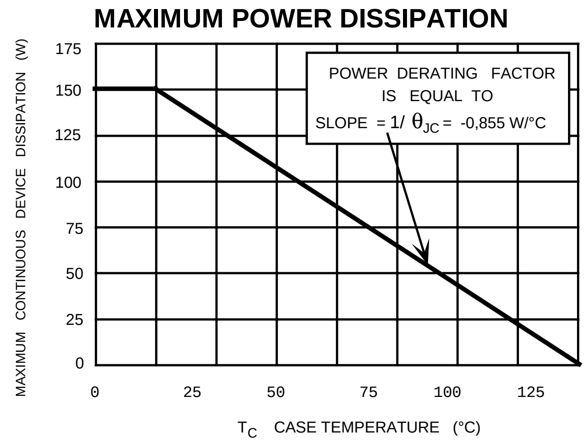
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.17	_C/W

*Indicates JEDEC Registered Data.
(1) Pulse Test: Pulse Width = 5 ms, Duty Cycle _ 10%.

Thermal data

	MIN	TYP	MAX
θ_{JC}	-	-	1,17 °C/W
θ_{JA}	-	-	43,7 °C/W

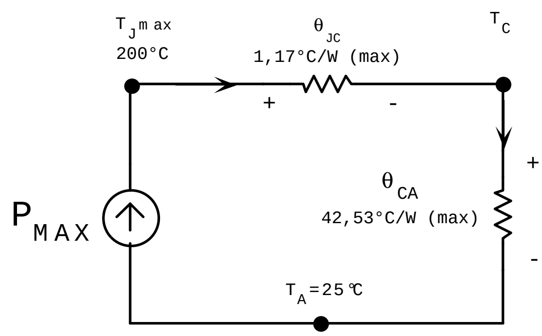


P_{MAX} is to be derated linearly at a rate of 0,855W/°C which corresponds to $1/\theta_{JC}$. Power derating is usually started at 25°C and ends at T_J max of the device where P_{MAX} =0.

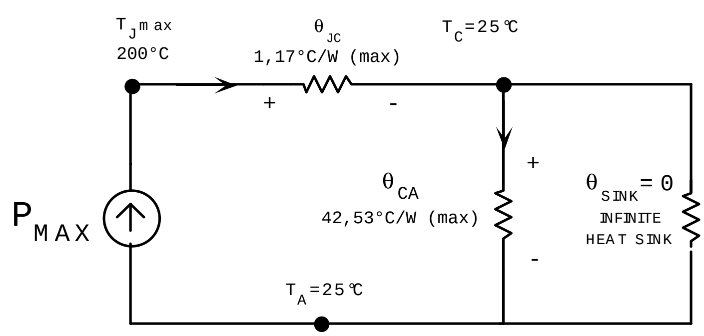
A) Verify that the absolute maximum power rating is 150W.

P_{MAX} depends on the maximum junction temperature of 200°C and the device thermal resistance θ_{JC}, that is:

$$P_{max} = \frac{T_{J(max)} - T_C}{\theta_{JC}} = \frac{200-25}{1{,}17} = 149{,}57W$$



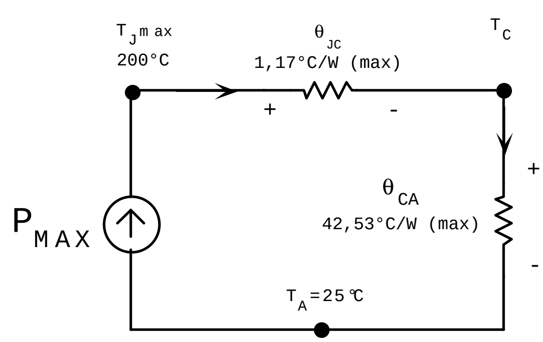
This maximum power can only be achieved if we mount the transistor on an infinite heat sink whose thermal resistance is zero. This is physically impossible and costly. In practice heat sink thermal resistances can be as low as 0,25 °C/W but the heat sinks become physically quite large.



B) What is the maximum power that can be dissipated without a heat sink at ambient temperatures of +25°C and +50°C?

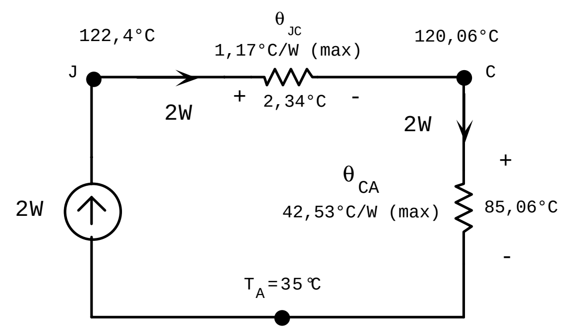
$$P_{max} = \frac{T_{J(max)} - T_A}{\theta_{JC} + \theta_{CA}} = \frac{200-25}{1{,}17+42{,}532} = 4{,}0W$$

$$P_{max} = \frac{T_{J(max)} - T_A}{\theta_{JC} + \theta_{CA}} = \frac{200-50}{1{,}17+42{,}532} = 3{,}43W$$

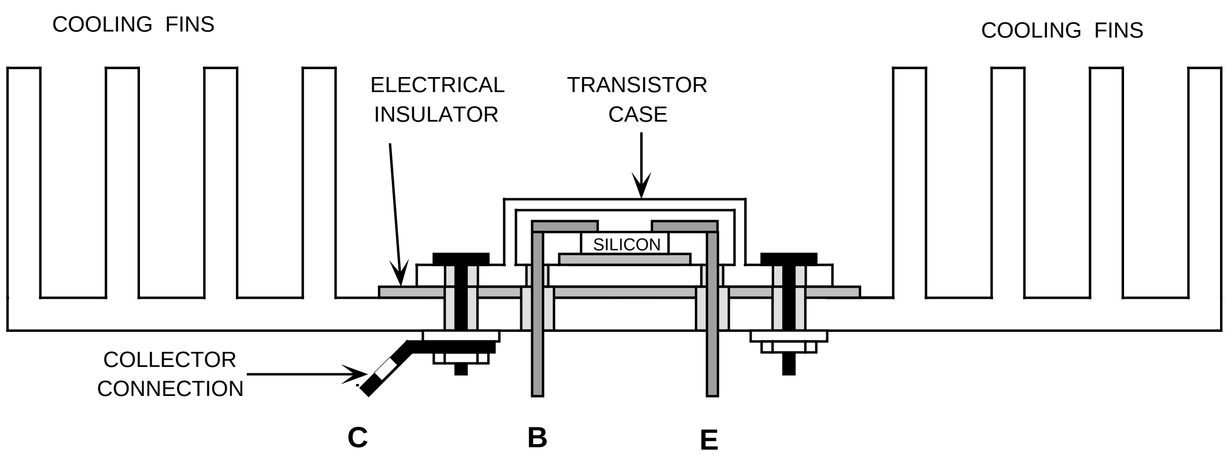


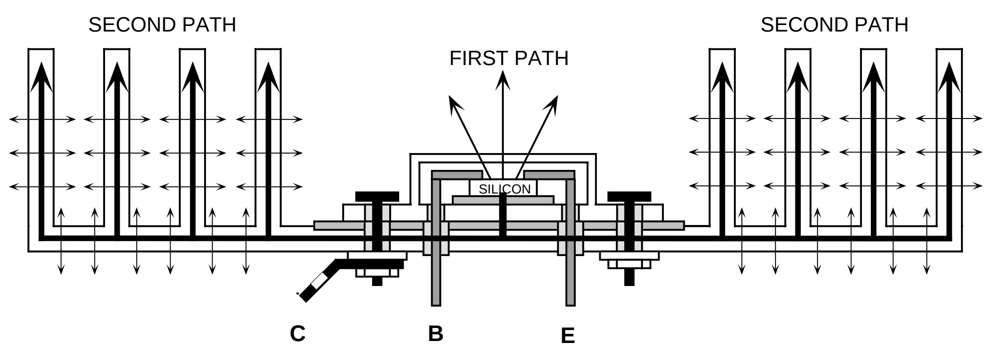
C) Determine the junction and case temperatures if the transistor dissipates 2W at an ambient temperature of 35°C - assume that no heat sink is used.

Using thermal Ohm's law, $\Delta T = P \times \theta$, results are easily obtained - see diagram shown beside.



5. THERMAL EQUIVALENT CIRCUIT WITH A HEAT SINK

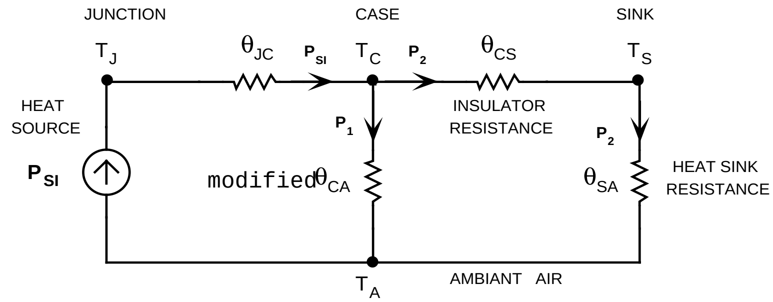




FIRST PATH: JUNCTION TO CASE TO AMBIANT AIR, HIGH RESISTANCE PATH

SECOND PATH: JUNCTION TO CASE TO HEAT SINK TO AMBIANT AIR, LOW RESISTANCE PATH.

When the heat sink is added, the case thermal resistance (θ_{CA}) is nearly doubled because its lower surface area is lost to the heat sink. If the heat sink area is very large then very little heat will be dissipated through the case and θ_{CA} can be ignored. In some heat sink data, θ_{CA} is lumped with the heat sink thermal resistance (θ_{SA}).

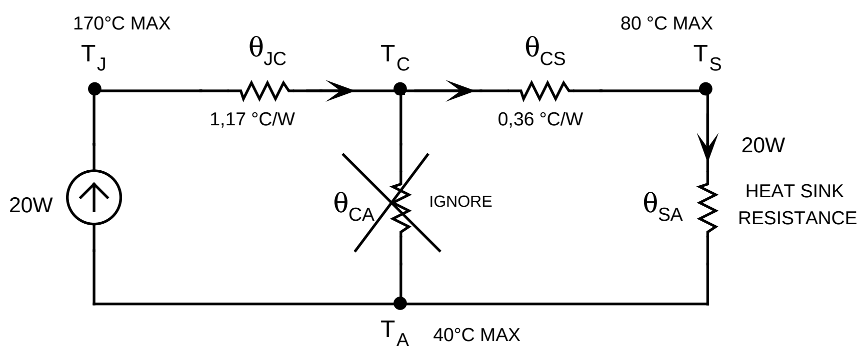


Typical insulator thermal resistance (θ_{CS})

	METAL-TO-METAL		USING AN INSULATOR	
CASE	dry	H/S compound	H/S compound	Type
T0-3	0,2°C/W	0,1°C/W	0,36°C/W	3 mil mica
T0-3	0,2°C/W	0,1°C/W	0,28°C/W	Anodized Aluminum
TO-66	1,5°C/W	0,5°C/W	0,9°C/W	2 mil mica
TO-220	1,2°C/W	1,0°C/W	1,6°C/W	2 mil mica

EXAMPLE-2 2N3773 NPN Power Transistor With Heat Sink

A) A 2N3773 power transistor which dissipates a continuous power of 20W is mounted on a heat sink with a 3 mil mica insulator with heat sink compound. Determine the maximum heat sink thermal resistance required if we want to keep the junction temperature at least 60°C below its absolute maximum (to extend its lifespan) and also to keep the heat sink temperature below 80 °C. Assume that the ambient temperature varies from +15°C to +40 °C. Assume natural convection.



$$T_J = T_A + P \times \theta_{tot} < 140 \Rightarrow \theta_{tot} < \frac{T_{J\,max} - T_A}{P} = \frac{140-40}{20} = 5^\circ C/W$$

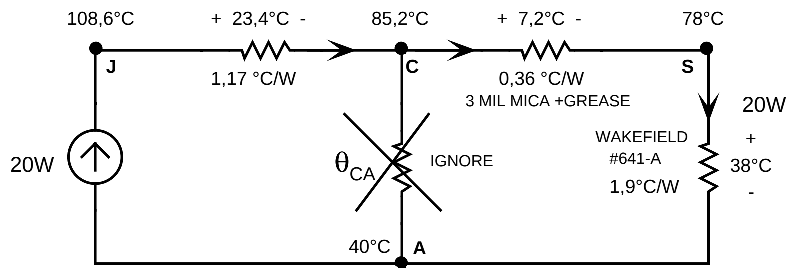
$$\theta_{SA} = \theta_{tot} - \theta_{JC} - \theta_{CS} = 5 - 1{,}17 - 0{,}36 < 3{,}47^\circ C/W$$

$$T_S = T_A + P \times \theta_{SA} < 80 \Rightarrow \theta_{SA} < \frac{T_{S\,max} - T_{A\,max}}{P} = \frac{80-40}{20} = 2^\circ C/W$$

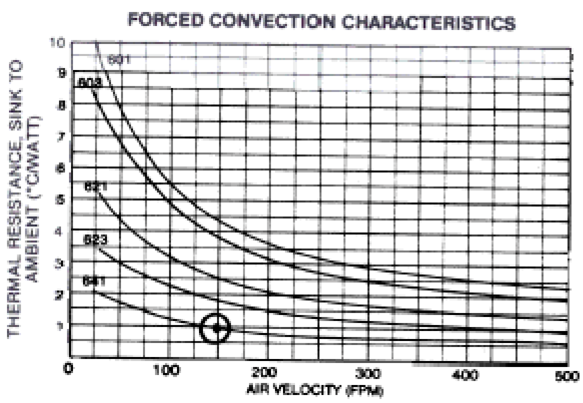
Answer

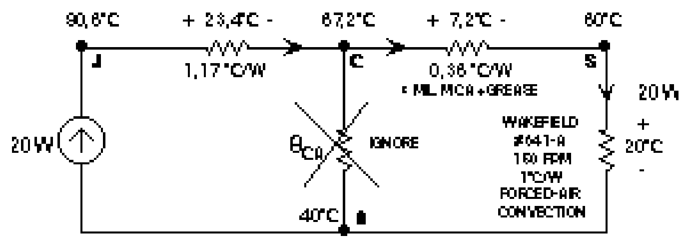
θ_{SA} < 2°C/W

B) Assuming that a Wakefield #641-A heat sink is used, determine T_J, T_C and T_S for an ambient temperature of 40°C when 20W continuous is dissipated. Assume natural convection.



C) Assuming again that a Wakefield #641-A heat sink is used, determine T_J, T_C and T_S for an ambient temperature of 40°C when 20W is dissipated. Assume that forced-air convection (a fan) is used with an air velocity of 150 FPM (feet per minute).



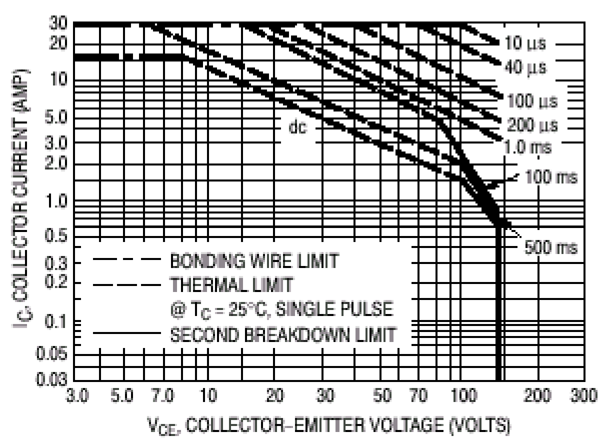


D) **Safe operating area (SOA)**

The operating limits of I_C and V_{CE} are not only limited by P_{MAX} (or T_J max) but they are also limited by $I_C$max (bonding wire melting if I_C too large), V_{CEO} max (avalanche breakdown) and "second breakdown" (current crowding in small parts of emitter leading to hot spot and burning). One should always check if the operating values of I_C and V_{CE} are within the SOA of the transistor with enough safety margin.

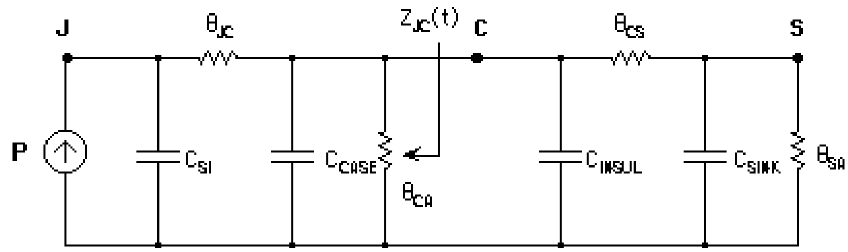
There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation: i.e., the transistor must not be subjected to greater dissipation than the curves indicate.
The data of Figure 7 (beside) is based on $T_{J(pk)}$ = 200 °C; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)}$ < 200 °C. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

2N3773 SAFE OPERATING AREA

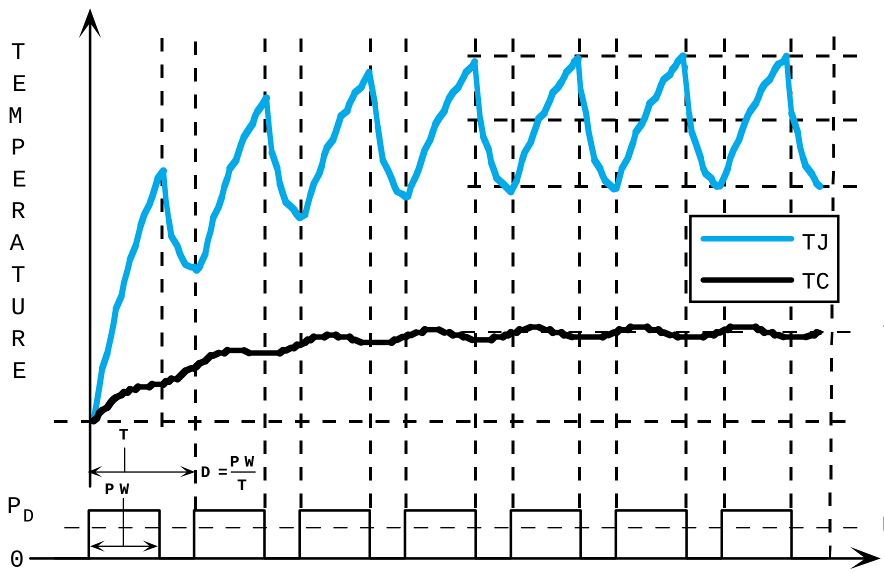


6. TRANSIENT THERMAL IMPEDANCE - PULSE OPERATION

If a power device is operated in a pulse mode (switched ON and OFF) temperature will vary as a function of time because of thermal capacitances involved along with thermal resistances.



The junction temperature of the device will vary as shown below where one is always interested in determining the maximum junction temperature to ensure that it is not excessive.



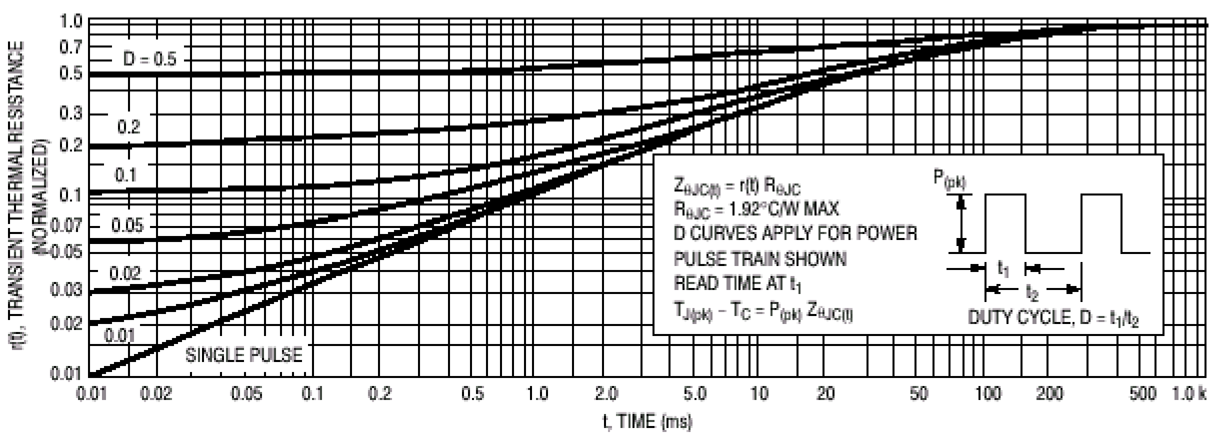
$$T_{J(MAX)} = T_C + (P_D \times Z_{JC}(t))$$

$$T_{J(AVE)} = T_C + (P_{D(AVE)} \times \theta_{JC})$$

$$Z_{JC}(t) = \theta_{JC} \times r(t)$$

$$T_{C(AVE)} = T_A + P_{D(AVE)} \times \theta_{CA}$$

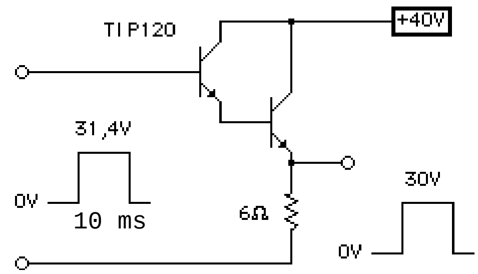
NORMALIZED THERMAL RESPONSE OF TIP120



EXAMPLE-3 PULSE OPERATION OF TIP120

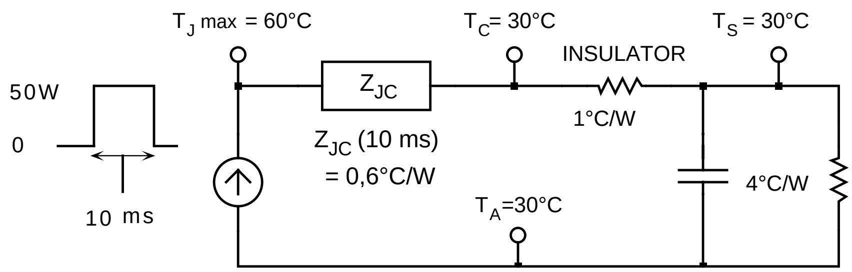
A TIP120 is mounted directly on a Wakefield 270-AB heat sink (no insulator) with thermal grease.

A) A TIP120 is driven by a single 10 ms pulse as shown below. Assume that the heat sink is large enough such that the case temperature does not have time to rise substantially within 10 ms - large time constant. Ambient temperature is 30°C. Determine T_J max, the approximate time constant of the junction to case material and sketch graph of T_J versus t.



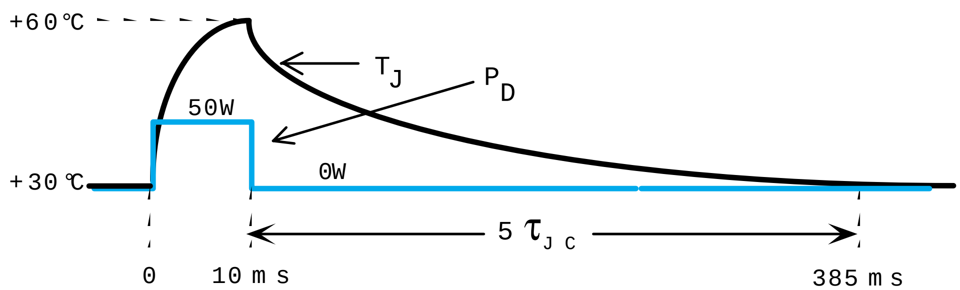
We can read r(t) = 0,31 at = 10 ms on the transient thermal impedance shown at the bottom of the previous page. (for TIP120)

$$Z_{JC}(t) = r(t)\times \theta_{JC} = 0{,}31\times 1{,}92 \approx 0{,}6°C/W$$

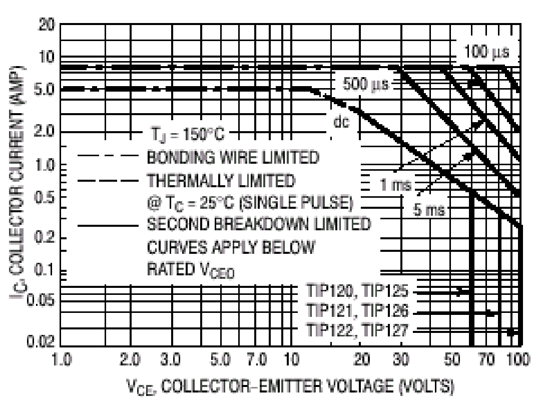


The thermal time constant from junction to case can be obtained from the 0% duty cucle curve:

after one τ_{JC}, r(t) = $(1-e^{-(t/\tau)})$ = 0,632 and we read t = τ_{JC} = 75 ms.



Let us verify that the load line lies within the SOA curve to ensure safe operation of the transistor.



There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation, i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)}$ = 150_C; T_C is variable depending on conditions. Second breakdown pulse limits are valid for duty cycles to 10% provided $T_{J(pk)}$ < 150_C. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown

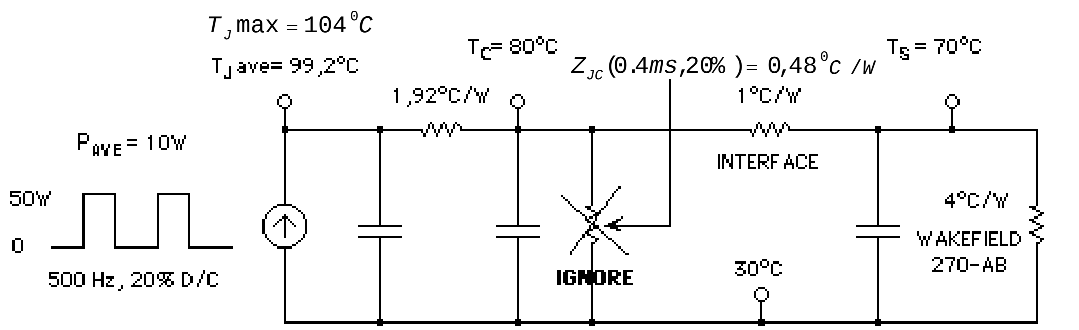
B) Repeat part A with repetitive pulses at 500 Hz and 20% duty cycle. Assume the same voltage levels (same peak power).

For average temperatures we can use the average power and use only the thermal resistances as done with continuous power dissipation.

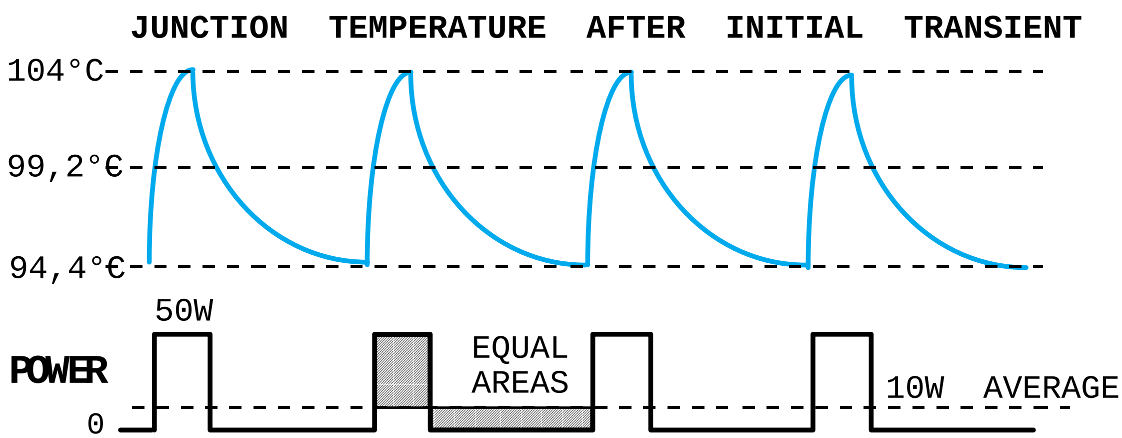
P_{AVE} = D x P_{MAX} = 0,2 * 50 = 10W.

For maximum T_J we can read r(t) = 0,4 at 0,4 ms with 20% duty cycle, therefore we have:

Z_{JC}(t,D)=r(t) x θ_{JC} = 0,25 x 1,92 = 0,48°C/W.



T_J will vary as shown below.



The above calculations show that T_J max is well below the maximum 200°C specified. After ensuring operation within the FBSOA the device is deemed to operate safely.

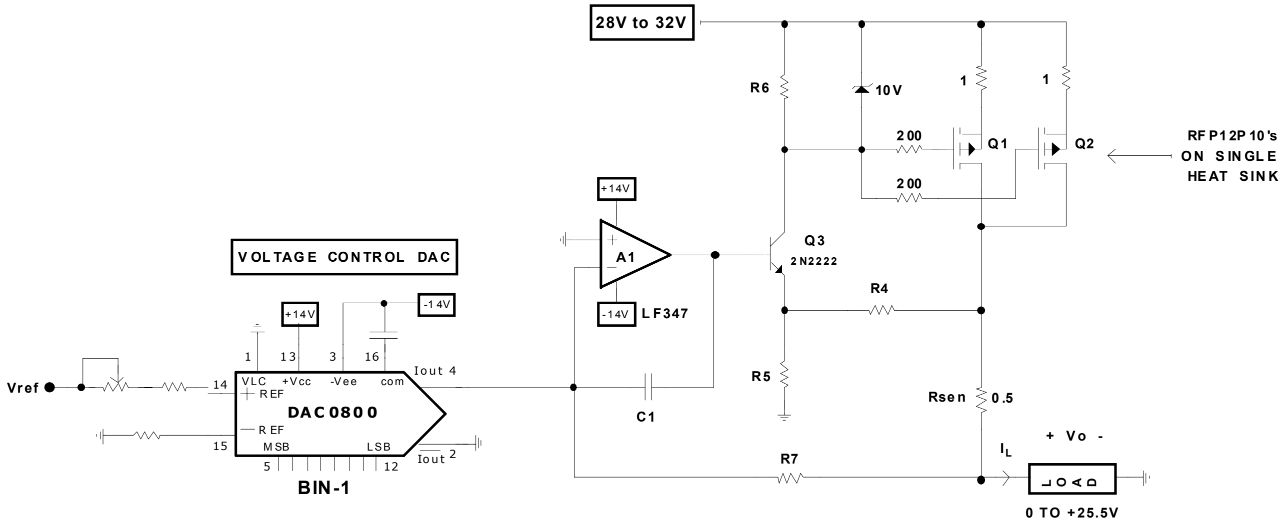
NOTE: The above calculations assume that the heat sink thermal time constant is large enough such that we can assume a quasi constant case temperature after the initial transient.

The average of a function is given by the following expression:

$$Ave\ f_{(t)} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} f_{(t)}\,dt \Rightarrow Ave\ f_{(t)} = \frac{1}{T}\int_{0}^{T} f_{(t)}\,dt$$ for a periodic function.

EXAMPLE-4 Programmable Power Supply

A) Determine the number of RFP12P10's required to handle maximum power dissipation if we want to maintain the transistors' junction temperature 30°C below the maximum rated value. Assume that ambient temperature ranges from 20 °C to 30 °C and that all transistors are to be mounted on a single heat sink using a 2-mil mica insulator. Also assume a maximum heat sink temperature of 60 °C. V_o of the programmable supply ranges from 0 to 25.5V and I_L from 0 to 2.55A.



The worst case power dissipation for the MOSFETs is when V_{DS} is maximum which occurs when V_o is 0V and I_L = 2.55A max.

$$P_{total} = V_{DS} I_D = \left(32 - 2.55 \times 0.5 - \frac{2.55}{N} \times 1\right) \times 2.55$$

Assuming N = 3 MOSFET, we have P_{total}=76.2W max

T_J max = 150 °C from data sheets.

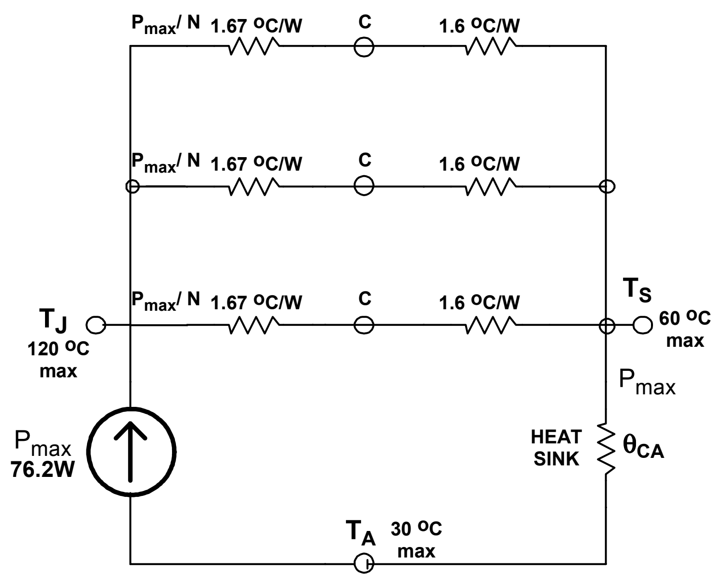
The insulator thermal resistance is that of a typical TO-220 insulator – see chart on page 6.

The maximum heat sink resistance is

$$\theta_{SA} < \frac{60-30}{76.2} = 0.394\ {}^oC/W$$

$$T_J \max = 60 + \frac{76.2}{N} \times (1.67 + 1.6) < 125$$

$$N > \frac{76.2 \times (1.67 + 1.6)}{125 - 60} = 3.83$$

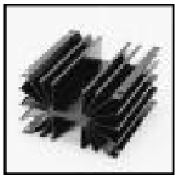


We will need 4 power transistors which will each dissipate a maximum power of:

$$P_{total} = V_{DS} I_D = \left(32 - 2.55 \times 0.5 - \frac{2.55}{4} \times 1\right) \times \frac{2.55}{4} = 19.18W$$

B) Find a suitable Wakefield heat sink and then calculate the maximum heat sink temperature and junction temperatures. I selected a Wakefield 433K from the data shown below – see data sheets at the end for better resolution of the pictures. It has a θ_{SA} of 0.28 $^oC/W$ with forced convection cooling of 250 LFM.

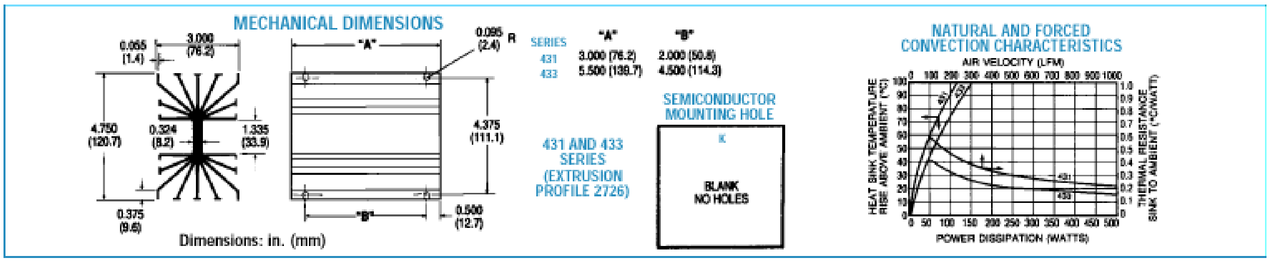
EXTRUDED HEAT SINKS FOR POWER SEMICONDUCTORS

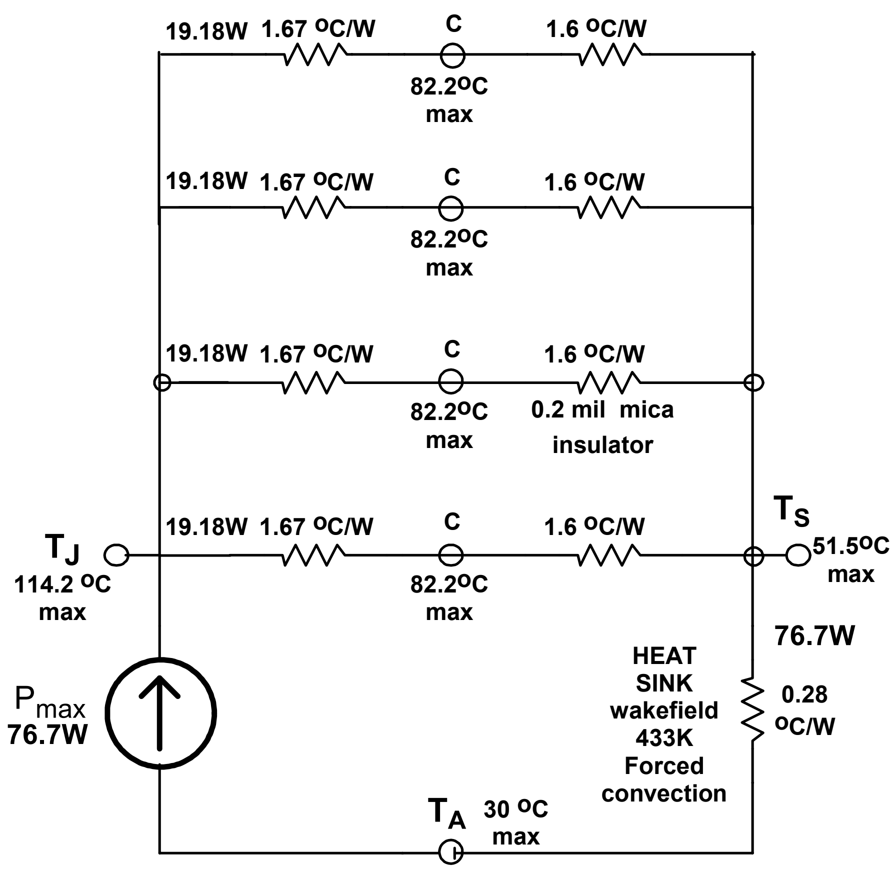


431 AND 433 SERIES *High-Performance Heat Sinks for 30-100W Metal Power Semiconductors* *TO-3; Stud-Mount*

Standard P/N	Width in. (mm)	Nominal Dimensions Length "A" in. (mm)	Height in. (mm)	Semiconductor Mounting Hole Pattern	Thermal Performance at Typical Load Natural Convection	Forced Convection	Weight lbs. (grams)
431K	4.750 (120.7)	3.000 (76.2)	3.000 (76.2)	None	55°C @ 50W	0.40°C/W @ 250 LFM	0.7800 (353.81)
433K ▲	4.750 (120.7)	5.500 (139.7)	3.000 (76.2)	None	42°C @ 50W	0.28°C/W @ 250 LFM	1.4900 (675.86)

Need maximum heat dissipation from a TO-3 rectifier heat sink in minimum space? The Wakefield 431 and 433 Series center channel double-surface heat sinks offer the highest performance-to-weight ratio for minimum volume occupied for TO-3, diode, and stud-mount metal power semiconductors in the 30- to 100-watt operating range. Additional interface resistance reduction for maximized overall performance can be achieved with proper application of Wakefield Type 126 silicone-free thermal compound. Material: Aluminum Alloy, Black Anodized.





Wakefield Engineering

EXTRUDED HEAT SINKS FOR POWER SEMICONDUCTORS

621 AND 623 SERIES *Low-Profile Heat Sinks for All Metal-Case Power Semiconductors*

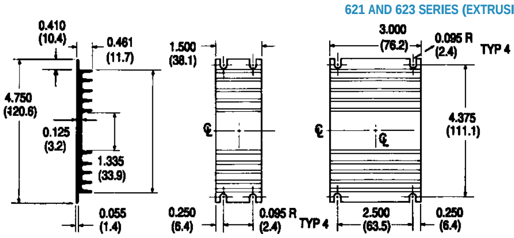
TO-3

Standard P/N	Footprint Dimensions in. (mm)	Height in. (mm)	Mounting Hole Pattern	Thermal Performance at Typical Load Natural Convection	Forced Convection	Weight lbs. (grams)
621A	4.750 (120.6) x 1.500 (38.1)	0.461 (11.7)	(1) TO-3	75°C @ 15W	2.0°C/W @ 250 LFM	0.1000 (45.36)
621K	4.750 (120.6) x 1.500 (38.1)	0.461 (11.7)	None	75°C @ 15W	2.0°C/W @ 250 LFM	0.1000 (45.36)
623A	4.750 (120.6) x 3.000 (76.2)	0.461 (11.7)	(1) TO-3	52°C @ 15W	1.5°C/W @ 250 LFM	0.2100 (95.26)
623K	4.750 (120.6) x 3.000 (76.2)	0.461 (11.7)	None	52°C @ 15W	1.5°C/W @ 250 LFM	0.2100 (95.26)

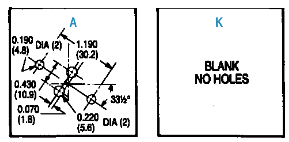
A general purpose yet efficient heat dissipator for TO-3 and virtually all other styles of metal case power semiconductor package types, the 621 and 623 Series low-profile flat back heat sinks find a wide variety of applications. The central channel between fins measures 1.300 in. (33.0) (min.) in width, accommodating many types of packages. Mounting hole pattern "A" is predrilled for the standard TO-3 package. Material: Aluminum Alloy, Black Anodized.

MECHANICAL DIMENSIONS

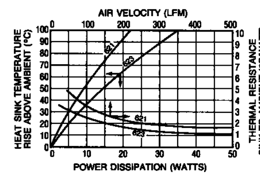
621 AND 623 SERIES (EXTRUSION PROFILE 1327)



SEMICONDUCTOR MOUNTING HOLES



NATURAL AND FORCED CONVECTION CHARACTERISTICS



Dimensions: in. (mm)

301/302/303 SERIES *Compact Heat Sinks for Dual Stud-Mounted Semiconductor Cases*

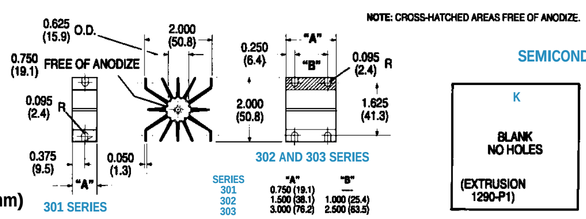
STUD-MOUNT

Standard P/N	Outline Dimensions in. (mm)	Length "A" in. (mm)	Mounting Hole (s) Pattern and Number	Thermal Performance at Typical Load Natural Convection	Forced Convection	Weight lbs. (grams)
301K	2.000 (50.8) x 2.000 (50.8)	0.750 (19.1)	None	70°C @ 15W	2.5°C/W @ 250 LFM	0.0580 (26.31)
301M	2.000 (50.8) x 2.000 (50.8)	0.750 (19.1)	(1) 10-32UNF, 0.625 in. thread depth	70°C @ 15W	2.5°C/W @ 250 LFM	0.0580 (26.31)
301N	2.000 (50.8) x 2.000 (50.8)	0.750 (19.1)	(1) 1/4 -28UNF, 0.625 in. thread depth	70°C @ 15W	2.5°C/W @ 250 LFM	0.0580 (26.31)
302M	2.000 (50.8) x 2.000 (50.8)	1.500 (38.1)	(1) 10-32UNF, 0.625 in. thread depth	50°C @ 15W	1.8°C/W @ 250 LFM	0.1330 (60.33)
302MM	2.000 (50.8) x 2.000 (50.8)	1.500 (38.1)	(2) 10-32UNF, 0.625 in. thread depth	50°C @ 15W	1.8°C/W @ 250 LFM	0.1330 (6033)
302N	2.000 (50.8) x 2.000 (50.8)	1.500 (38.1)	(1) 1/4 -28UNF, 0.625 in. thread depth	50°C @ 15W	1.8°C/W @ 250 LFM	0.1330 (60.33)
302NN ▲	2.000 (50.8) x 2.000 (50.8)	1.500 (38.1)	(2) 1/4 -28UNF, 0.625 in. thread depth	50°C @ 15W	1.8°C/W @ 250 LFM	0.1330 (60.33)
303M	2.000 (50.8) x 2.000 (50.8)	3.000 (76.2)	(1) 10-32UNF, 0.625 in. thread depth	37°C @ 15W	1.3°C/W @ 250 LFM	0.2680 (121.56)
303MM	2.000 (50.8) x 2.000 (50.8)	3.000 (76.2)	(2) 10-32UNF, 0.625 in. thread depth	37°C @ 15W	1.3°C/W @ 250 LFM	0.2680 (121.56)
303N ▲	2.000 (50.8) x 2.000 (50.8)	3.000 (76.2)	(1) 1/4 -28UNF, 0.625 in. thread depth	37°C @ 15W	1.3°C/W @ 250 LFM	0.2680 (121.56)
303NN	2.000 (50.8) x 2.000 (50.8)	3.000 (76.2)	(2) 1/4 -28UNF, 0.625 in. thread depth	37°C @ 15W	1.3°C/W @ 250 LFM	0.2680 (121.56)

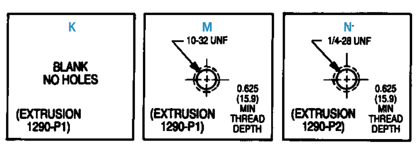
The large fin area in minimum total volume provided by the radial design of the 301/302/303 Series offers maximum heat transfer efficiency in natural convection. All types are available with one tapped mounting hole for rectifiers and other stud-mounting semiconductors; the 302 and 303 Series offer maximum cost savings with dual mounting locations ("MM" and "NN" mounting hole patterns) for two stud-mount devices. Material: Aluminum Alloy, Black Anodized.

MECHANICAL DIMENSIONS

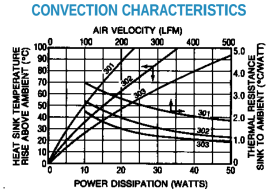
NOTE: CROSS-HATCHED AREAS FREE OF ANODIZE.



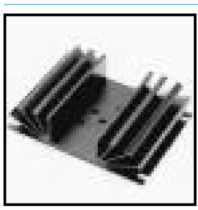
SEMICONDUCTOR MOUNTING HOLES



NATURAL AND FORCED CONVECTION CHARACTERISTICS



Dimensions: in. (mm)



641 SERIES *Maximum Performance Natural Convection Heat Sink for all Metal-Case Semiconductors*

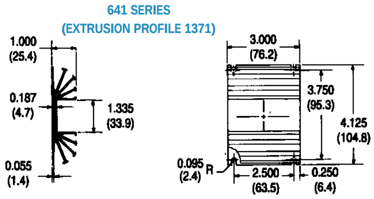
TO-3

Standard P/N	Outline Dimensions in. (mm)	Height in. (mm)	Mounting Hole Pattern	Thermal Performance at Typical Load Natural Convection	Forced Convection	Weight lbs. (grams)
641A ▲	4.125 (104.8) x 3.000 (76.2)	1.000 (25.4)	(1) TO-3	36°C @ 15W	0.9°C/W @ 250 LFM	0.2900 (131.54)
641K ▲	4.125 (104.8) x 3.000 (76.2)	1.000 (25.4)	None	36°C @ 15W	0.9°C/W @ 250 LFM	0.2900 (131.54)

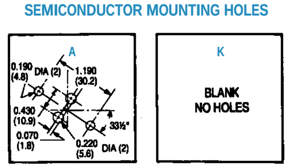
Available with a standard TO-3 mounting hole pattern predrilled for cost-effective mounting in limited-height applications, the 641 Series provides maximum performance in natural convection with an optimized heat sink surface area. The 641K type with an open channel area of 1.300 in. (33.0) and no predrilled mounting holes can be adapted to meet mounting requirements for most metal case power semiconductor types. Material: Aluminum Alloy, Black Anodized.

MECHANICAL DIMENSIONS

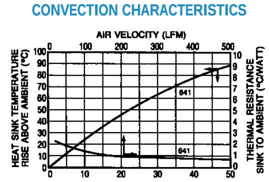
641 SERIES (EXTRUSION PROFILE 1371)



SEMICONDUCTOR MOUNTING HOLES



NATURAL AND FORCED CONVECTION CHARACTERISTICS



Dimensions: in. (mm)

EXTRUDED HEAT SINKS FOR POWER SEMICONDUCTORS

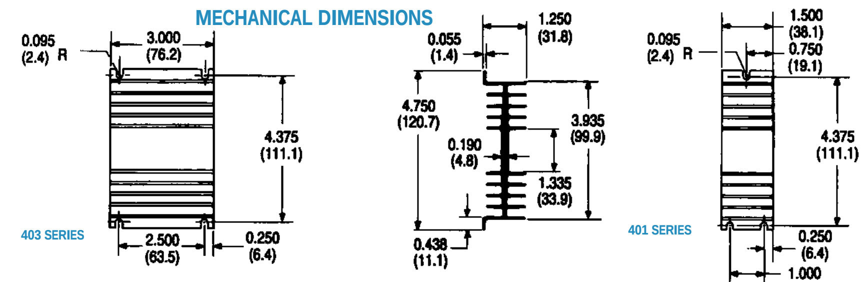
401 AND 403 SERIES *Double-Surface Heat Sinks for TO-3 Case Styles*

TO-3; Stud-Mount

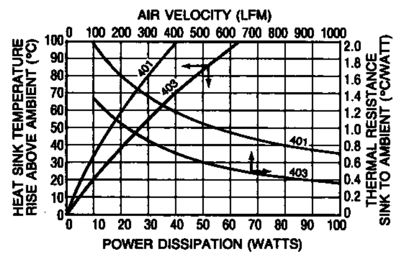
Standard P/N	Width in. (mm)	Overall Dimensions in. (mm)	Height in. (mm)	Semiconductor Mounting Hole Pattern	Thermal Performance at Typical Load: Natural Convection	Thermal Performance at Typical Load: Forced Convection	Weight lbs. (grams)
401A ▲	4.750 (120.7)	1.500 (38.1)	1.250 (31.8)	(1) TO-3	80°C @ 30W	1.5°C/W @ 250 LFM	0.1500 (68.04)
401F	4.750 (120.7)	1.500 (38.1)	1.250 (31.8)	0.270 in. (6.9)-Dia Hole	80°C @ 30W	1.5°C/W @ 250 LFM	0.1500 (68.04)
401K ▲	4.750 (120.7)	1.500 (38.1)	1.250 (31.8)	None	80°C @ 30W	1.5°C/W @ 250 LFM	0.1500 (68.04)
403A ▲	4.750 (120.7)	3.000 (76.2)	1.250 (31.8)	(1) TO-3	55°C @ 30W	0.9°C/W @ 250 LFM	0.3500 (158.76)
403F ▲	4.750 (120.7)	3.000 (76.2)	1.250 (31.8)	0.270 in. (6.9)-Dia Hole	55°C @ 30W	0.9°C/W @ 250 LFM	0.3500 (158.76
403K ▲	4.750 (120.7)	3.000 (76.2)	1.250 (31.8)	None	55°C @ 30W	0.9°C/W @ 250 LFM	0.3500 (158.76)

With fins oriented vertically in cabinet sidewall applications, 401 and 403 Series heat sinks are recommended for critical space applications where maximum heat dissipation is required for high-power TO-3 case styles. Forced convection performance is also exemplary with these double surface fin types. Semiconductor mounting hole style "F" offers a single centered 0.270 in. (6.9)-diameter mounting hole (with a 0.750 in. (19.1)-diameter area free of anodize) for mounting stud-type diodes and rectifiers. Hole pattern "V" available upon request. Material: Aluminum Alloy, Black Anodized.

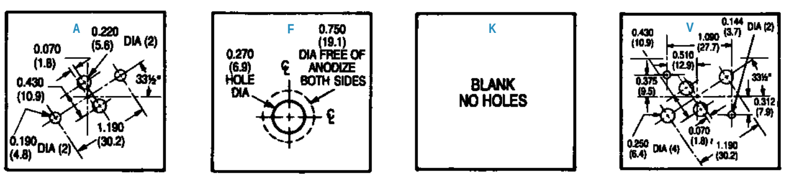
MECHANICAL DIMENSIONS



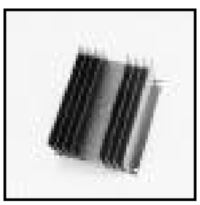
NATURAL AND FORCED CONVECTION CHARACTERISTICS

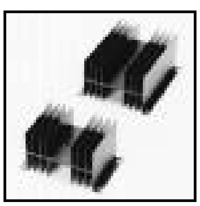


SEMICONDUCTOR MOUNTING HOLES



401 AND 403 SERIES (EXTRUSION PROFILE 1024)





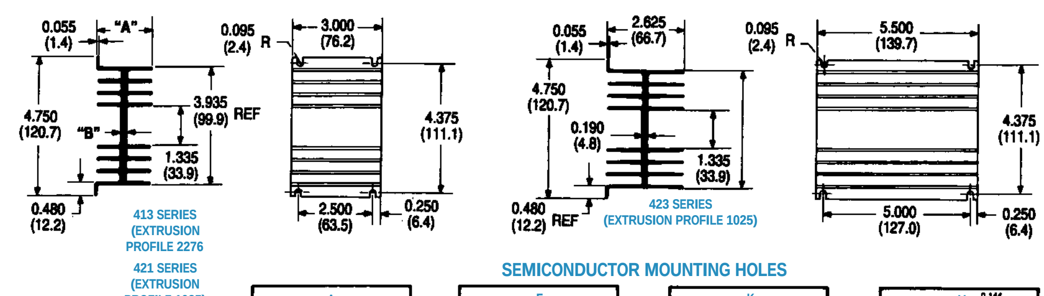
413/421/423 SERIES *Low-Height Double-Surface Heat Sinks for TO-3 Case Styles and Diodes*

TO-3; DO-5; Stud-Mount

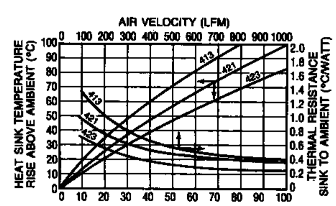
Standard P/N	Nominal Dimensions: Width in. (mm)	Nominal Dimensions: Length in. (mm)	Nominal Dimensions: Height "A" in. (mm)	Semiconductor Mounting Hole Pattern	Thermal Performance at Typical Load: Natural Convection	Thermal Performance at Typical Load: Forced Convection	Weight lbs. (grams)
413A	4.750 (120.7)	3.000 (76.2)	1.875 (47.6)	(1) TO-3	72°C @ 50W	0.85°C/W @ 250 LFM	0.6300 (285.77)
413F	4.750 (120.7)	3.000 (76.2)	1.875 (47.6)	0.270 in. (6.9)-Dia Hole	72°C @ 50W	0.85°C/W @ 250 LFM	0.6300 (285.77)
413K ▲	4.750 (120.7)	3.000 (76.2)	1.875 (47.6)	None	72°C @ 50W	0.85°C/W @ 250 LFM	0.6300 (285.77)
421A	4.750 (120.7)	3.000 (76.2)	2.625 (66.7)	(1) TO-3	58°C @ 50W	0.7°C/W @ 250 LFM	0.6300 (285.77)
421F	4.750 (120.7)	3.000 (76.2)	2.625 (66.7)	0.270 in. (6.9)-Dia Hole	58°C @ 50W	0.7°C/W @ 250 LFM	0.6300 (285.77)
421K ▲	4.750 (120.7)	3.000 (76.2)	2.625 (66.7)	None	58°C @ 50W	0.7°C/W @ 250 LFM	0.6300 (285.77)
423A	4.750 (120.7)	5.500 (140.2)	2.625 (66.7)	(1) TO-3	47°C @ 50W	0.5°C/W @ 250 LFM	1.1700 (530.71)
423K ▲	4.750 (120.7)	5.500 (140.2)	2.625 (66.7)	None	47°C @ 50W	0.5°C/W @ 250 LFM	1.1700 (530.71)

Space-saving double surface 413, 421, and 423 Series utilize finned surface area on both sides of the power semiconductor mounting surface to provide maximum heat dissipation in a compact profile. Ready to install on popular power components in natural and forced convection applications. Apply Wakefield Type 126 silicone-free thermal compound or Wakefield DeltaPad™ interface materials for maximum performance. Material: Aluminum Alloy, Black Anodized.

MECHANICAL DIMENSIONS



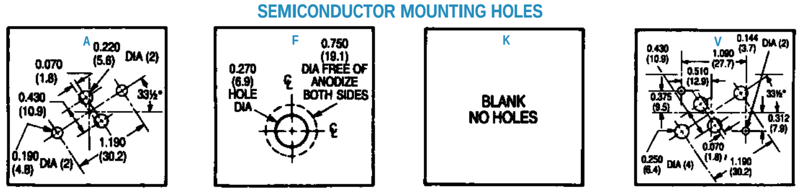
NATURAL AND FORCED CONVECTION CHARACTERISTICS



SERIES	"A"	"B"
413	1.875 (47.6)	0.200 (5.1)
421	2.625 (66.7)	0.190 (4.8)

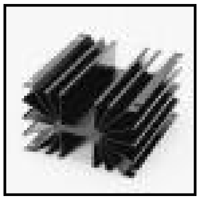
Dimensions: in. (mm)

SEMICONDUCTOR MOUNTING HOLES



▲ Normally stocked

EXTRUDED HEAT SINKS FOR POWER SEMICONDUCTORS



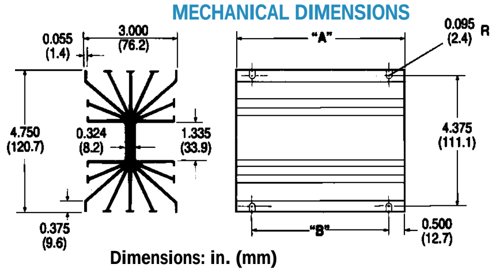
431 AND 433 SERIES — *High-Performance Heat Sinks for 30-100W Metal Power Semiconductors*

TO-3; Stud-Mount

Standard P/N	Nominal Dimensions: Width in. (mm)	Length "A" in. (mm)	Height in. (mm)	Semiconductor Mounting Hole Pattern	Thermal Performance at Typical Load: Natural Convection	Forced Convection	Weight lbs. (grams)
431K	4.750 (120.7)	3.000 (76.2)	3.000 (76.2)	None	55°C @ 50W	0.40°C/W @ 250 LFM	0.7800 (353.81)
433K ▲	4.750 (120.7)	5.500 (139.7)	3.000 (76.2)	None	42°C @ 50W	0.28°C/W @ 250 LFM	1.4900 (675.86)

Need maximum heat dissipation from a TO-3 rectifier heat sink in minimum space? The Wakefield 431 and 433 Series center channel double-surface heat sinks offer the highest performance-to-weight ratio for minimum volume occupied for TO-3, diode, and stud-mount metal power semiconductors in the 30- to 100-watt operating range. Additional interface resistance reduction for maximized overall performance can be achieved with proper application of Wakefield Type 126 silicone-free thermal compound. Material: Aluminum Alloy, Black Anodized.

MECHANICAL DIMENSIONS

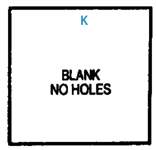


SERIES	"A"	"B"
431	3.000 (76.2)	2.000 (50.8)
433	5.500 (139.7)	4.500 (114.3)

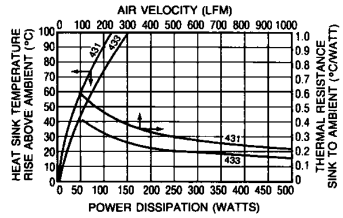
Dimensions: in. (mm)

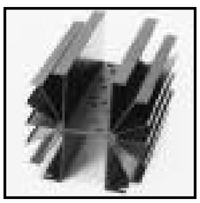
431 AND 433 SERIES (EXTRUSION PROFILE 2726)

SEMICONDUCTOR MOUNTING HOLE



NATURAL AND FORCED CONVECTION CHARACTERISTICS





435 SERIES — *Lightweight Quadruple Mount Heat Sink for TO-3 Case Styles*

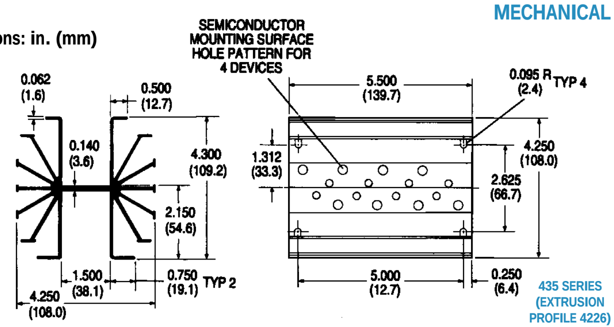
TO-3

Standard P/N	Nominal Dimensions: Width in. (mm)	Length in. (mm)	Height in. (mm)	Semiconductor Mounting Hole Pattern	Thermal Performance at Typical Load: Natural Convection	Forced Convection	Weight lbs. (grams)
435AAAA	4.250(108.0)	5.500(139.7)	4.300(109.2)	(4) TO-3	37°C @ 50W 54°C @ 80W	0.38°C/W @ 250 LFM 0.24°C/W @ 600 LFM	1.1500 (521.64)

This lightweight high-performance heat sink is designed to mount and cool efficiently one to four TO-3 style metal case power semiconductors. The Type 435AAAA is the standard configuration available from stock, predrilled for mounting four TO-3 style devices. Increased performance can be achieved with the proper selection and installation of a Wakefield Type 175 DeltaPad Kapton™ interface material for each power semiconductor or, for maximum reduction of case-to-sink interface loss, the application of Wakefield Type 126 silicone-free thermal compound. Material: Aluminum Alloy, Black Anodized.

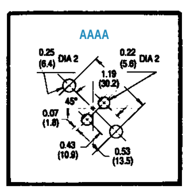
MECHANICAL DIMENSIONS

Dimensions: in. (mm)

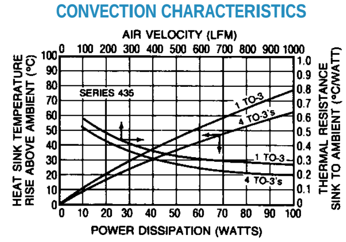


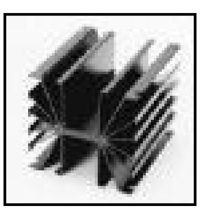
435 SERIES (EXTRUSION PROFILE 4226)

SEMICONDUCTOR MOUNTING HOLES



NATURAL AND FORCED CONVECTION CHARACTERISTICS





441 SERIES — *High-Performance Natural Convection Heat Sinks for Rectifiers and Diodes*

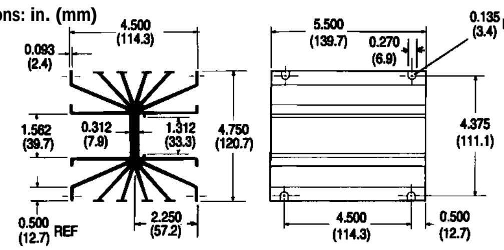
Stud-Mount

Standard P/N	Nominal Dimensions: Width in. (mm)	Length in. (mm)	Height in. (mm)	Semiconductor Mounting Hole Pattern	Thermal Performance at Typical Load: Natural Convection	Forced Convection	Weight lbs. (grams)
441K ▲	4.750 (120.7)	5.500 (139.7)	4.500 (114.3)	None	34°C @ SOW 47°C @ 80W	0.30°C/W @ 250 LFM 0.19°C/W @ 600 LFM	1.9700 (893.59)

Designed for vertical mounting within a power supply enclosure or equipment cabinet without forced airflow available. This Wakefield 441 Series heat sink will dissipate up to 100 watts efficiently in natural convection with a maximum 55°C heat sink temperature rise above ambient. When applied in a forced convection environment, the 441K Type will achieve thermal resistance of 0.18°C/W (sink to ambient) at 1000 LFM. Supplied with no predrilled device mounting hole pattern. Material: Aluminum Alloy, Black Anodized.

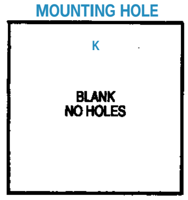
MECHANICAL DIMENSIONS

Dimensions: in. (mm)

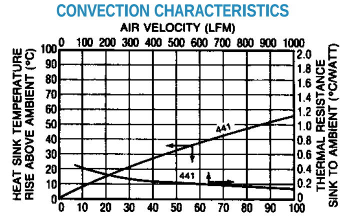


441 SERIES (EXTRUSION PROFILE 1273)

SEMICONDUCTOR MOUNTING HOLE



NATURAL AND FORCED CONVECTION CHARACTERISTICS



EXTRUDED HEAT SINKS FOR POWER SEMICONDUCTORS

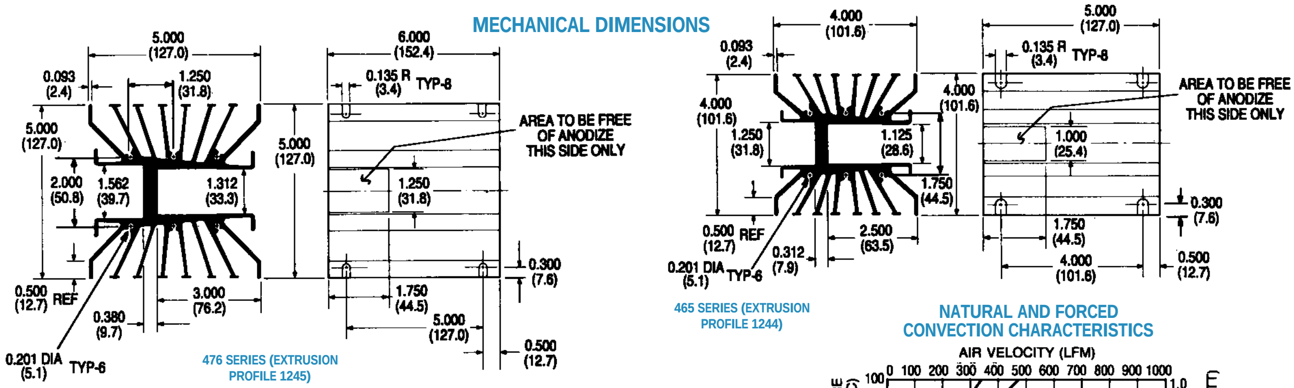
465 AND 476 SERIES — *High-Power Heat Sinks for Medium Hex-Type Rectifiers and Diodes*

Stud-Mount

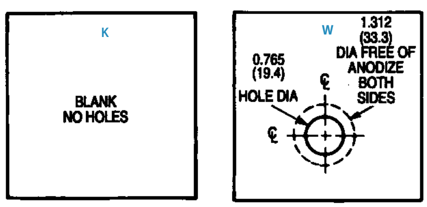
Standard P/N	Width in. (mm)	Nominal Dimensions Length in. (mm)	Height in. (mm)	Hex Style Type	Mounting Hole Pattern	Thermal Performance at Typical Load Natural Convection	Forced Convection	Weight lbs. (grams)
465K	4.000 (101.6)	5.000 (127.0)	4.000 (101.6)	1.060 in. Hex	None	38°C @ 50W	0.27°C/W @500 LFM	1.9300 (875.45)
476K	5.000 (127.0)	6.000 (152.4)	5.000 (127.0)	1.250 in. Hex	None	25°C @ 50W	0.19°C/W @500 LFM	2.8200(1279.15)
476W	5.000 (127.0)	6.000 (152.4)	5.000 (127.0)	1.250 in. Hex	0.765 in. (19.4)Dia. Center Mount	25°C @ 50W	0.19°C/W @500 LFM	2.8000(1270.08)

Wakefield Engineering has designed four standard heat sink types for ease of installation and efficient heat dissipation for industry standard hex-type rectifiers and similar stud-mount power devices: 465, 476, 486, and 489 Series. The 465 and 476 Series shown here are designed for 1.060 in. Hex (465 Type) and 1.250 in. Hex (476 Type). The 476W Type is available predrilled for an 0.765 in. (19.4) dia, mounting hole, Material: Aluminum Alloy, Black anodized.

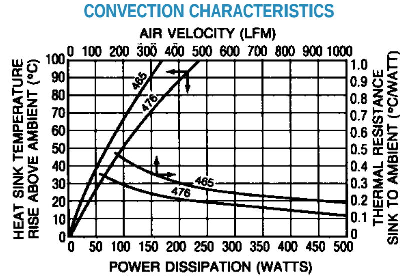
MECHANICAL DIMENSIONS



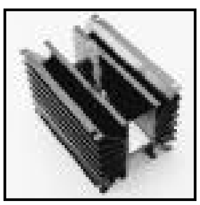
SEMICONDUCTOR MOUNTING HOLES



NATURAL AND FORCED CONVECTION CHARACTERISTICS



Dimensions: in. (mm)



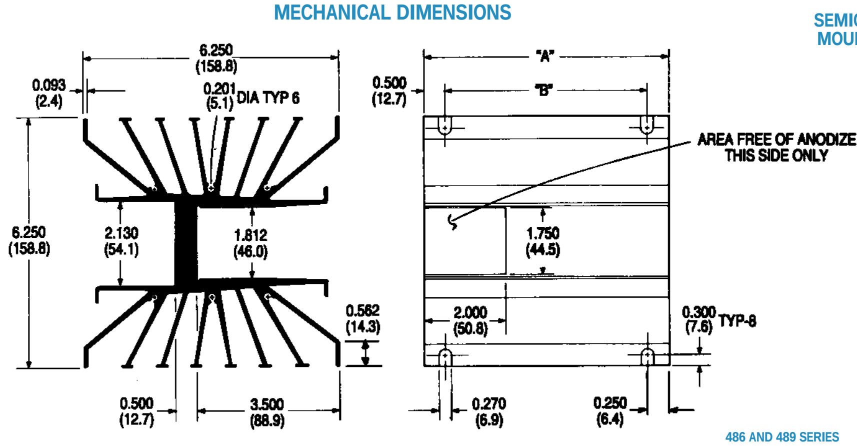
486 AND 489 SERIES — *Heat Sinks for High-Power Hex-Type Rectifiers and Diodes*

Stud-Mount

Standard P/N	Width in. (mm)	Nominal Dimensions Length in. (mm)	Height in. (mm)	Hex Style Type	Mounting Hole Pattern	Thermal Performance at Typical Load Natural Convection	Forced Convection	Weight lbs. (grams)
486K ▲	6.250 (158.8)	6.000 (152.4)	6.250 (158.8)	1.750 in. Hex	None	24°C @ 50W 86°C @ 250W	0.20°C/W @250 LFM 0.13°C/W @500 LFM	4.2100 (1909.66)
489K ▲	6.250 (158.8)	9.000 (228.6)	6.250 (158.8)	1.750 in. Hex	None	19°C @ 50W 75°C @ 250W	0.15°C/W @250 LFM 0.10°C/W @500 LFM	6.1400 (2785.10)

These two heat sink types accept industry standard 1.750 in. (44.5) hex-type devices for mounting and efficient heat dissipation. Each type is provided with a 1.750 in. (44.5) x 2.000 in. (50.8) area on the semiconductor base mounting surface which is free of anodize. Material: Aluminum Alloy, Black Anodized.

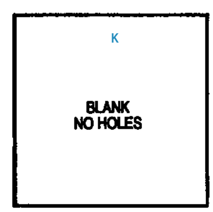
MECHANICAL DIMENSIONS



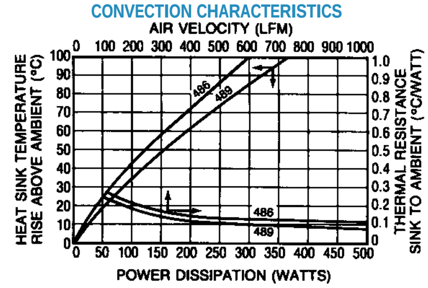
SERIES	"A"	"B"
486	6.000 (152.4)	5.000 (127.0)
489	9.000 (228.6)	8.000 (203.2)

Dimensions: in. (mm)

SEMICONDUCTOR MOUNTING HOLE

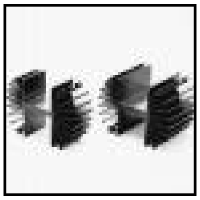


NATURAL AND FORCED CONVECTION CHARACTERISTICS



▲ Normally stocked

EXTRUDED HEAT SINKS FOR POWER SEMICONDUCTORS



490 SERIES *King Size Heat Sinks for High-Power Rectifiers*

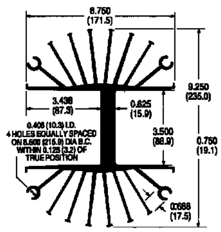
GENERAL PURPOSE

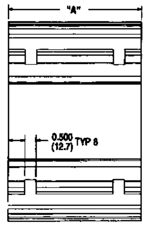
Standard P/N	Width in. (mm)	Nominal Dimensions Length "A" in. (mm)	Height in. (mm)	Semiconductor Mounting Hole Pattern	Thermal Performance at Typical Load Natural Convection	Forced Convection	Weight lbs. (grams)
490-35K	9.250 (235.0)	3.500 (88.9)	6.750 (171.5)	None	84°C @ 200W	0.18°C/W @ 600 LFM	3.2400(1469.66)
490-6K ▲	9.250 (235.0)	6.000 (152.4)	6.750 (171.5)	None	60°C @ 200W	0.13°C/W @ 600 LFM	5.4700(2481.19)
490-12K ▲	9.250 (235.0)	12.000 (304.8)	6.750 (171.5)	None	45°C @ 200W	0.09°C/W @ 600 LFM	10.62 (4817.23)

The 490 Series can be used to mount a single high-power rectifier or a grouping of smaller power devices. The semiconductor device mounting surface is free of anodize on the entire surface on one side only; finish overall is black anodize. Use Type 109 mounting brackets (see accessories section) for mounting to enclosure wall and for electrical isolation. The anodize-free mounting surface is milled for maximum contact area. The 490 Series Can also be drilled for mounting and cooling IGBTs and other isolated power modules. Material: Aluminum Alloy, Black Anodized.

MECHANICAL DIMENSIONS

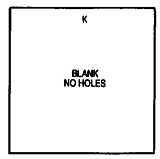
490 SERIES
(EXTRUSION PROFILE 2131)



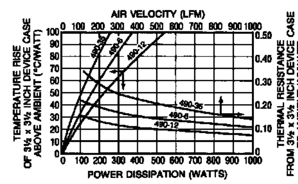


Dimensions: in. (mm)

SEMICONDUCTOR MOUNTING HOLE



NATURAL AND FORCED CONVECTION CHARACTERISTICS



PERFORMANCE, LOW PROFILE HEAT SINKS FOR POWER MODULES & IGBT'S

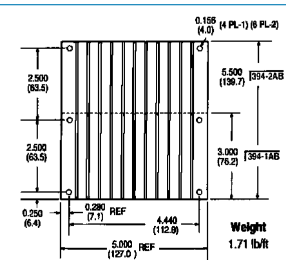
394, 395, 396 SERIES

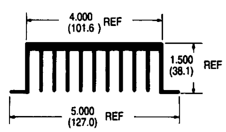
Standard P/N	Length in. (mm)	Overall Dimensions: in. (mm) Height in. (mm)	Width in. (mm)	Device Base Mounting Area (mm)	Base Mounting Holes	Thermal Resistance at Typical Load Natural Convection (Øsa)[1] (°C/W)	Forced Convection (Øsa) (°C/W @ 500 LFM)
394-1AB	3.000 (76.2)	1.500 (38.1)	5.000 (127.0)	101 x 76	4	1.85	0.90
394-2AB	5.500 (139.7)	1.500 (38.1)	5.000 (127.0)	101 x 139	6	1.51	0.60
395-1AB	3.000 (76.2)	2.500 (63.5)	5.000 (127.0)	50 x 76	4	1.10	0.50
395-2AB	5.500 (139.7)	2.500 (63.5)	5.000 (127.0)	50 x 139	6	0.90	0.32
396-1AB	3.000 (76.2)	1.380 (35.1)	5.000 (127.0)	50 x 76	4	1.85	1.07
396-2AB	5.500 (139.7)	1.380 (35.1)	5.000 (127.0)	50 x 139	6	1.51	0.64

Note: *1.Thermal resistance values shown are for black anodized finish at 50°C rise above ambient.*

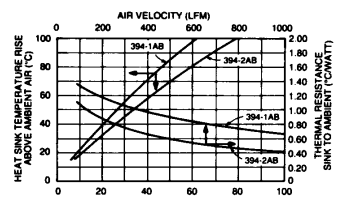
MECHANICAL DIMENSIONS

394 SERIES
(EXTRUSION PROFILE 7332)

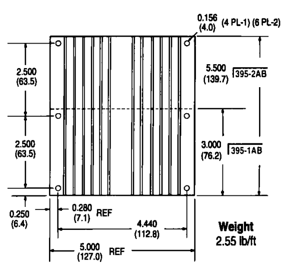


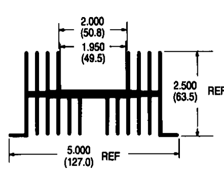


NATURAL AND FORCED CONVECTION CHARACTERISTICS

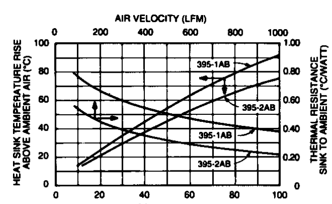


395 SERIES
(EXTRUSION PROFILE 7330)

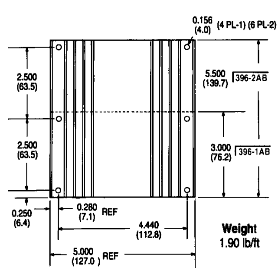


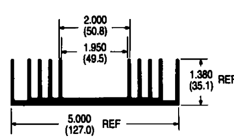


NATURAL AND FORCED CONVECTION CHARACTERISTICS

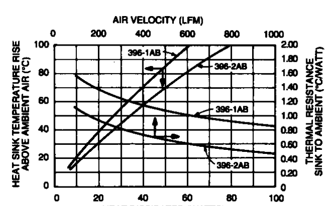


396 SERIES
(EXTRUSION PROFILE 7331)



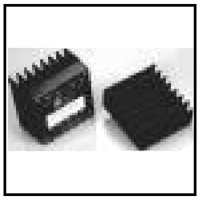


NATURAL AND FORCED CONVECTION CHARACTERISTICS



Dimensions: in. (mm)

EXTRUDED HEAT SINKS FOR POWER SEMICONDUCTORS



SERIES 517, 527, 518 AND 528 ***Heat Sinks for "Half Brick" DC/DC Converters***

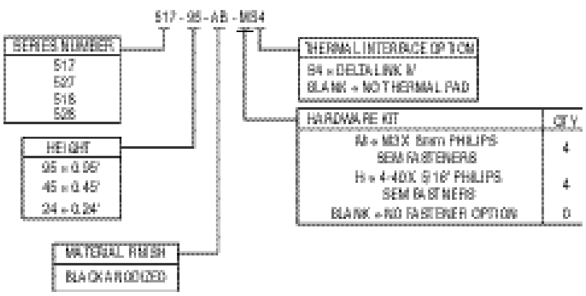
Standard P/N	Footprint Dimensions in. (mm)	Height in. (mm)	Fin Orientation	Number of Fins	Thermal Performance: Natural Convection Power Dissipation (Watts) 60°C Rise Heat Sink to Ambient	Thermal Performance: Forced Convection Thermal Resistance at 300 ft/min
517-95AB	2.28 (57.9) x 2.40 (61.0)	0.95 (24.1)	Horizontal	8	11W	2.0 °C/W
527-45AB	2.28 (57.9) x 2.40 (61.0)	0.45 (11.4)	Horizontal	11	7W	3.2 °C/W
527-24AB	2.28 (57.9) x 2.40 (61.0)	0.24 (6.1)	Horizontal	11	5W	5.8 °C/W
518-95AB	2.40 (61.0) x 2.28 (57.9)	0.95 (24.1)	Vertical	8	11W	2.0 °C/W
528-45AB	2.40 (61.0) x 2.28 (57.9)	0.45 (11.4)	Vertical	11	7W	3.2 °C/W
528-24AB	2.40 (61.0) x 2.28 (57.9)	0.24 (6.1)	Vertical	11	5W	5.8 °C/W

Material: Aluminum, Black Anodized.

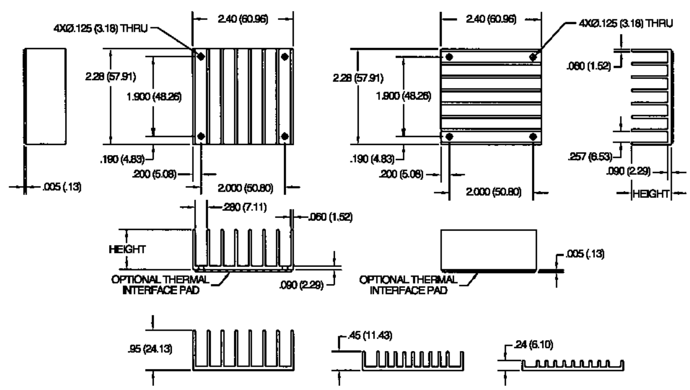
Keep your "half brick" size AT&T and Computer Products power modules cool with these efficient black anodized aluminum heat sinks made for natural or forced convection applications. To include four M3 x 8mm Phillips head SEM attachment screws, add an "M" suffix to standard part number. To specify factory applied Deltalink IV thermal interface material, add an "S4" suffix to standard part number. Deltalink IV is a non-insulating graphite based material used as a clean, thermally efficient alternative to thermal grease.

MECHANICAL DIMENSIONS **517, 527, 518 AND 528 SERIES**

PRODUCT DESIGNATION



517/527 SERIES DIMENSIONS **518/528 SERIES DIMENSIONS**



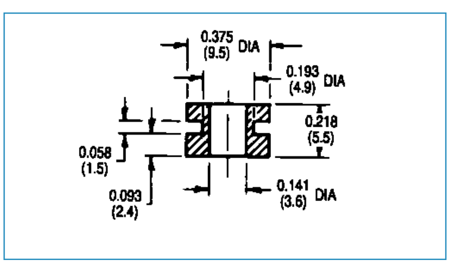
Dimensions: in. (mm)

MOUNTING HARDWARE FOR EXTRUDED HEAT SINKS

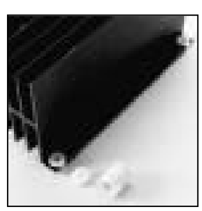
100 SERIES ***Teflon Mounting Insulators***

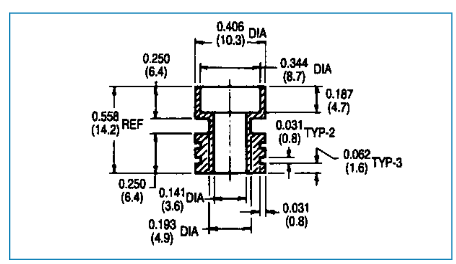
Standard P/N	Description	For Use with Series	Mounting Hardware	Material	Hipot Rating (VAC)	Weight lbs. (grams)
▲ 103	Spool-shaped insulator	300, 400, 600, 111, 113	#6-32 screw	Teflon	1500	0.00012 (0.05)
107	Spool-shaped insulator	300, 400, 600, 111, 113	#6-32 screw, nut	Teflon	5000	0.0034 (1.54)

103 SERIES



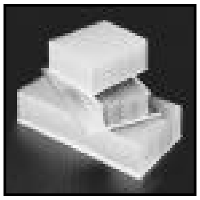
107 SERIES





Wakefield Engineering

HIGH FIN DENSITY HEAT SINKS FOR POWER MODULES, IGBTs, RELAYS



510, 511 AND 512 SERIES

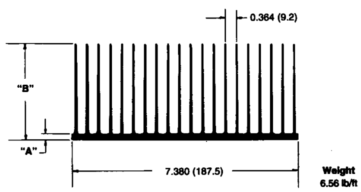
Standard Catalog P/N[5] Milled Base[1]	Nonmilled Base[2]	Base Width in. (mm)	Length in. (mm)	Height: Milled Base[1] ("M Series") in. (mm)	Height: Nonmilled Base[2] ("U" Series) in. (mm)	Thermal Resistance[5] (Øsa) at Typical Load: Natural Convection[3] (°C/W)	Thermal Resistance[5] (Øsa) at Typical Load: Forced Convection[4] (°C/W @ 100 CFM)
510-3M	510-3U	7.380 (187.452)	3.000 (76.2)	3.106 (78.9)	3.136 (79.7)	0.56	0.088
510-6M	510-6U	7.380 (187.452)	6.000 (152.4)	3.106 (78.9)	3.136 (79.7)	0.38	0.070
510-9M	510-9U	7.380 (187.452)	9.000 (228.6)	3.106 (78.9)	3.136 (79.7)	0.29	0.066
510-12M ▲	510-12U ▲	7.380 (187.452)	12.000 (304.8)	3.106 (78.9)	3.136 (79.7)	0.24	0.062
510-14M ▲	510-14U ▲	7.380 (187.452)	14.000 (355.6)	3.106 (78.9)	3.136 (79.7)	0.21	0.059
511-3M	511-3U	5.210 (132.33)	3.000 (76.2)	2.350 (59.7)	2.410 (61.2)	0.90	0.120
511-6M	511-6U	5.210 (132.33)	6.000 (152.4)	2,350 (59.7)	2.410 (61.2)	0.65	0.068
511-9M	511-9U	5.210 (132.33)	9.000 (228.6)	2,350 (59.7)	2.410 (61.2)	0.56	0.060
511-12M	511-12U	5.210 (132.33)	12.000 (304.8)	2.350 (59.7)	2.410 (61.2)	0.45	0.045
512-3M	512-3U	7.200 (182.88)	3.000 (76.2)	2.350 (59.7)	2.410 (61.2)	0.90	0.120
512-6M	512-6U	7.200 (182.88)	6.000 (152.4)	2.350 (59.7)	2.410 (61.2)	0.65	0.068
512-9M	512-9U	7.200 (182.88)	9.000 (228.6)	2.350 (59.7)	2.410 (61.2)	0.56	0.060
512-12M	512-12U	7.200 (182.88)	12.000 (304.8)	2.350 (59.7)	2.410 (61.2)	0.45	0.045

Notes:
1. *Precision-milled base for maximum heat transfer performance (flatness 0.002 in./in.)*
2. *Nonmilled base flatness: 0.006 in./in.*
3. *Natural convection heat dissipation for distributed heat sources at 50°C rise.*
4. *Forced convection heat dissipation for distributed heat sources at 100 cubic feet per minute, shrouded condition.*
5. *Standard models are provided without finish.*

MECHANICAL DIMENSIONS

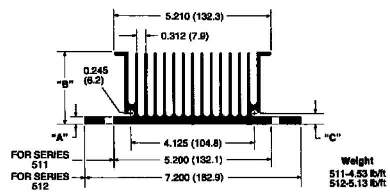
510 SERIES — 510 Series (Extrusion Profile 5113)

Series	A	B	Flatness
510-U	0.216 (5.5)	3.136 (79.7)	0.006 in./in. (0.15 mm/mm)
510-M	0.165 (4.2)	3.106 (78.9)	0.002 in./in. (0.05 mm/mm)



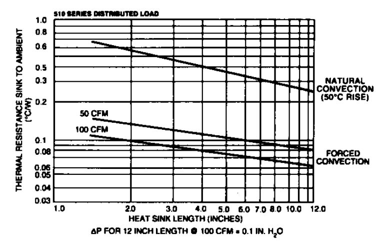
511 AND 512 SERIES — 511 Series (Extrusion Profile 6438-1), 512 Series (Extrusion Profile 6438-2)

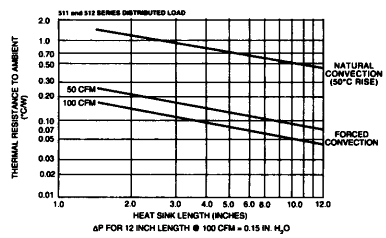
Series	A	B	C	Flatness
511-U 512-U	0.250 (6.4)	2.410 (61.2)	0.372 (9.4)	0.006 in./in. (0.15 mm/mm)
511-M 512-M	0.220 (5.6)	2.350 (59.7	0.342 (8.7)	0.002 in./in. (0.05 mm/mm)



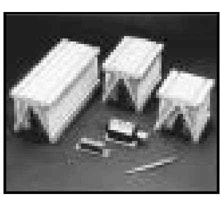
Dimensions: in. (mm)

NATURAL AND FORCED CONVECTION CHARACTERISTICS





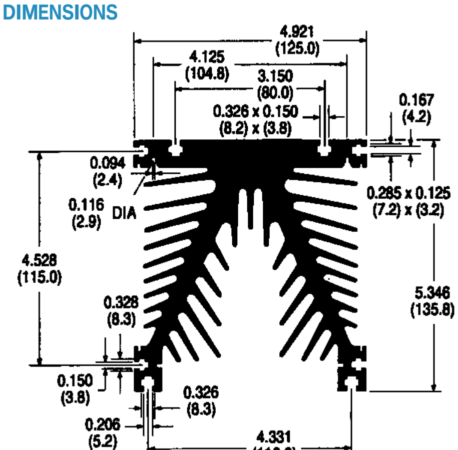
392 SERIES HIGH PERFORMANCE HEAT SINKS FOR POWER MODULES, IGBTs AND SOLID STATE RELAYS



Standard P/N, Finish: Black Anodized	Gold Iridite	Length in. (mm)	Thermal Resistance at Typical Load: Natural Convection (Øsa) (°CW)	Thermal Resistance at Typical Load: Forced Convection (Øsa) (°CW)	Weight lbs. (grams)
392-120AB	392-120AG	4.725 (120.0)	0.50	0.16 @ 100 CFM	4.452 (2019.43)
392-180AB ▲	392-180AG ▲	7.087 (180.0)	0.43	0.11 @ 100 CFM	6.636 (3010.09)
392-300AB ▲	392-300AG ▲	11.811 (300.0)	0.33	0.08 @ 100 CFM	1O.420 (4726.51)

MECHANICAL DIMENSIONS

392 SERIES (EXTRUSION PROFILE 5658)



Dimensions: in. (mm)

NATURAL AND FORCED CONVECTION CHARACTERISTICS