Single-Phase Bridge Rectifier Design

單相橋式整流器設計

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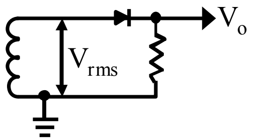
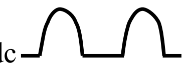
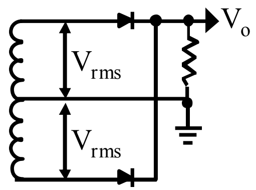
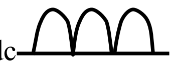
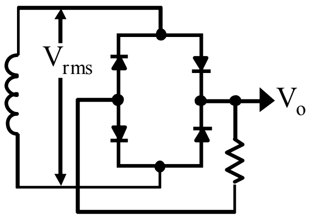
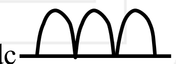
Lab808: 電力電子系統與晶片實驗室
Power Electronic Systems & Chips, NCTU, TAIWAN
台灣新竹•交通大學•電機與控制工程研究所

Contents

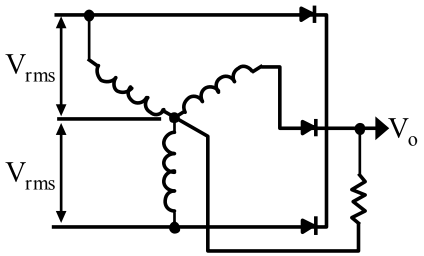
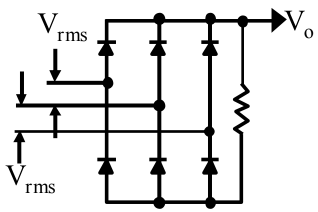
Characteristics of Basic Rectifier Circuits (I)

with an unfiltered resistive load

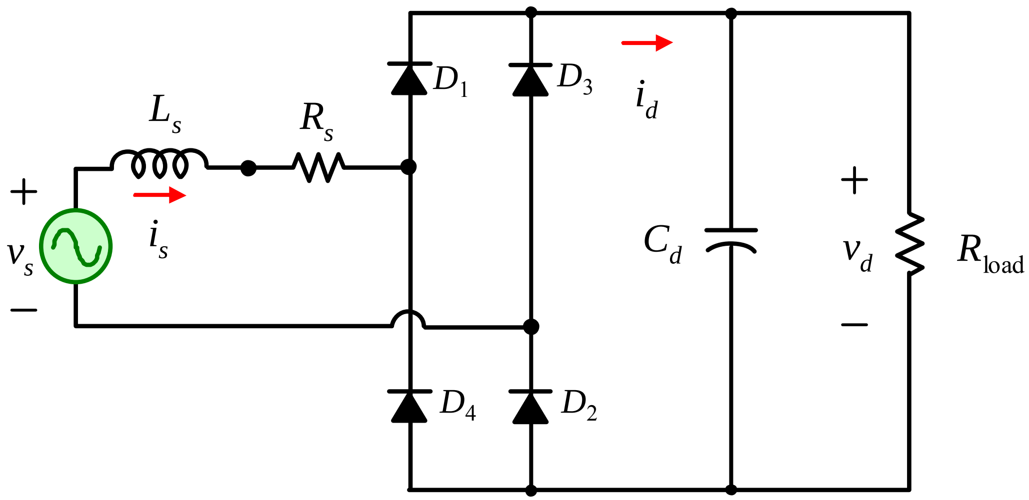
Configuration	Circuit	V_{in}	$V_{o(peak)}$	$V_o dc$	Peak inverse voltage per diode	RMS ripple voltage	Fundamental output ripple frequency*	Output waveform
	Single-phase half wave	V_{rms}	$1.41\ V_{rms}$	$\frac{1}{\pi}V_{o(peak)} = 0.45V_{rms}$	$1.41\ V_{rms}$	$0.54V_{rms}$	$1F_L$	0Vdc 
	Single-phase center tap	V_{rms}	$1.41V_{rms}$	$\frac{2}{\pi}V_{o(peak)} = 0.90V_{rms}$	$2.82V_{rms}$	$0.43V_{rms}$	$2F_L$	0Vdc 
	Single-phase bridge	V_{rms}	$1.41V_{rms}$	$\frac{2}{\pi}V_{o(peak)} = 0.90V_{rms}$	$1.41V_{rms}$	$0.43V_{rms}$	$2F_L$	0Vdc 

*F_L = Line frequency

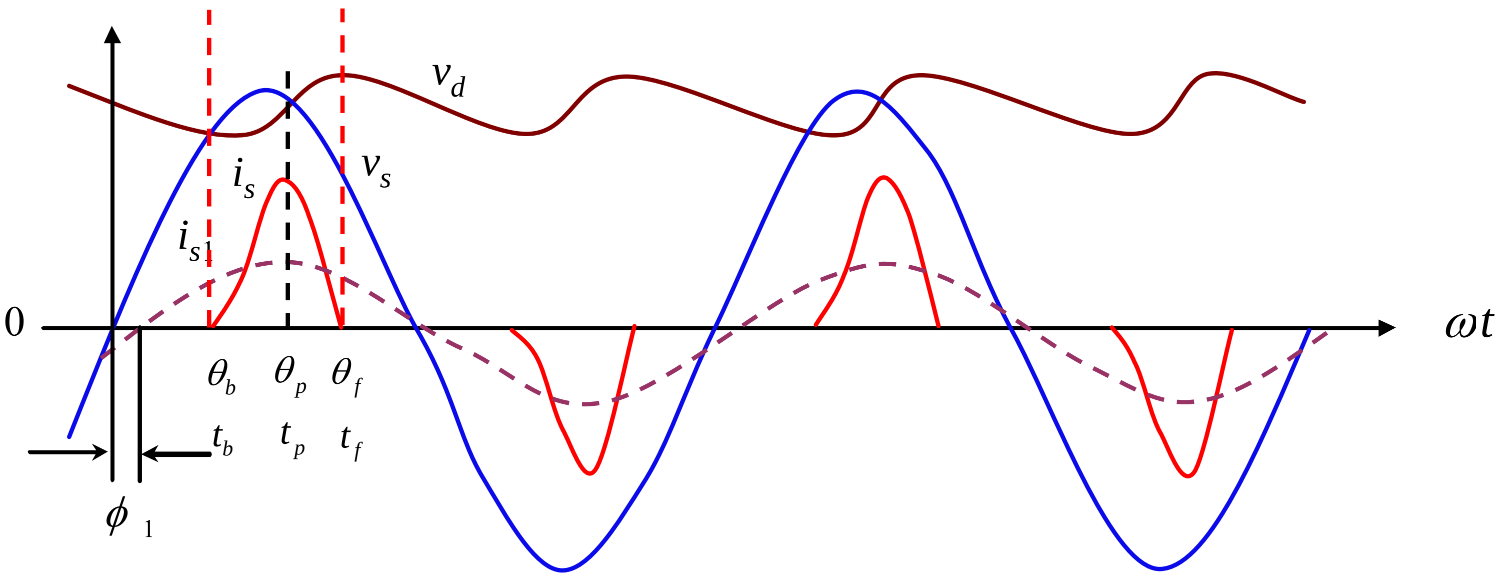
Characteristics of Basic Rectifier Circuits (II)
with an unfiltered resistive load

	Three-phase WYE V_{rms} Line to neutral	V_{rms}	1.41 V_{rms}	1.17 V_{rms}	2.45 V_{rms}	0.21 V_{rms}	$3F_L$	
	Three-phase bridge V_{rms} line to line	V_{rms}	1.41 V_{rms}	1.35 V_{rms}	2.45 V_{rms}	0.057 V_{rms}	$6F_L$	

Rectifier with Output Filter



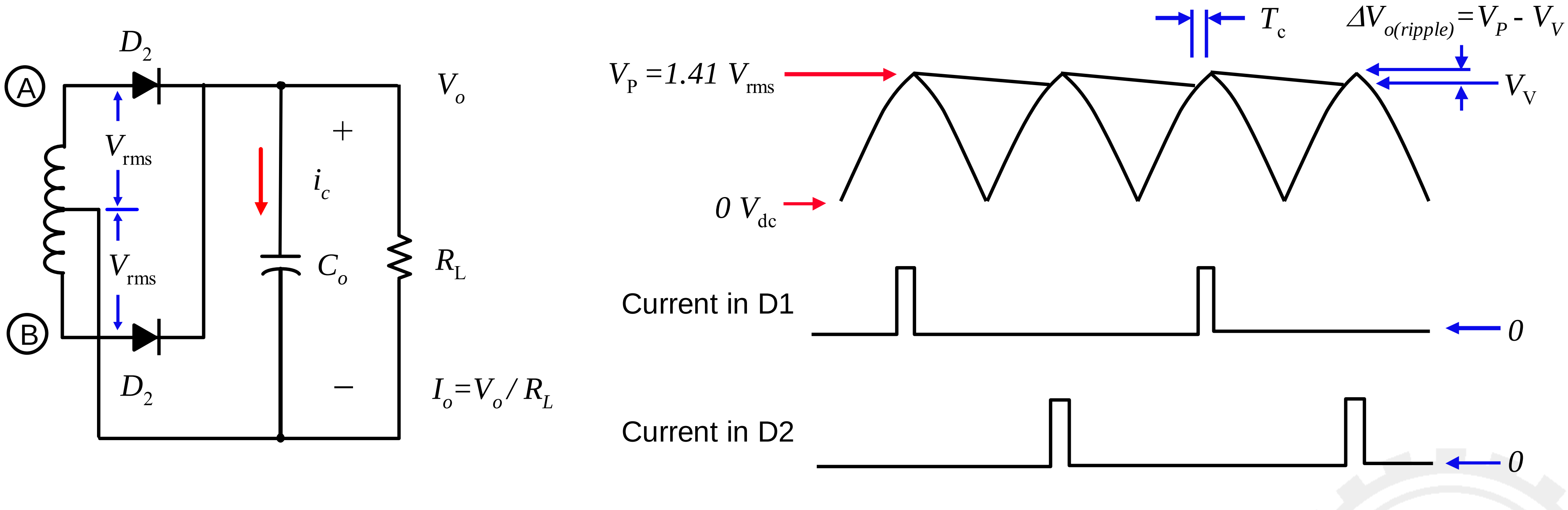
Practical diode-bridge rectifier with a filter



Conduction Period of the Filter Capacitor

- Filter capacitors at the output provide the energy storage to supply current to the loads in the interval between rectified peaks.
- If the voltage is to be held up by the filter capacitor for the full time between rectifier peaks, for the the half-wave rectifier, the capacitor must supply full load current for a full cycle of the line frequency or 15.6 msec for 60 Hz.
- For the single-phase, full-wave center tap or bridge rectifier, the filter capacitor must supply load current by itself for a half cycle or 8.3 msec at 60 Hz.
- In the three-phase, line-to-neutral, half-wave "wye," peaks come at intervals of one-third of a period and the filter capacitor must supply current for 16.6/3 or 5.5 msec.
- Finally in the three-phase, full-wave bridge, the filter capacitor supplies the full load current for one-sixth of a cycle or 16.6/6 or 2.8 msec at 60 Hz line frequency.
- It is these time intervals and the load currents that determine the size of the filter capacitor required to yield any specified peak-to-peak ripple.

Capacitive Input Filters



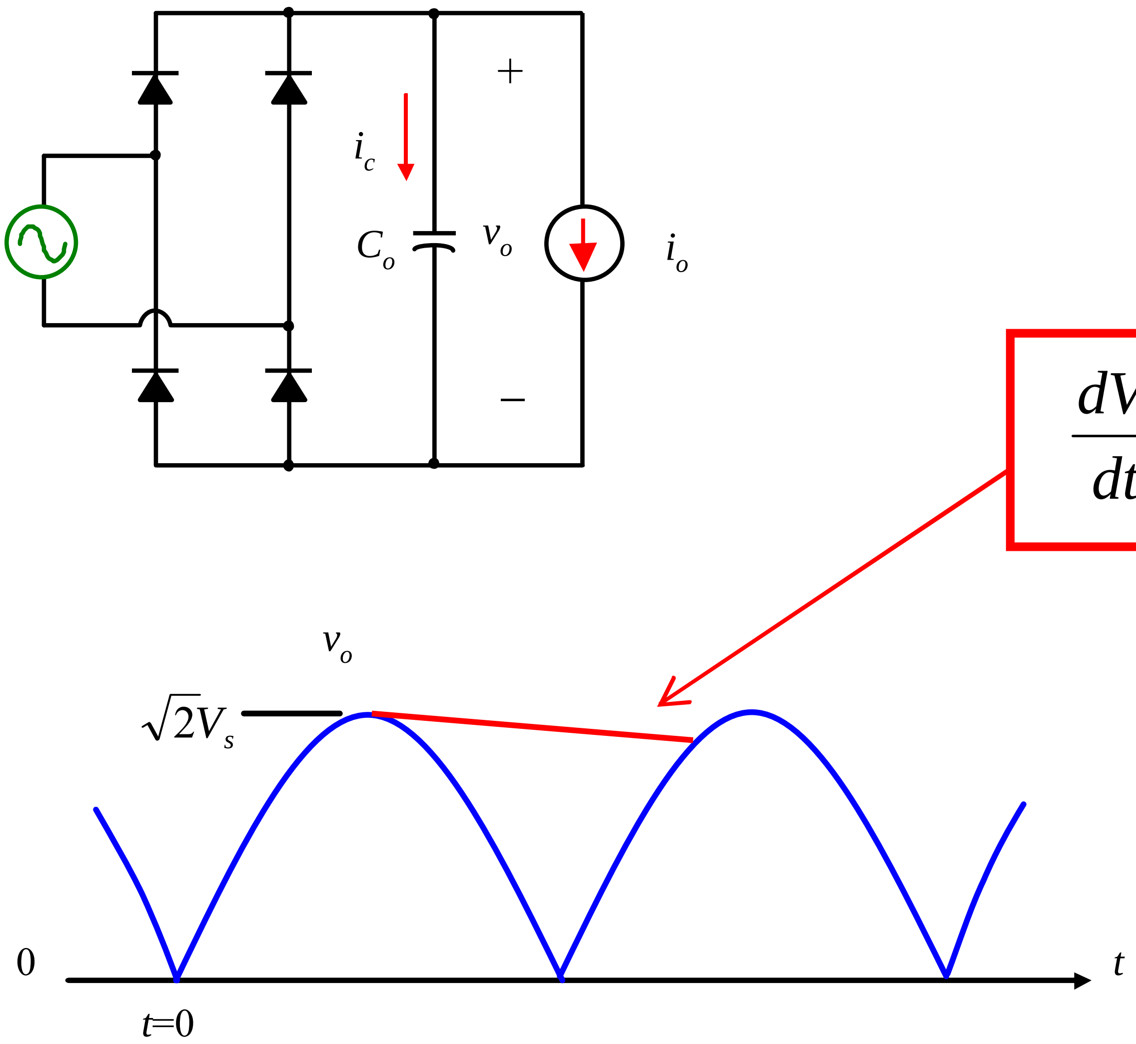
Ripple output voltage and rectifier diode current in a single-phase, full-wave rectifier with capacitive input filter.

Output Ripple, Filter Capacitance, and Load-Current

Peak ripple voltage (V_p)	Ripple valley voltage (V_v)	Peak-to-peak ripple voltage ($\Delta V_o = V_p - V_v$)	Filter capacitor conduction angle $(90^\circ + \sin^{-1}(\frac{V_v}{V_p}))$	Filter capacitor current carrying time for 60 Hz single-phase, full-wave (msec)
V_p	0.95 V	0.05 V_p	161.8°	7.48
V_p	0.90 V	0.10 V_p	154.2°	7.14
V_p	0.85 V_T,	0.15 V_p	148.2°	6.86
V_p	0.80 V	0.20 V_p	143.1°	6.62
V_p	0.75 V	0.25 V_p	138.6°	6.41

Filter capacitor conduction angle and current carrying time in 60-Hz, single-phase, full-wave rectifier with capacitive input filter,

Voltage Descending Rate at Constant Load Current



$$\frac{dV}{dt} = \frac{I_o}{C_o}$$

Filter Capacitor Conduction Angle

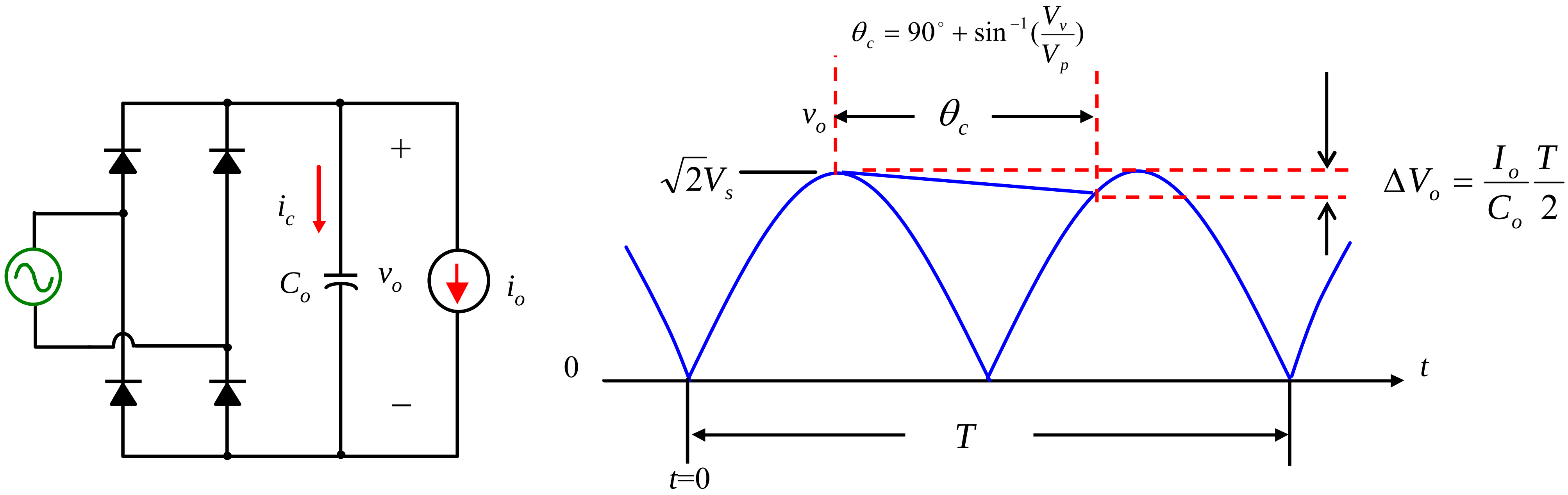
The exact time interval during which C_o alone supplies current is fixed by the permissible peak-to-peak ripple voltage. The peak of the ripple triangle, V_p, can be assumed to be at the peak of the ac sine wave (assuming negligible rectifier diode drop). For ripple valley voltage of V_v, the filter capacitor conduction angle is

$$\theta_c = 90^\circ + \sin^{-1}\left(\frac{V_v}{V_p}\right)$$

The duration of time during which the filter capacitor supplies the load current by itself in a 60-Hz, single-phase, full-wave rectifier is

$$T_c = \frac{\theta_c}{180^\circ} 8.33 \text{ msec}$$

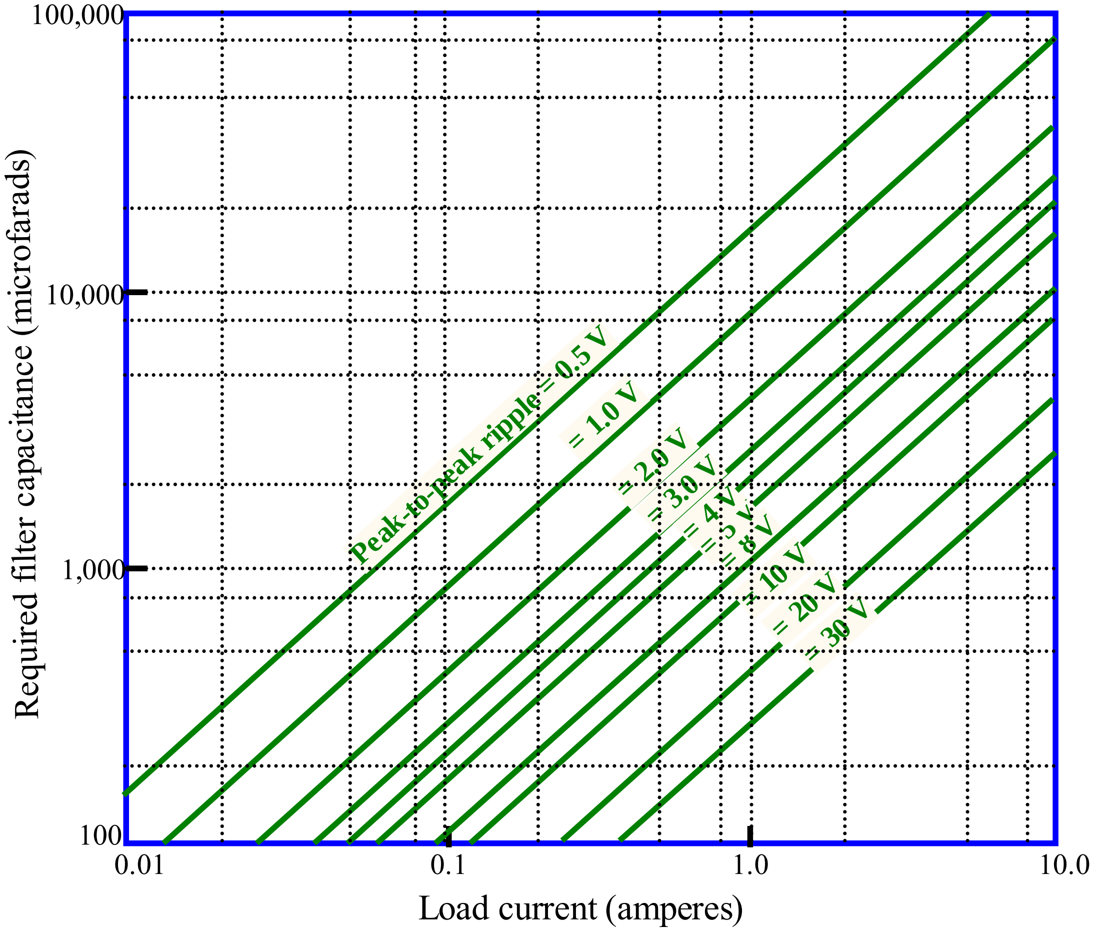
Filter Capacitance of a Full-Wave Rectifier



Generally, ripple voltages will not be permitted larger than about 10% of V_p. For peak-to-peak ripple voltages of 0.1 V_p, it is seen that the filter capacitor conduction time is 7.14 msec for a 60-Hz single-phase, full-wave rectifier. In calculating the required magnitude of the filter capacitor, for simplicity it is often assumed it must carry current for the entire half cycle or 8.33 msec. This provides margin for capacitor tolerance and variation with temperature. Then assuming full half-cycle conduction angle for the filter capacitor, the peak-to-peak ripple is

$$\Delta V_o = \frac{I_o}{C_o}\frac{T}{2}$$

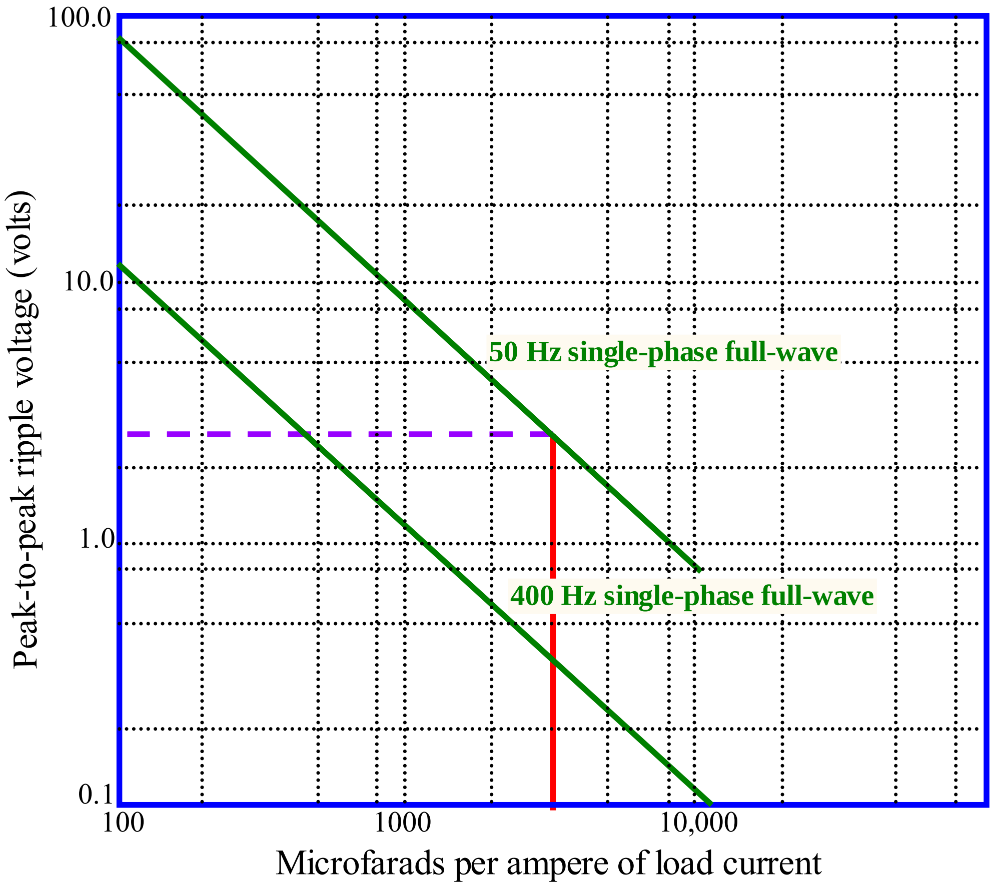
Required Filter Capacitance



$$C_o = \frac{I_o}{\Delta V_o}\left(\frac{T}{2} = 8.33 \times 10^{-3}\right) \text{farads}$$

Required filter capacity versus dc load current. For various peak-to-peak ripple voltages in a 60 Hz single-phase center-tap or bridge rectifier, as calculated from the above equation under the following conditions: peak-to-peak ripple less than 10% of output voltage, and capacitor assumed to carry a dc load current for a full half cycle.

Filter Capacitance Proportional to Load Current



$$\Delta V_o = \frac{I_o}{C_o}\left(\frac{T}{2} = 8.33 \times 10^{-3}\right) \text{farads}$$

Assume $C_o = kI_o$

$$\Delta V_o = (8.33 \times 10^{-3})\frac{1}{k}\text{farads} \quad \text{(A1)}$$

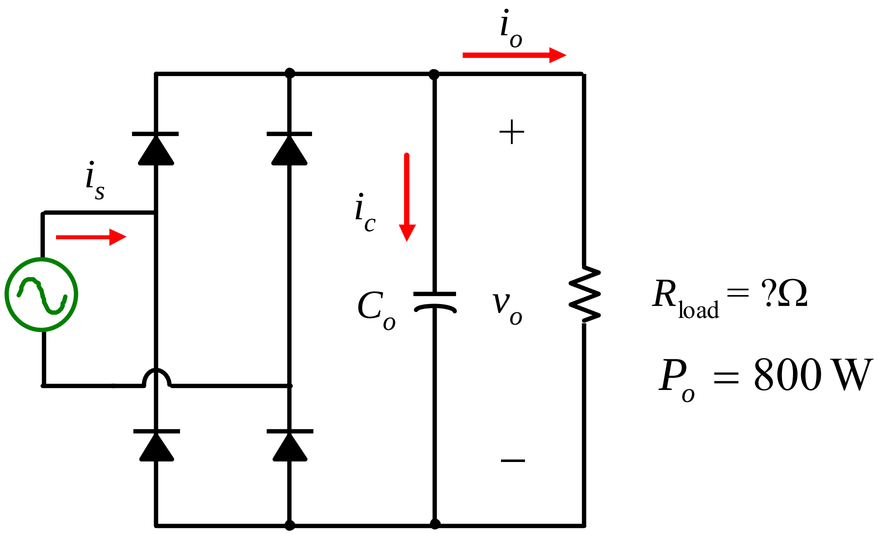
$$V_{dc} = V_p - \frac{\Delta V_o}{2} = 1.41V_{rms} - V_{diode} - 0.5\Delta V_o$$

Peak-to-peak ripple voltage versus microfarads per ampere of load current for a single-phase, full-wave rectifier with capacitive input filter. Plotted from Eq. A1.

The proportionality constant *k* will generally range from 1,000 to 4,000 μF/ampere of load current for a line frequency of 60 Hz and from 500 to 2,000 μF/ampere for a line frequency of 400 Hz.
Equation A1 is plotted in the above figure. A usual value of k for 60 Hz single-wave rectifiers is 3,000 μF/ampere of load current. From the above figure, it is seen this results in 2.75 V peak-to-peak ripple voltage.

Design Example of a 800W Resistive Load

Design Example:



A full-bridge rectifier given with the following parameters:
$V_{rms} = 220V$ at 60Hz, $P_o = 800$W. If the voltage ripple factor is designed to be 10%, what is the equivalent resistance and desired output filter capacitance?

Solution:

$$V_p = 220\sqrt{2} = 311 \text{ V}$$

A ripple factor of 10% is allowed, therefore, $\Delta V = 10\% V_p = 31.1$ V

$$V_o = V_p - \frac{\Delta V_o}{2} = 1.41 V_{rms} - V_{diode} - 0.5\Delta V_o = 311 - 1 - 0.5 \times 31.1 = 294 \text{ V}$$

Determination of DC-Link Capacitance

The average output current is $I_o = \frac{P_o}{V_o} = \frac{800}{294} = 2.72\ \text{A}$

The equivalent resistance is $R_o = \frac{V_o}{I_o} = \frac{294}{2.72} = 108\ \Omega$

$$C_o = \frac{I_o}{\Delta V_o}\left(\frac{T}{2} = 8.33\times 10^{-3}\right)\text{farads} = \frac{2.72}{31.1} 8.33\times 10^{-3} = 728\ \mu\text{F}$$

Suggest to select two aluminum electrolytic capacitors with 470 μF (a total of 940 μF), or three 330 μF (a total of 990μF), 400V_{dc}, 105°C.

Rectifier Diode Characteristics and Ratings

- **Peak Repetitive Reverse Voltage** $V_{rm(\mathrm{rep})}$
- **Average Forward Rectified Current** I_o **@** $\mathrm{T_c}=50^{\circ}\mathrm{C}$
- **RMS Rectifier Current** $I_{o(\mathrm{rms})}$
- **Nonrepetitive Forward Surge Current** $I_{fm(\mathrm{surge})}$
- I^2t **Rating**
- **Junction–to-case Thermal Resistance** θ_{jc}

Peak Repetitive Reverse Voltage $V_{rm(\mathrm{rep})}$

This is the maximum anode-to-cathode reverse voltage that the vendor specifies shall be allowed across the diode. Good worst-case design practice is to derate the vendor's specified value. Here too there is no industry concensus on what constitutes safe derating factors. An often-used factor is 0.6-0.7, i.e., no more than 0.6-0.7 of the manufacturer's rated maximum voltage shall be permitted across the rectifier repetitively.

In general, a safe design for equipment powered from commercial power lines should assume line voltage transients (envelope of the normal ac sine wave) of ±15 % above the normal steady-state voltage tolerance, which is usually ±10%. Duration of such transients should be assumed at 2-4 sec.

$V_{rm(rep)}$ of a Single-Phase 220V, 60 Hz, Full-wave Rectifier

$$V_{rm(rep)} = V_{rms(nominal)} \times \sqrt{2} \times 1.15 \times \frac{1}{70\%}$$

Derating Fcator (0.6 – 0.7)

Utility variations (±15%)

Full-wave rectifier (1.414) and
half-wave rectifier (2.828)

For a single-phase 220V, 60 Hz full-wave rectifier, the peak repetitive reverse voltage is:

$$V_{rm(rep)} = 220 \times \sqrt{2} \times 1.15 \times \frac{1}{70\%} = 511.06 \text{ V}$$

Input Transients

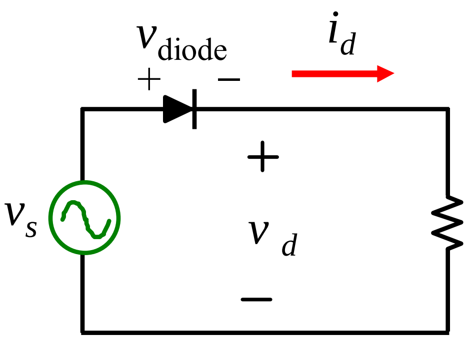
For narrow transients (under about 1 msec), a series inductor (the input RFI filter) and a thresholding shunt element, such as a pair of back-to-back power Zener diodes become feasible. Another possible shunt element is a ***nonlinear resistor*** such as "Thyrite" a proprietary G.E. material in which current is proportional to some high power (up to seventh power) of the applied voltage.

Thyrite comes as resistors in the shape of rods and discs with various power and resistance ratings. Application notes on the use of Thyrite in transient suppression circuits are available from the vendor.

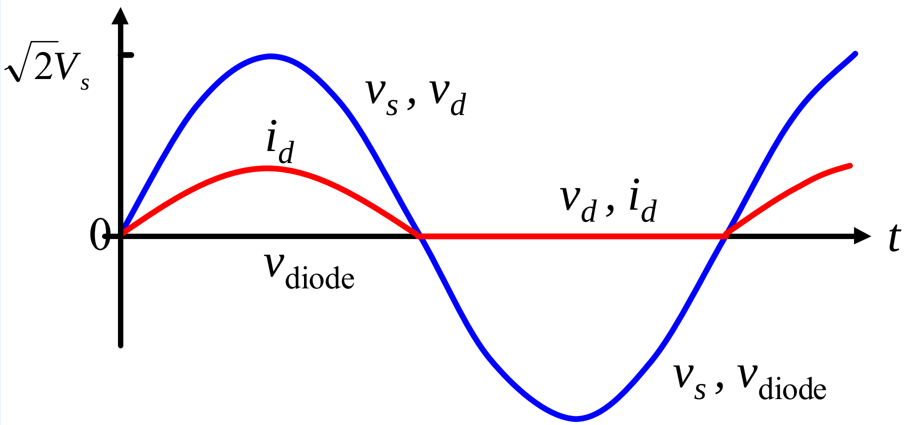
Average Forward Rectified Current I_o

This is the maximum permissible value of the average diode or load current in a half-wave rectifier with resistive load and no capacitive filtering.

In a full-wave center-tap or bridge rectifier, the total load current can be twice the specified value, since this amounts, to the same average current per diode.



(a)



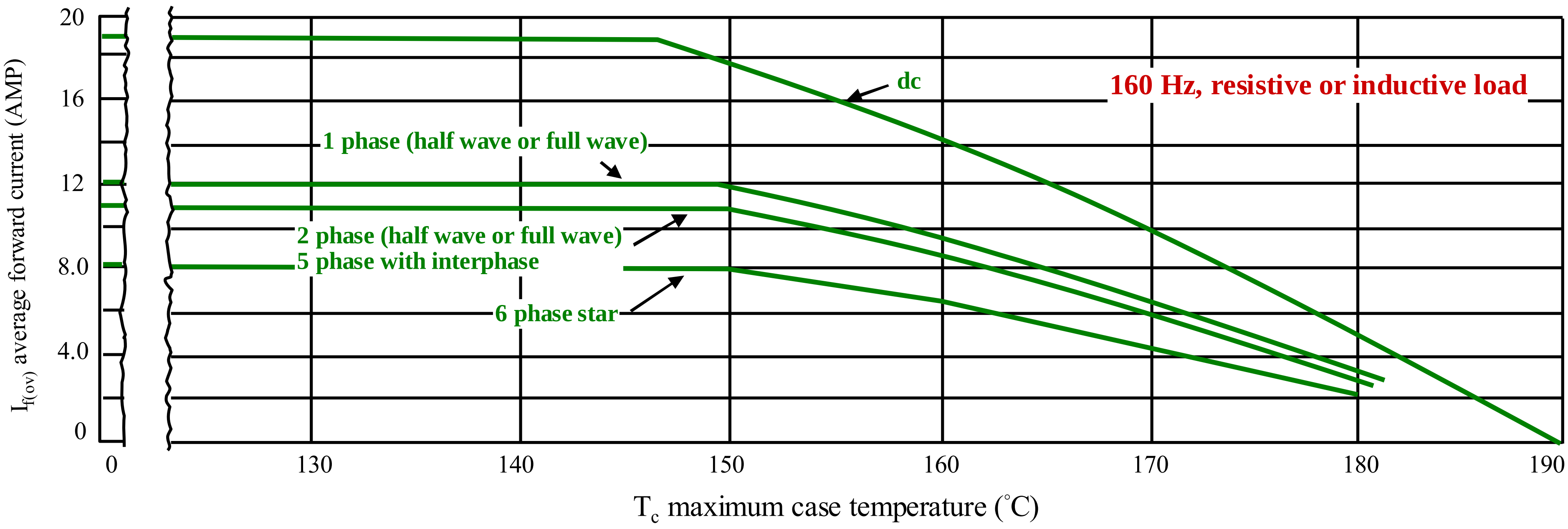
(b)

$$\text{Crest Factor} = \frac{I_{d(peak)}}{I_{d(rms)}} = 2$$

$$\text{Form Factor} = \frac{I_{d(rms)}}{I_{d(average)}} = \frac{\left(\frac{1}{\sqrt{2}}\frac{V_s}{R}\right)}{\left(\frac{\sqrt{2}}{\pi}\frac{V_s}{R}\right)} = \frac{\pi}{2}$$

$$I_{d(\mathrm{peak})} = 2 \times I_{d(\mathrm{rms})} = 2 \times \frac{\pi}{2} \times I_{d(\mathrm{average})} = \pi \times I_{d(\mathrm{average})}$$

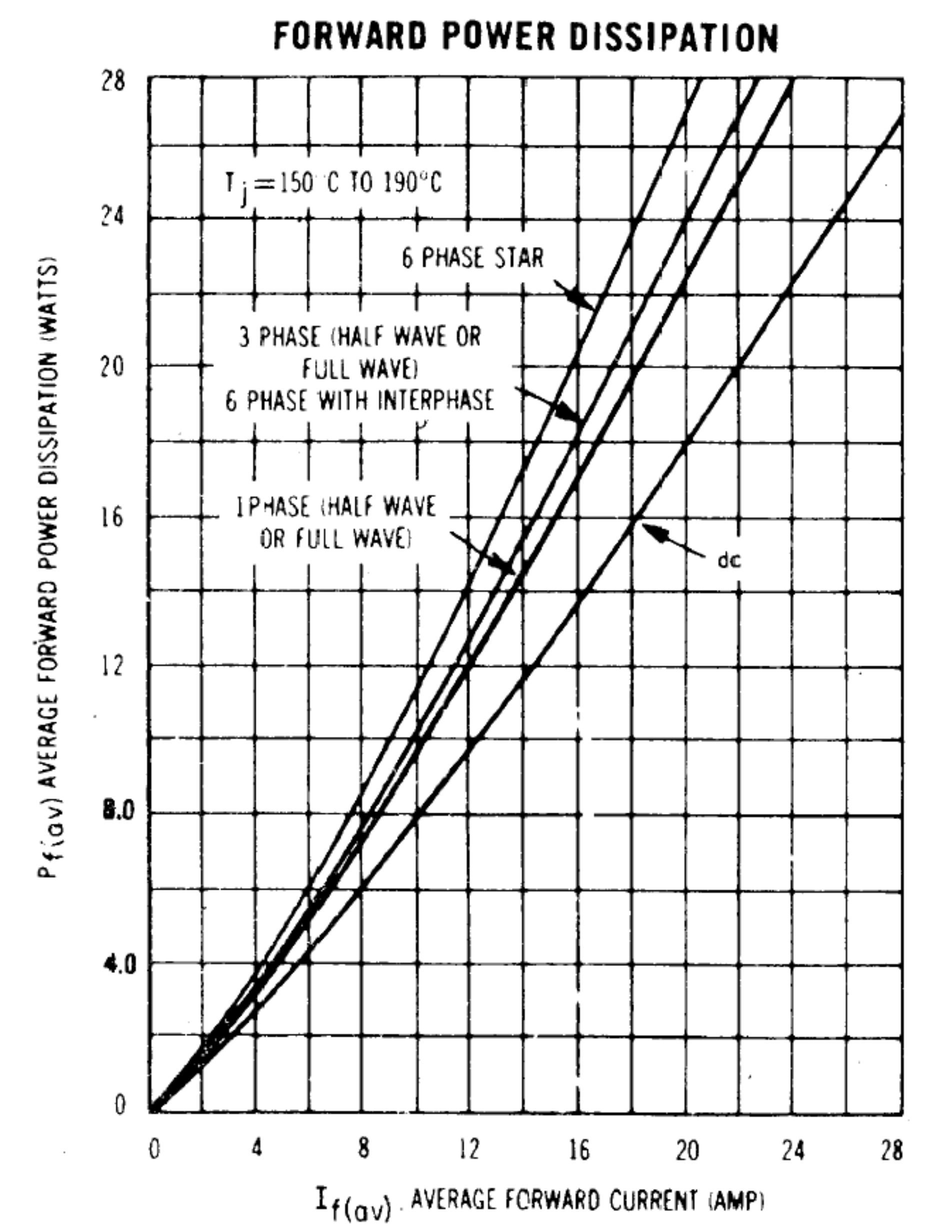
Interpretation of Average Forward Rectified Current



Maximum average current ratings showing lower permissible currents for multiphase rectifiers because of the higher rms currents for shorter conducting periods. (Courtesy Motorola, Inc.)

In multiphase rectifiers, since conduction takes place over only part of a half cycle, the ratio of peak to average current is greater, and since heating effect is proportional to the square of the current, the heating effect or rms value of a narrow large-amplitude current waveform is greater than that of a smaller wider current waveform of the same average value.

Forward Power Dissipation



Hence, maximum average forward current limits for the same rectifier diode are lower for multiphase rectifier service. Correspondingly, the forward current limit is greatest for dc (or half-cycle, square-wave current pulses in the rectifier).

A small inductor can be inserted before the rectifier to reduce the current crest factor.

Average Forward Rectified Current

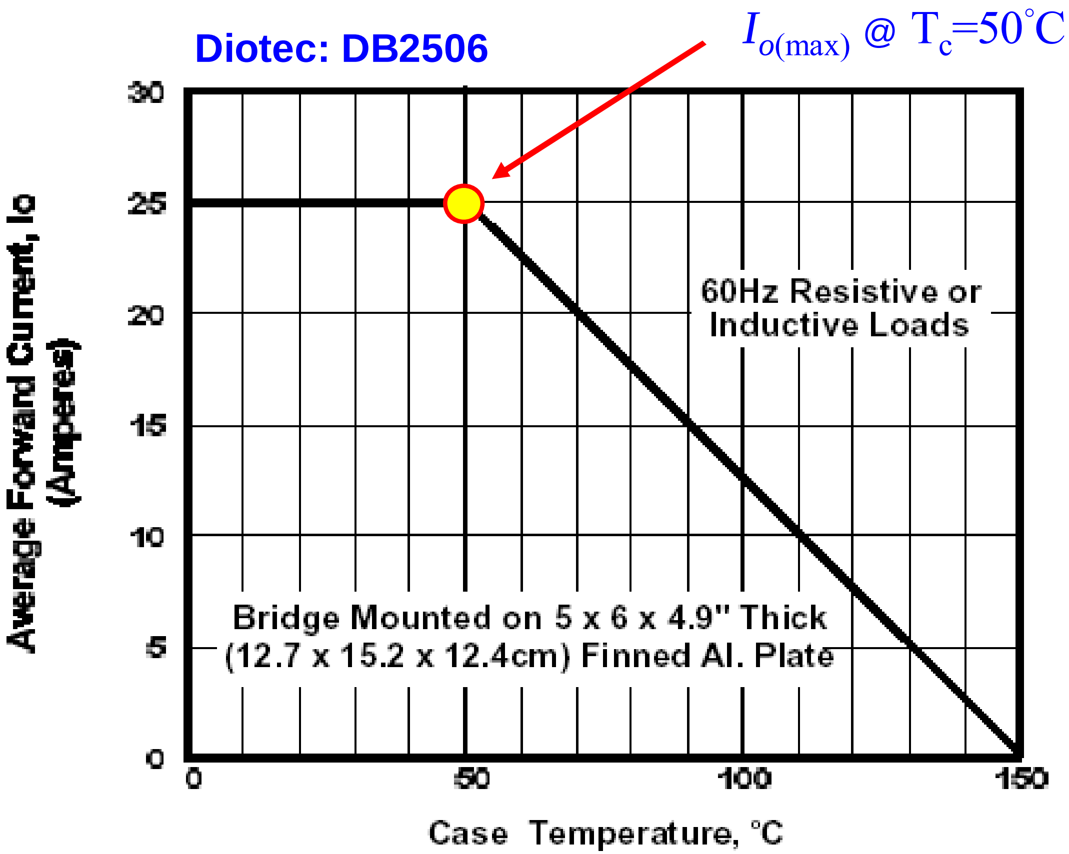


FIGURE 1. FORWARD CURRENT DERATING CURVE

This current is specified generally at 150°C case temperature (more recently, they are specified at 50°C, such as **Diotec: DB2506**) and is that average current in resistor loaded half-wave rectifier service, where $I_{average} = (1/\pi)I_{peak}$, which results in the maximum specified junction temperature for the specified thermal resistance from junction to case.

Thermal Derating of I_o

It should be noted that in the selection of a power semiconductor device, the final criterion is the junction temperature can not above the permitted under worst-case load conditions.

The junction temperature can be calculated as:

$$T_{j(\max)} = T_a + P_{HS}\theta_{hsa} + P_D(\theta_{iw} + \theta_{jc})$$

$$T_{j(\max)} = T_a + P_{HS}\theta_{hsa} + P_D(\theta_{iw} + \theta_{jc})$$

$T_{j(\max)}$: maximum allowable junction temperature

$T_{a(\max)}$: ambient temperature

P_{HS} : power dissipated in heat sink

P_D : power dissipated in rectifier

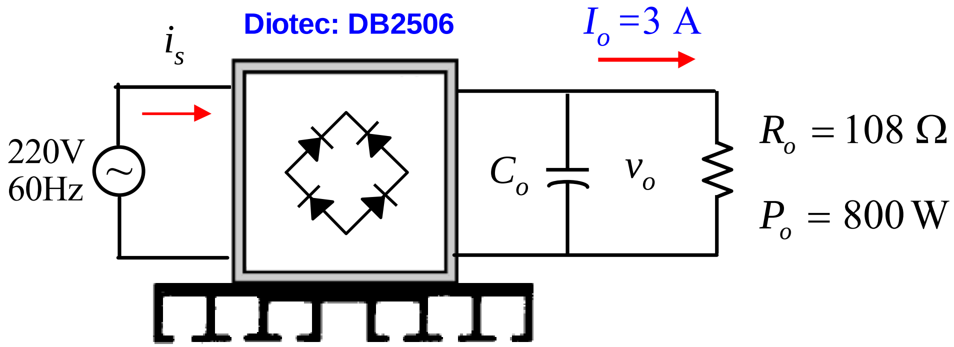
θ_{hsa} : thermal resistance of heat sink

θ_{iw} : thermal resistance of diode insulating washer

θ_{jc} : thermal resistance of diode junction to case

A decision must be made as to how high rectifier diode temperatures shall be permitted to go. Although the vendors establish 190-200 °C as maximum limits for ac line frequency rectifiers, a good worst-case design should derate this. A frequent derating factor for rectifier junction temperatures is 65-70% of the vendor's specified maximum value.

Thermal Dissipation of the Rectifier



For an average load current of 3A, the average forward current of the diode of a full-wave rectifier is 6 A, voltage is about 0.82V. The total power dissipated in the bridge rectifier (4 diodes) is:

$$P_D = 4 \times I_o \times V_{FD} = 4 \times 3 \times 0.82 = 9.84\ \text{W}$$

The junction-to-case thernal resistance of the bridge rectifier is:

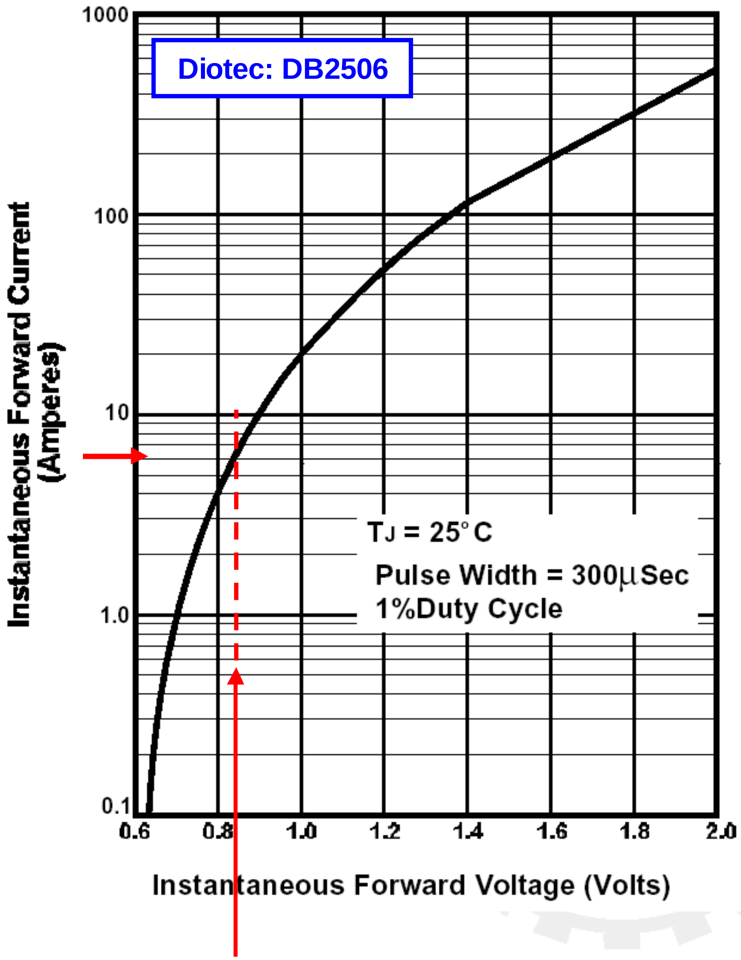
$$\theta_{jc} = 1.6\,°C/\text{W}$$

This poser dissipation will increase a temperature rise to the rectifier case:

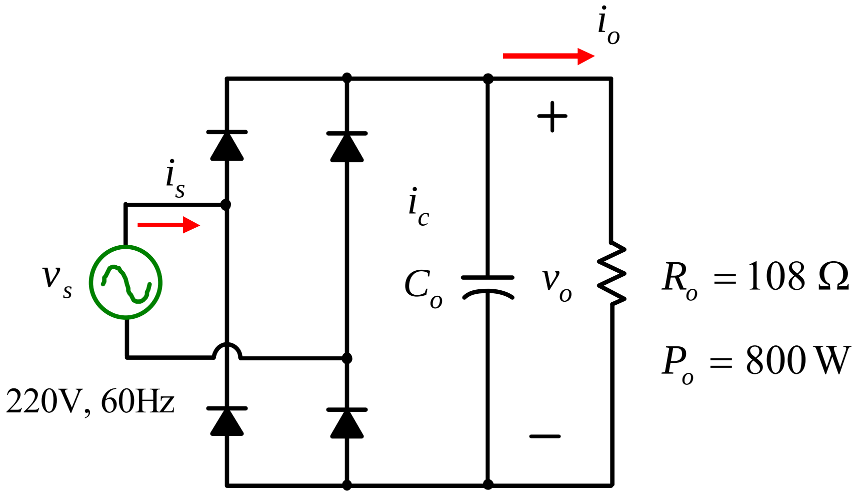
$$\Delta T = P_D \theta_{jc} = 9.84\,\text{W} \times 1.6\,°C/\text{W} = 15.7°C$$

$$T_c = T_{hs} + \Delta T = T_{hs} + P_D \theta_{jc}$$

Design Example:

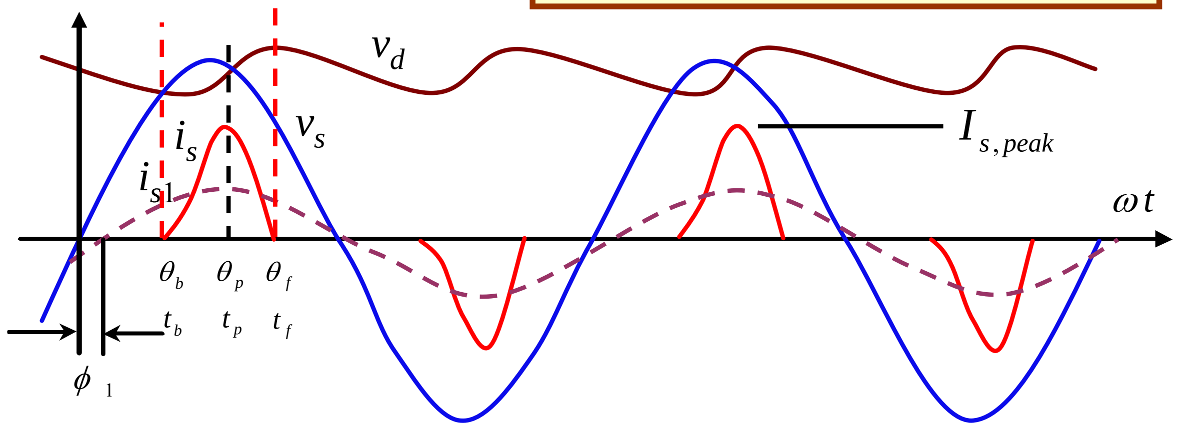


Repetitive Peak Diode Current for Rectifier Capacitive Load



Practical diode-bridge rectifier with a filter

$$\text{crest factor} = \frac{I_{s,\text{peak}}}{I_s} = \frac{\text{peak value}}{\text{rms value}}$$



Design Example:

A full-bridge rectifier given with the following parameters:

$V_{rms} = 220V$ at 60Hz, $P_o = 800$W, $C_o = 940\mu$F, $R_o = 108\Omega$. What is the current crest factor? What is the repetitive peal current for the diode?

Solution:

Assume there is no loss on the rectifier, then $P_{ac} = V_{s(rms)} I_{s(rms)} = P_o = 800\ \mathrm{W}$

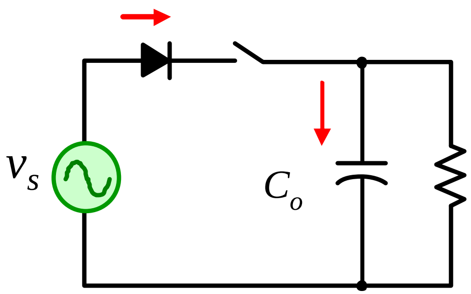
$$I_{s(rms)} = \frac{P_o}{V_{s(rms)}} = \frac{800\ \mathrm{W}}{220\ \mathrm{V}} = 3.64\ \mathrm{A}$$

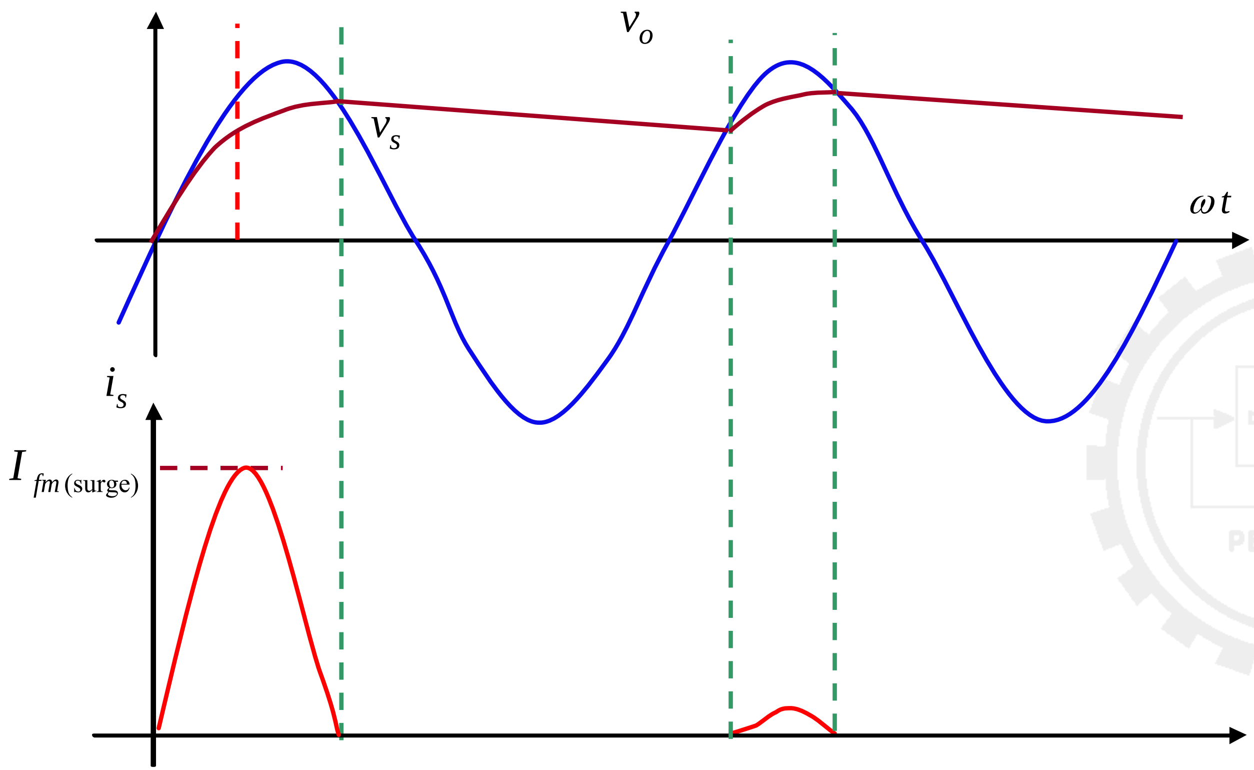
If the current crest factor is 3, the repetitive peak current is 11 A.

Nonrepetitive Forward Surge Current $I_{fm(\text{surge})}$

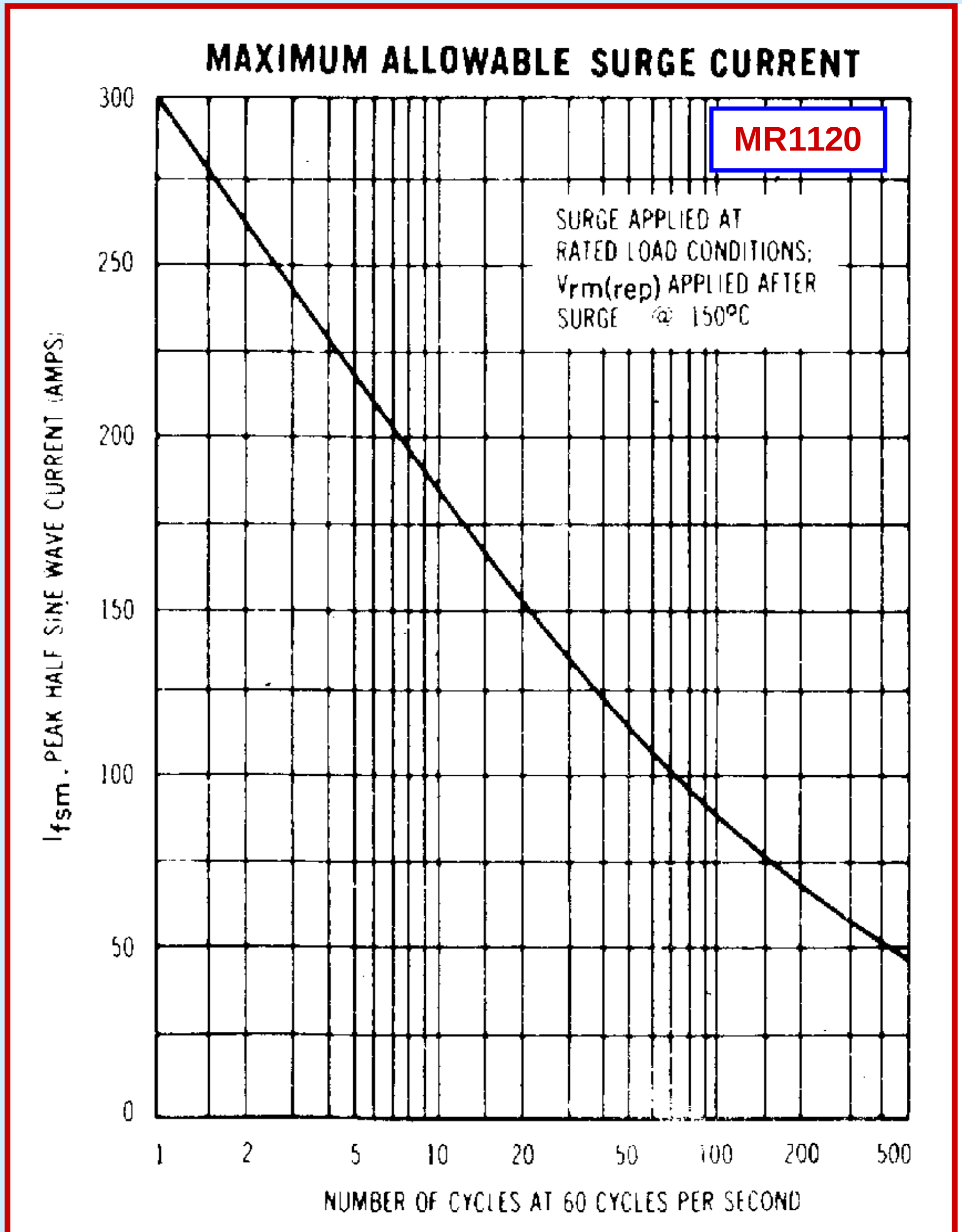
$I_{fm(\text{surge})}$ is defined as the peak allowable single half sine wave (duration 8.3 msec) of current spaced in time between the normal maximum amplitude current half sine waves in a 60-Hz, single-phase rectifier.

The rms value of this current waveform is the rms value of a half-cycle sine wave within one full cycle. For a peak amplitude I_p, the rms value of this permissible fault current is $I_{\text{rms}} = I_p/2$.





Maximum Allowable Surge Current

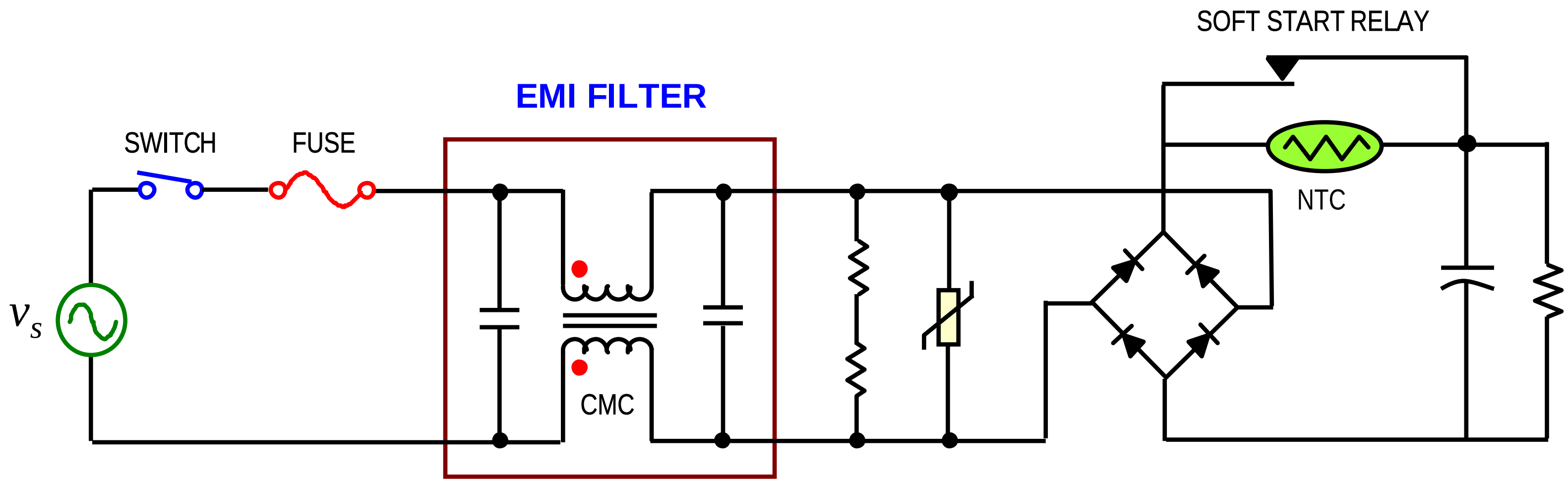


Another way of describing this permissible fault current, then, is to say that over any 16.6 msec interval, there can be any waveform of current whose rms value over that 16.6 msec is one-half the peak specified half sine wave.

Thus, for the Motorola MR1120, the specified maximum nonrecurrent peak surge current is. 300 A. The rms value of this is $I_p/2$ or 150 A.

The $I_{fm(surge)}$ spec thus also permits a square wave of current of 150 A for the full 16.6 msec.

Inrush Surge Current



- The surge current rating also permits larger number of surge pulses at the 60-Hz rate but of lesser amplitude. High-energy surge pulses can occur at initial turnon, especially with capacitive input filters, when the main power switch is closed at the peak of the input power sine wave.
- Directly-off-the-ac-line rectifiers fed from a 220 V ac line source can have trouble with inrush surges exceeding these limits. The usual EMI line filter in series with the rectifier diodes serves to limit inrush current surges.
- If there is no such limiting impedance, it is essential in any new aesign to measure input surges with an oscilloscope and current probe. If limits are exceeded, either a small resistor shorted out by a relay contact after a short time delay may be added. Or it may be more economical in space and dollars not to limit the current surge at all, but simply to go to the rectifier diode with the next higher current rating, since rectifier diodes are quite inexpensive.
- **There generally is no problem with inrush current surges on rectifiers fed from transformers, for transformer leakage inductance is usually sufficient to provide the limiting action.**

I^2t Rating

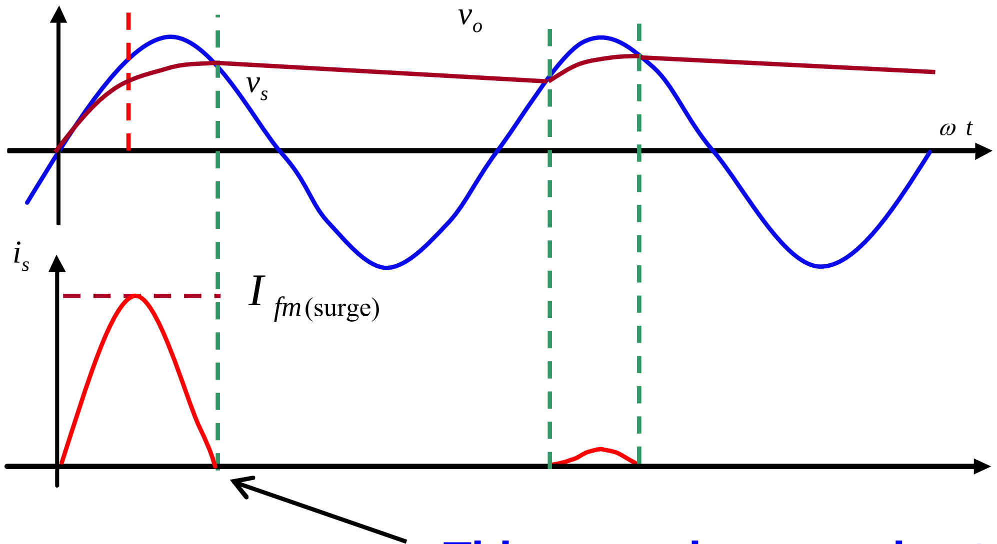
This is a measure of the maximum energy deliverable to the diode ***in a single high-current pulse***. It is the maximum permissible product of the square of the rms current and its time duration.

I^2t rating is simply another way of expressing the "***nonrepetitive peak surge current***" I_{fm}(surge) rating and is derivable from it. The rms value of I_{fm}(surge) over a full period of 60 Hz is 0.5 I_{fm}(surge).

This rms current can be carried for a full cycle of 60 Hz. Hence, the equivalent I^2t rating is $(0.5\, I_{fm}(\text{surge}))^2(0.0166)$ and its units are square amperes $\times$ seconds.

Selection of the Rectifier Diode

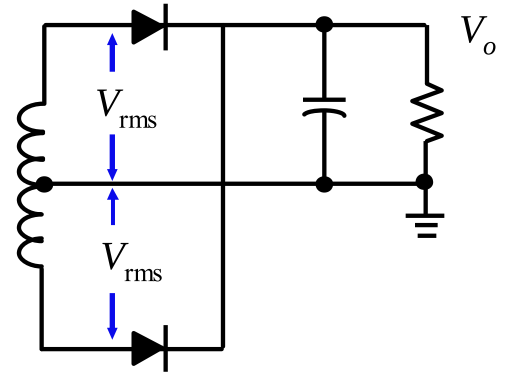
For example, the **DIOTEC DB2506** has an I_{fm}(surge) rating of 300 A. Its I^2t rating is then (300/2)2 (0.0166) = 375 A^2-sec. This is precisely the value quoted for I^2t in the device data sheets.



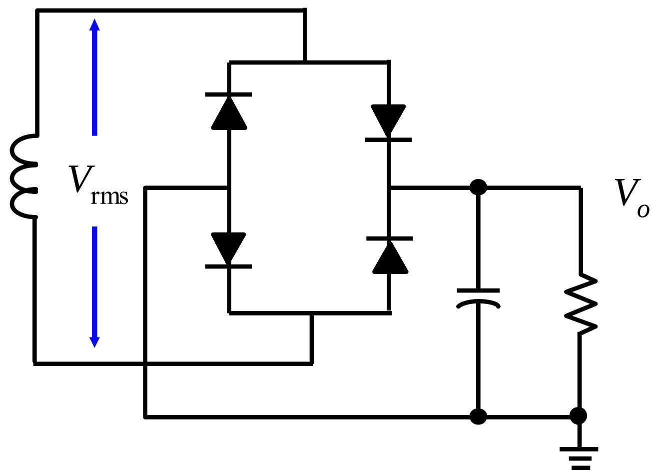
$$I^2t = \int_0^{T/2} i_s^2(t)dt$$
$$= \int_0^{T/2} I_{fm(surge)} \sin 120\pi t dt$$
$$= \int_0^{0.0083} I_{fm(surge)} \sin 120\pi t dt = \frac{1}{2} I_{fm(surge)}$$

This surge is approximated by a half-wave sine.

Bridge Rectifiers vs. Center-Tap Rectifiers



CENTER-TAP RECTIFIER

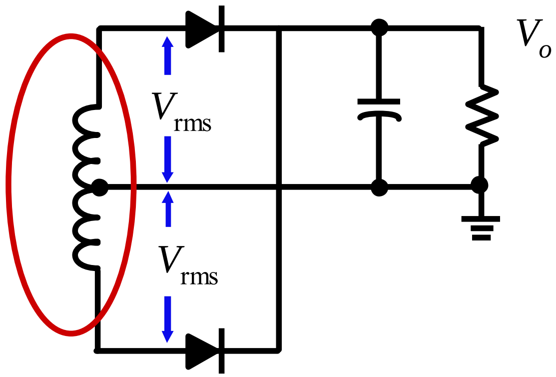


BRIDGE RECTIFIER

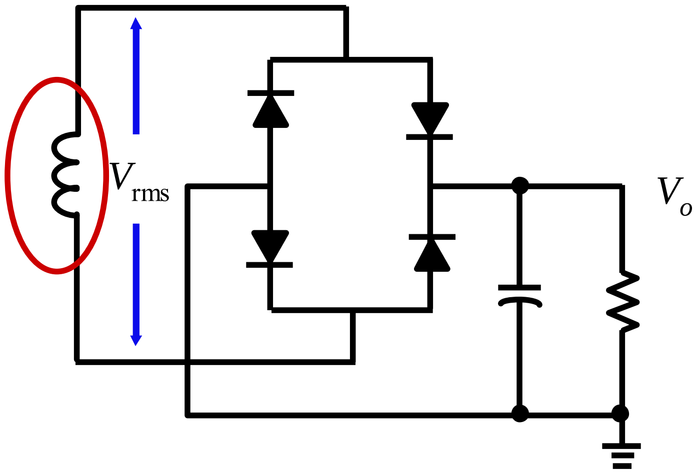
The first decision to be made in single-phase rectifiers is the type of circuit configuration: full-wave center tap or full-wave bridge. The half-wave rectifier, especially at power line frequencies, is usable only for low-output currents, for the filter capacitor must supply load current for almost the full cycle of 16.6 msec as contrasted to 8.3 msec for full-wave rectifiers, this requires twice the filter capacitance for the same ripple output voltage. Nevertheless, for high-frequency, square-wave output rectifiers, the half-wave circuit is an economical and often overlooked circuit.

The bridge and center-tap configurations each has its own merits. Because it has two rather than four rectifier diodes, the center-tap circuit dissipates less power, requires less space, and is more economical than the bridge. But for the same do output voltage, it requires diodes with twice the peak inverse voltage rating. Because the impedance looking back into the rectifier from the load is that of one diode rather than two in series, the center-tap circuit has lower output impedance.

Transformer Considerations



CENTER-TAP RECTIFIER



BRIDGE RECTIFIER

The center-tap circuit results in a larger transformer, since it has twice as many secondary turns for the same do output voltage.

The rms current in the single, winding in a bridge is twice that of the current in either half of the center tap circuit, since the single-bridge winding conducts on each half cycle. Thus, for the same coil current density or temperature rise, the bridge transformer wire size must be greater.

Despite this, the bridge circuit, because it has half the number of turns of the center tap, still results in a smaller transformer - this is perhaps its chief advantage.

中心抽頭整流器與全橋式整流器相較，在相同額定狀況下，其變壓器次級線圈的圈數增加一倍，線徑則為0.707，但體積仍較大。

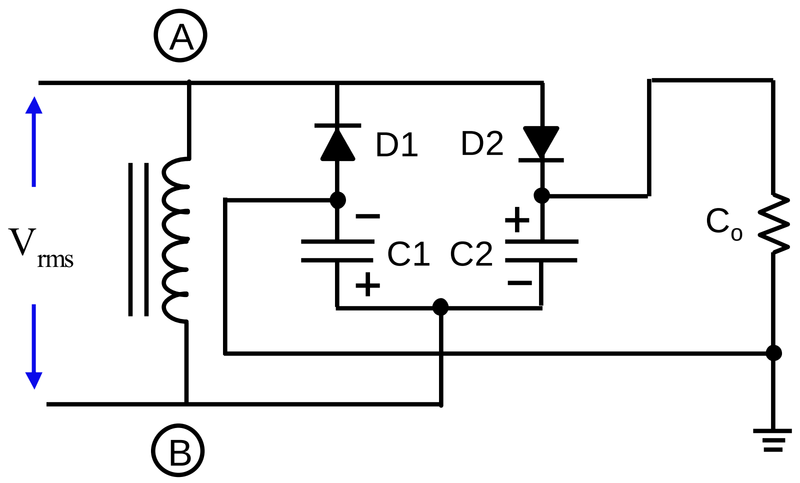
Peak DC Output Voltage of Common Rectifier Circuits

Peak dc output voltage (volts)

Nominal rms input voltage (volts)	Nominal ac voltage	10% high-line input	10% transient above 10% high line	10% low-line input	-10% transient below 10% low line
Single-phase, bridge					
115 line to line	162	178	196	146	131
120 line to line	169	180	205	152	137
220 line to line	310.	341	375	279	251
Three-phase, half-wave, "wye"					
115 line to neutral	162	178	196	146	131
120 line to neutral	169	186	205	152	137
Three-phase, full-wave, bridge					
208 line to line	293	323	354	264	237

Peak dc output voltages for commonly used rectifier circuits on common ac line voltages in off-the-ac-line rectifiers.

Full-Wave Doubler

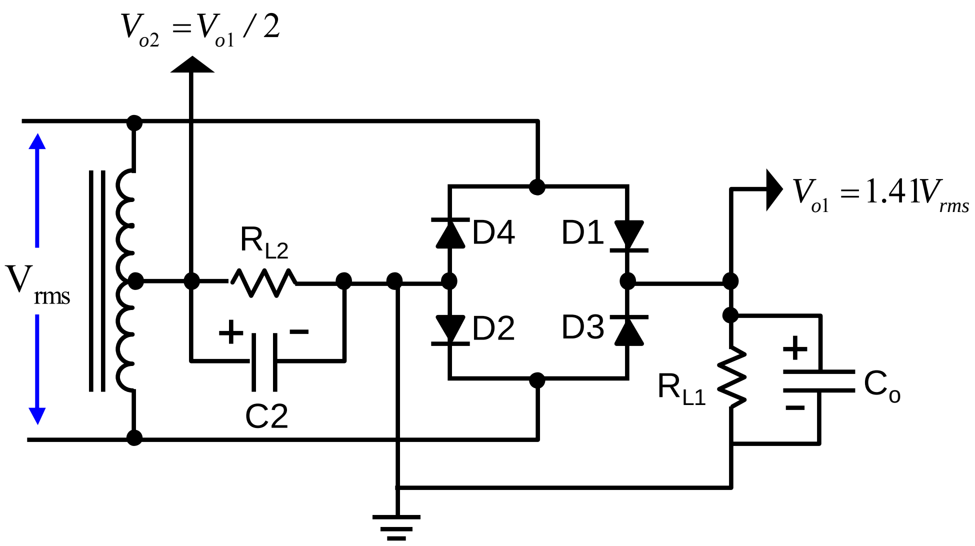


$$V_o = 2 \times V_{rms} \times 1.414$$

This circuit is derived from the full-wave bridge. On the half cycle-when A is positive relative to B, D2 charges C2 in the polarity shown to a peak voltage $1.414V_{rms}$. On the next half cycle when B is positive relative to A, D1 charges C1 in the polarity shown to $1.414V_{rms}$.

The load is connected between the positive end of C2 and negative end of C1. It is seen the voltages across C1 and C2 add in series to a voltage of $2.828V_{rms}$

Full- and Half-Output Voltage from Bridge Rectifier

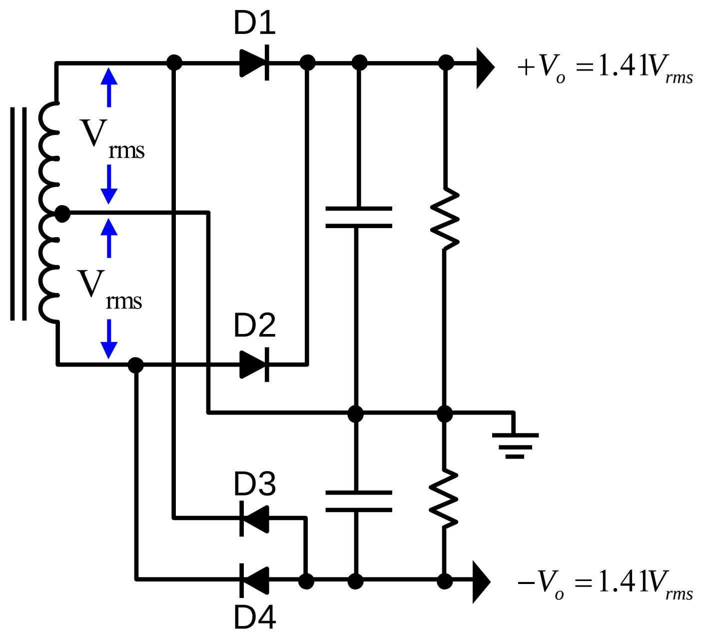


It is often necessary to have an output voltage lower than the full output from a rectifier. This can always be done with an additional transformer winding, of course, but the above figure shows how it may be done with only a center tap on a winding for a bridge rectifier.

Diodes D1-D4 form the conventional bridge rectifier. A load with capacitive filter C2 is bridged between the transformer center tap and the D2-D4 junction. Co charges up to the conventional 1.41 V_{rms} of a bridge rectifier. But diodes D4 and D2 act as a full-wave, center-tap rectifier and charge C2 up to $1.414V_{rms}/2$, V_{o1}, and V_{o2} have a common negative terminal and are both positive with respect to that terminal.

If R_{L2} is bridged between the center tap and the D1-D3 junction, V_{o1} and V_{o2} will have a common positive terminal, although the voltage magnitudes will be unchanged.

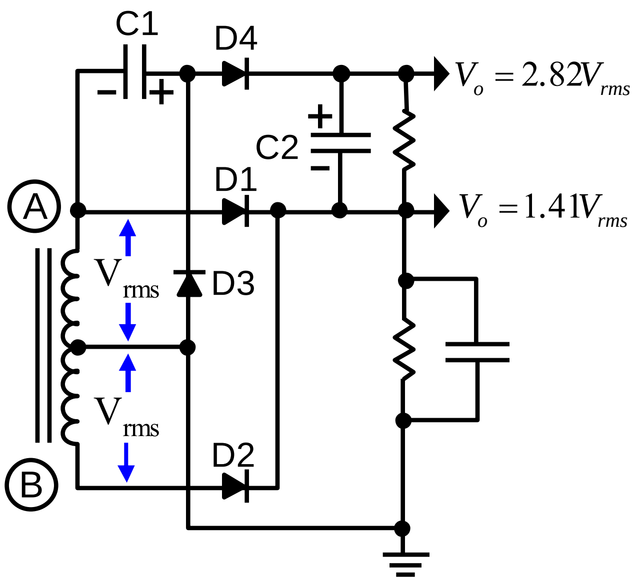
Positive and Negative Outputs from the Same Center-Tap Rectifier Winding



It is often necessary to have equal positive and negative voltages about a common ground point. This is simply achieved as shown in the above circuit with diodes D1 and D2 providing the rectified positive output. Diodes D3 and D4 are reversed in polarity and provide the rectified negative output.

Each transformer half winding now conducts on every half cycle, not on alternate half cycles as in a single-ended rectifier. Coil wire size must be chosen to take this into account.

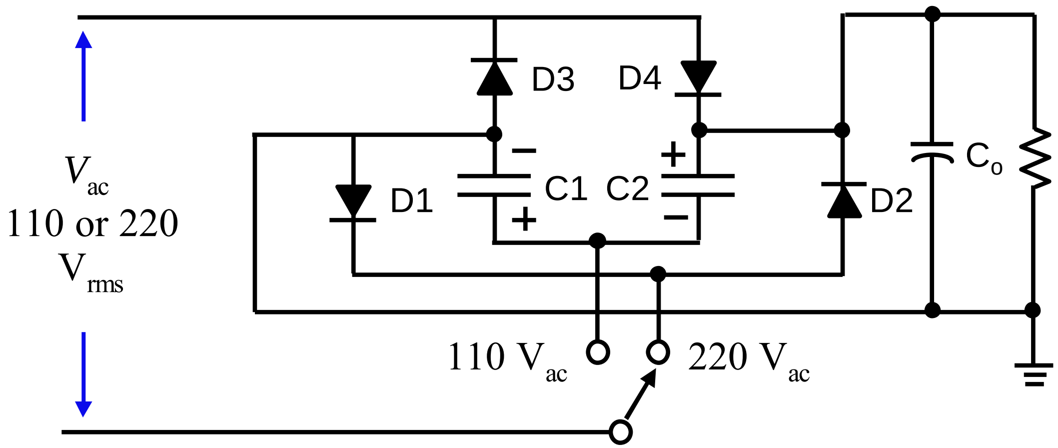
Normal and Double-Output Voltage from Single Center-Tap Winding



Often in a full-wave, center-tap rectifier it is necessary to have a voltage level above the normal output without adding an additional transformer winding. This can be done as in the above circuit. Diodes D 1 and D2 and both transformer halves about the center tap comprise the standard center-tap rectifier yielding an output voltage of $1.414V_{rms}$.

Diodes D3 and D4 and capacitors C 1 and C2 form a half-wave voltage doubling circuit. When A is negative relative to B, D3 charges C1 up to a potential of $1.414V_{rms}$ in the polarity shown. On the next half cycle, A goes positive relative to ground by $1.414V_{rms}$ and lifts the negative end of C1 up with it. Thus, the positive end of C1 is raised to $2.828V_{rms}$ and charges the top end of C2 up to that potential via D4.

Rectifier with Same Output Voltage
for Either 110V or 220V Input



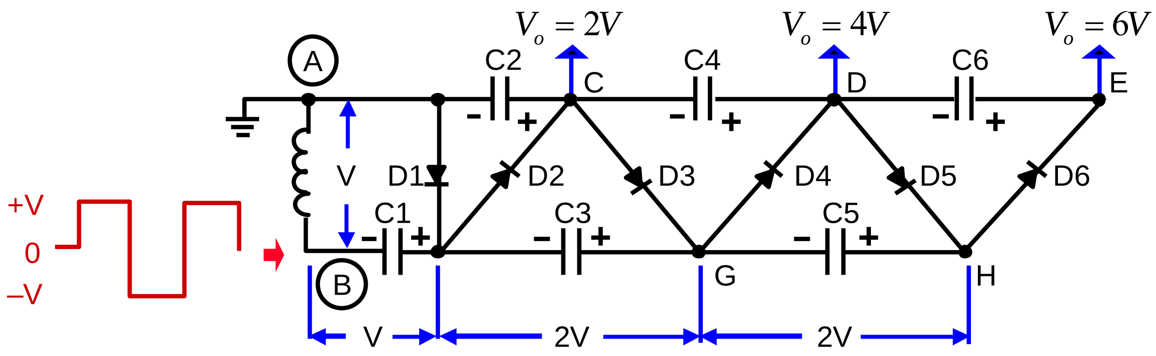
$$V_o = 1.414 \times 220$$
$$= 2 \times 1.414 \times 110$$
$$= 311 \text{ Volts}$$

Power line voltage in many countries is standardized at 220 V. It is often necessary that equipment to be sellable for either the 110 V or 220 V market must be usable at either location by only a simple linkage change. This is easily done, with equipment having power transformer input by providing a tap on the primary.

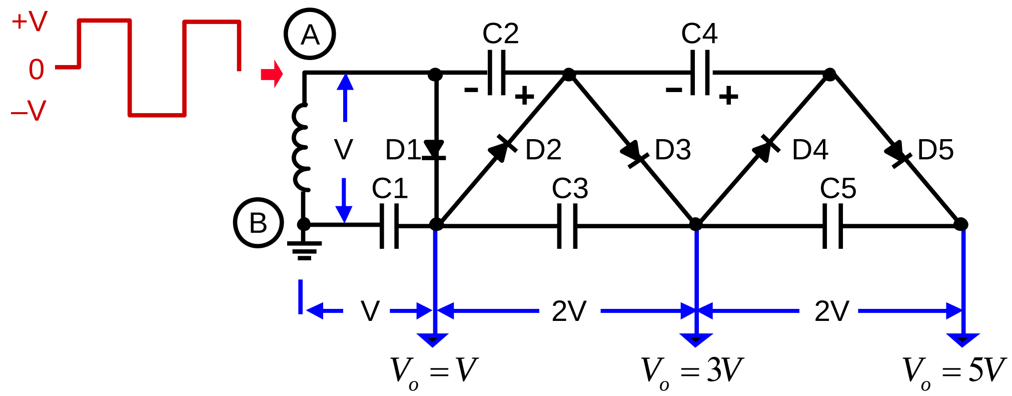
Most modern power supplies having directly-off-the-ac-line rectifiers can use a scheme such as shown in the above figure. The output will always be 311 V, as if there were a bridge rectifier off the 220 V ac line.

For 220Vac, the linkage shown is thrown to the 220V position. This throws in diodes D1 and D2, which together with D3 and D4 comprise a bridge rectifier and yield (1.41)(220)=311V. When input voltage is 110V, the linkage is thrown to "115," and C1 and C2 together with diodes D3 and D4 comprise a voltage doubler. Diodes DI and D2 are back biased and effectively out of the circuit. Output voltage at Co is 2(1.41)(110) = 311 V.

Multiplier Rectifier



(A)



(B)

(A) A voltage multiplier multiplying peak voltage at B by even numbers.

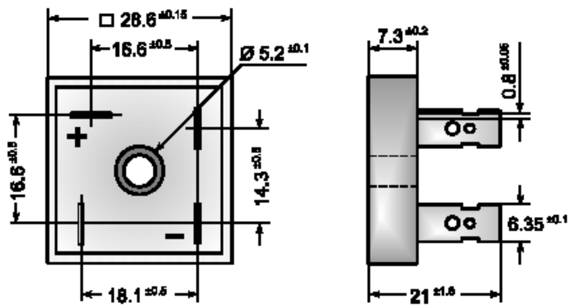
(B) A voltage multiplier multiplying peak voltage at A by odd numbers.

The basic principle in such multipliers is to have a stack of capacitors in series and force equal voltage increments across each one. An array of auxiliary capacitors and diodes is used to drop equal voltage increment on the string of series capacitors.

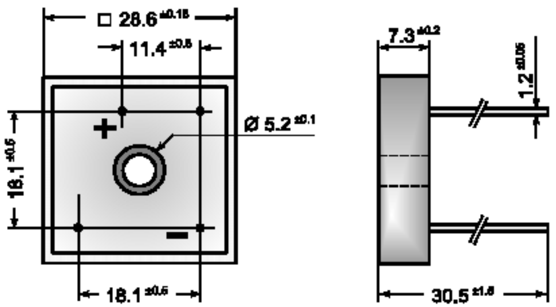
Appendix: DB2500-DB2510

DIOTEC ELECTRONICS CORP.
18020 Hobart Blvd., Unit B
Gardena, CA 90248 U.S.A
Tel.: (310) 767-1052 Fax: (310) 767-7958

Type "F"



Type "W"



FEATURES

- VOID FREE VACUUM DIE SOLDERING FOR MAXIMUM MECHANICAL STRENGTH AND HEAT DISSIPATION (Solder Voids: Typical < 2%, Max. < 10% of Die Area)
- BUILT-IN STRESS RELIEF MECHANISM FOR SUPERIOR RELIABILITY AND PERFORMANCE
- ELECTRICALLY ISOLATED METAL CASE FOR MAXIMUM HEAT DISSIPATION
- UL RECOGNIZED - FILE #E141956

MECHANICAL DATA

- Case: Metal (Potting epoxy carries U/L flammability Rating 94V-0)
- Terminals: Round silver plated copper pins or fast-on terminals
- Soldering: Per MIL-STD 202 Method 208 guaranteed (Note 1)
- Polarity: Marked on side of case
- Mounting Position: Any. Through hole for #8 screw.
  Max. mounting torque = 20 in-lb.
- Weight: Fast-on Terminals - 1.1 Ounces (31.6 Grams)
  Wire Leads - 0.95 Ounce (28.5 Grams)

Bridge Rectifier: Diotec: DB2506 (600V, 25A)

Diotec: DB2500 – DC2510

MAXIMUM RATINGS & ELECTRICAL CHARACTERISTICS

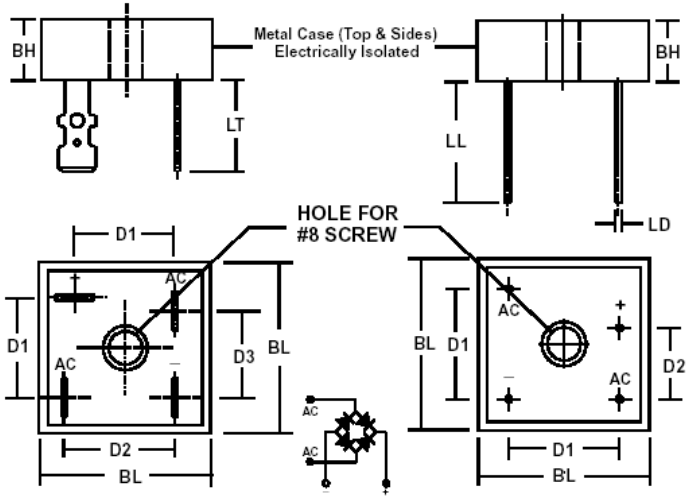
Ratings at 25 °C ambient temperature unless otherwise specified. Single phase, half wave, 60Hz, resistive or inductive load. For capacitive loads, derate current by 20%.

PARAMETER (TEST CONDITIONS)	SYMBOL	RATINGS: CONTROLLED AVALANCHE			RATINGS: NON-CONTROLLED AVALANCHE							UNITS
Series Number		ADB 2504	ADB 2506	ADB 2508	DB 2500	DB 2501	DB 2502	DB 2504	DB 2506	DB 2508	DB 2510	
Maximum DC Blocking Voltage / Working Peak Reverse Voltage / Maximum Peak Recurrent Reverse Voltage	V_{RM} / V_{RWM} / V_{RRM}	400	600	800	50	100	200	400	600	800	1000	VOLTS
RMS Reverse Voltage	$V_{R(RMS)}$	280	420	560	35	70	140	280	420	560	700	VOLTS
Rating for Fusing (Non Repetitive; 1mS < t < 8.3mS)	I^2t	375										AMPS² SEC
Peak Forward Surge Current. Single 60Hz Half-Sine Wave Superimposed on Rated Load (JEDEC Method). T_J = 150° C	I_{FSM}	300										AMPS
Average Forward Rectified Current @ T_C = 50° C	I_O	25										AMPS
Junction Operating and Storage Temperature Range	T_J, T_{STG}	-55 to +150										°C
Mimimum Avalanche Voltage	$V_{(BR)}$ Min	450	650	850	n/a							VOLTS
Maximum Avalanche Voltage	$V_{(BR)}$ Max	900	1100	1300	n/a							VOLTS
Maximum Forward Voltage (Per Diode) at 12.5 Amps DC	V_{FM}	1.03										VOLTS
Maximum Reverse Current at Rated V_{RM} @ T_A = 25°C / @ T_A = 125°C	I_{RM}	1 / 10										µA
Minimum Insulation Breakdown Voltage (Circuit to Case)	V_{ISO}	2000										VOLTS
Typical Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.6										°C/W

Bridge Rectifier: Diotec: DB2506 (600V, 25A)

MECHANICAL SPECIFICATION

SERIES: DB2500 - DB2510 and ADB2504 - ADB2508



SYM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
BL	28.4	28.7	1.12	1.13
BH	11.0	11.2	0.43	0.44
D1	15.7	16.7	0.62	0.66
D2	17.5	18.5	0.69	0.73
D3	13.5	14.5	0.53	0.57
LT	n/a	14.2	n/a	0.56

SYM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
BL	28.4	28.7	1.12	1.13
BH	11.0	11.2	0.43	0.44
D1	17.5	18.5	0.69	0.73
D2	10.9	11.9	0.43	0.47
LL	20.6	n/a	0.81	n/a
LD	1.0	1.1	0.039	0.042

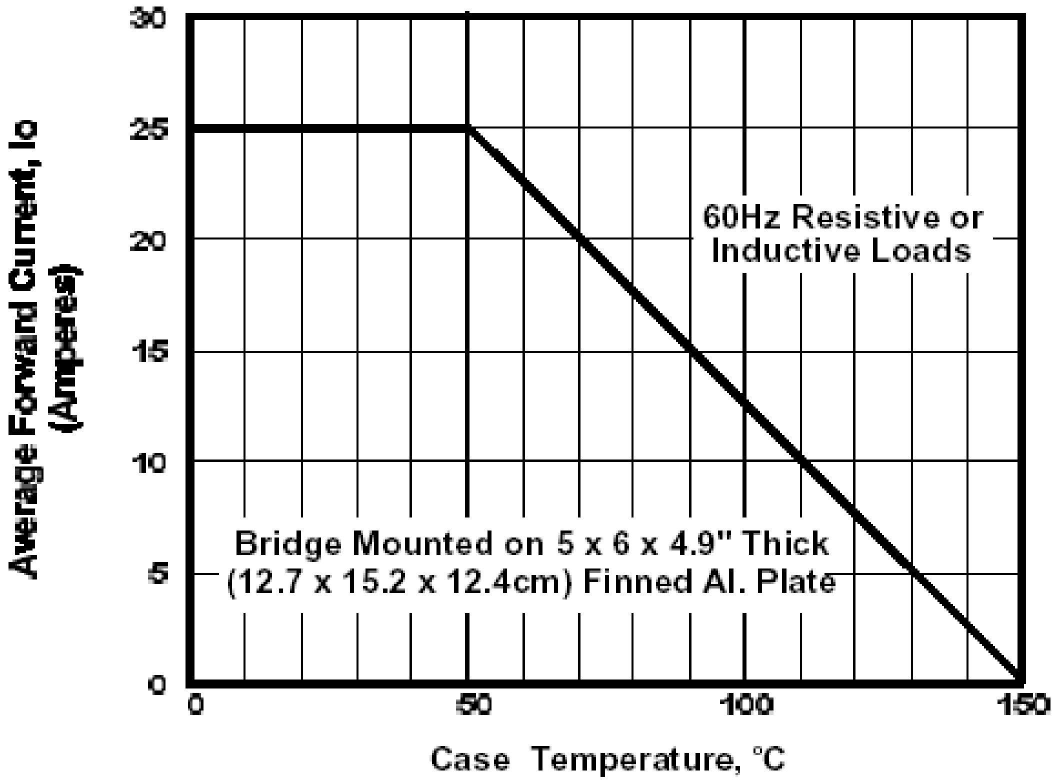


FIGURE 1. FORWARD CURRENT DERATING CURVE

References

[1] Abraham I. Pressman, Chap. 5: Elements of Rectifier7 Design, **Switching and Linear Power Supply, Power Converter Design**, Hayden Book Co., 1977.

[2] Irving M. Gottlieb, **Power Supplies, Switching Regulators, Inverters, and Converters**, McGraw-Hill, 1994.

[3] I. Rosa, "The harmonic spectrum of DC link currents in inverters," *Proceedings of the Fourth International PCI Conference on Power Conversion*, Intertec Communications, Oxnard, CA, pp. 38-52.

[4] EPRI Report, "AC/DC power converter for batteries and fuel cells," *Project 841-1, Final Report, EPRI*, Palo Alto, CA, Sept. 1981.