

## FC020-Series Power Modules: dc-dc Converters; 28 Vdc Input, 20 W

### Features

- Wide input range: 18 V to 36 V
- Low profile: 0.5 in.
- High power-density: 6 W/in.<sup>3</sup>
- Output overvoltage clamp
- No minimum load
- Short-circuit protection
- Parallel operation with load sharing
- Input-to-output isolation
- Synchronization
- Remote sense
- Remote on/off
- UL\* recognized, CSA† certified

### Applications

- Computers and computer accessories
- Local power distribution
- Digital circuits
- Distributed power architectures
- Redundant power



The FC020-Series Power Modules use advanced, surface-mount technology and deliver high-quality, compact, dc-dc conversion at an economical price.

### Description

The FC020A, B, and C Power Modules are 20 W, isolated, dc-dc converters that operate from nominal 28 Vdc inputs and provide 5 Vdc, 12 Vdc, and 15 Vdc outputs, respectively. The power modules incorporate peak-current control circuitry and power trains that combine high-efficiency power conditioning with precisely regulated output voltages.

State-of-the-art packaging techniques are combined with high-frequency switching technology to produce low-profile, high power-density devices. The modules, which mount on printed-circuit boards, are 3.6 in. long, 1.9 in. wide, and 0.5 in. high. In a natural convection environment, the devices operate up to 70 °C with no heat sink.

\* UL is registered trademark of the Underwriters Laboratories, Inc.

† CSA is a registered trademark of Canadian Standards Association.

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### Absolute Maximum Ratings

Ratings apply to all devices.

Stresses in excess of the Absolute Maximum Ratings can cause permanent damage to the device. These are absolute stress ratings only. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operations sections of the data sheet. Exposure to Absolute Maximum Ratings for extended periods can adversely affect device reliability.

Parameter	Symbol	Min	Max	Unit
Input Voltage	$V_I$	—	36	V
I/O Isolation Voltage	—	—	500	V
Operating Ambient Temperature (Natural convection, see Thermal Management section.)	$T_A$	0	70	°C
Storage Temperature	$T_{stg}$	−40	100	°C

### Electrical Specifications

Unless otherwise indicated, specifications apply over all operating input voltage, resistive load, and temperature conditions.

Specifications apply to all devices.

**Table 1. Input Specifications**

Parameter	Symbol	Min	Typ	Max	Unit
Operating Input Voltage	$V_I$	18	28	36	V
Maximum Input Current ( $V_I = 0$ V to $V_{I, max}$ ; see Figure 1.)	$I_{I, max}$	—	—	2.0	A
Inrush Transient	$i^2t$	—	—	0.6	A <sup>2</sup> s
Input Reflected-ripple Current, Peak-to-peak (5 Hz to 20 MHz, 12 $\mu$ H source impedance; see Figure 12.)	—	—	50	—	mA p-p
Input Ripple Rejection (120 Hz)	—	—	60	—	dB

### Fusing Considerations

**CAUTION: This power module is not internally fused. An input line fuse must always be used.**

This encapsulated power module can be used in a wide variety of applications, ranging from simple stand-alone operation to an integrated part of a sophisticated power architecture. To preserve maximum flexibility, internal fusing is not included; however, to achieve maximum safety and system protection, always use an input line fuse. The Safety Agencies require a normal-blow, dc fuse with a maximum rating of 5 A (see Safety Considerations section). Based on the information provided in this data sheet on inrush energy and maximum dc input current, the same type of fuse with a lower rating can be used. Refer to the fuse manufacturer's data for further information.

## Electrical Specifications (continued)

**Table 2. Output Specifications**

Parameter	Device	Symbol	Min	Typ	Max	Unit
Output Voltage (Over all operating input voltage, resistive load, and temperature conditions until end of life.)	FC020A	$V_o$	4.75	—	5.25	Vdc
	FC020B	$V_o$	11.40	—	12.60	Vdc
	FC020C	$V_o$	14.25	—	15.75	Vdc
Output Voltage Set Point ( $V_i = 28\text{ V}$ ; $I_o = I_{o, \max}$ ; $T_A = 25\text{ }^\circ\text{C}$ )	FC020A	$V_{o, \text{set}}$	4.90	5.00	5.10	Vdc
	FC020B	$V_{o, \text{set}}$	11.75	12.00	12.25	Vdc
	FC020C	$V_{o, \text{set}}$	14.70	15.00	15.30	Vdc
Output Regulation: Line ( $V_i = 18\text{ V}$ to $36\text{ V}$ ) Load ( $I_o = I_{o, \min}$ to $I_{o, \max}$ ) Temperature ( $T_A = 0\text{ }^\circ\text{C}$ to $70\text{ }^\circ\text{C}$ ; see Figure 2.)	all	—	—	—	0.1	%
	all	—	—	—	0.2	%
	FC020A	—	—	—	50	mV
	FC020B, C	—	—	—	100	mV
Output Ripple and Noise: RMS  Peak-to-peak (5 Hz to 20 MHz)	FC020A	—	—	—	20	mV rms
	FC020B	—	—	—	25	mV rms
	FC020C	—	—	—	30	mV rms
	FC020A	—	—	—	150	mV p-p
	FC020B	—	—	—	200	mV p-p
	FC020C	—	—	—	250	mV p-p
Output Current	FC020A	$I_o$	0	—	4.0	A
	FC020B	$I_o$	0	—	1.7	A
	FC020C	$I_o$	0	—	1.35	A
Output Current-limit Inception: $V_o = 4.5\text{ V}$ (See Figure 3.) $V_o = 10.8\text{ V}$ $V_o = 13.5\text{ V}$	FC020A	—	—	4.8	—	A
	FC020B	—	—	2.1	—	A
	FC020C	—	—	1.7	—	A
Output Current Limit ( $V_i = 36\text{ V}$ ; $V_o = 1.0\text{ V}$ ; see Figure 3.)	FC020A	—	4.5	—	8.5	A
	FC020B	—	2.3	—	5.0	A
	FC020C	—	2.0	—	5.0	A
Output Short-circuit Current ( $V_o = 250\text{ mV}$ ; see Figure 3.)	FC020A	—	—	8.0	—	A
	FC020B	—	—	6.0	—	A
	FC020C	—	—	5.0	—	A
Efficiency ( $V_i = 28\text{ V}$ ; $I_o = I_{o, \max}$ ; $T_A = 25\text{ }^\circ\text{C}$ ; see Figures 4 and 13.)	all	$\eta$	76	82	—	%
Dynamic Response ( $\Delta I_o/\Delta t = 1\text{ A}/\mu\text{s}$ , $V_i = 28\text{ V}$ , $T_A = 25\text{ }^\circ\text{C}$ ; see Figures 5 to 10.): Load Change from $I_o = 50\%$ to $75\%$ of $I_{o, \max}$ Peak Deviation  Settling Time ( $V_o < 10\%$ peak deviation) Load Change from $I_o = 50\%$ to $25\%$ of $I_{o, \max}$ Peak Deviation  Settling Time ( $V_o < 10\%$ peak deviation)	FC020A	—	—	60	—	mV
	FC020B, C	—	—	100	—	mV
	all	—	—	250	—	$\mu\text{s}$
	FC020A	—	—	60	—	mV
	FC020B, C	—	—	100	—	mV
	all	—	—	250	—	$\mu\text{s}$

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**Electrical Specifications** (continued)

Specifications apply to all devices.

**Table 3. Isolation Specifications**

Parameter	Min	Typ	Max	Unit
Isolation Capacitance	—	1200	—	pF
Isolation Resistance	1	—	—	MΩ

**General Specifications**

Specifications apply to all devices.

Parameter	Min	Typ	Max	Unit
Calculated MTBF ( $I_o = 80\%$ of $I_{o, max}$ ; $T_c = 40\text{ }^\circ\text{C}$ )		1,460,000		hours
Weight	—	—	3.5(99)	oz.(g)

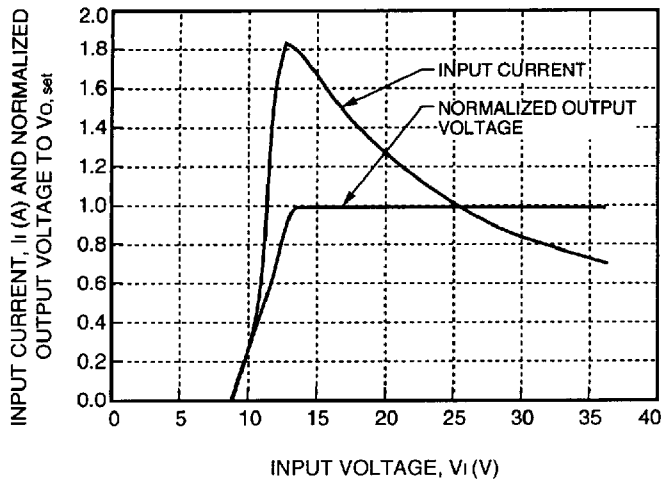
## Feature Specifications

Unless otherwise indicated, specifications apply over all operating input voltage, resistive load, and temperature conditions. See Feature Descriptions and Design Considerations for further information.

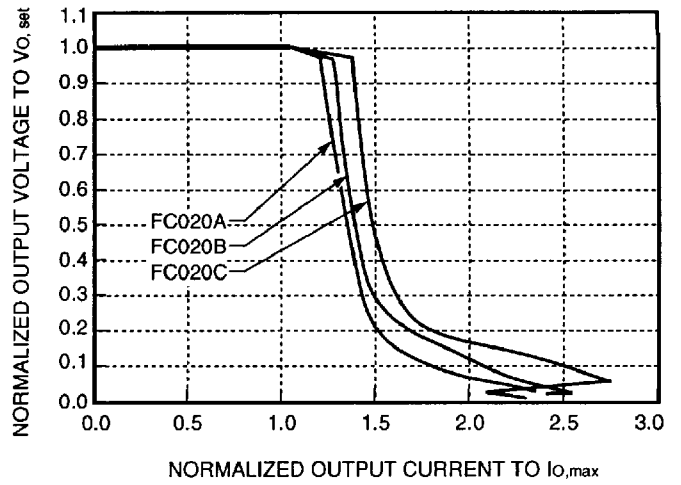
Parameter	Device	Symbol	Min	Typ	Max	Unit
Remote On/Off ( $V_i = 18\text{ V}$ to $36\text{ V}$ ; open collector or equivalent compatible; signal referenced to $V_i(-)$ terminal; see Figure 16 and Feature Descriptions.): Logic Low—Module Off Logic High—Module On Module Specifications: On/Off Current—Logic Low On/Off Voltage: Logic Low Logic High ( $I_{on/off} = 0$ ) Open Collector Switch Specifications: Leakage Current During Logic High ( $V_{on/off} = 11\text{ V}$ ) Output Low Voltage During Logic Low ( $I_{on/off} = 500\text{ }\mu\text{A}$ ) Turn-on Time (See Figure 11.) ( $I_o = 80\%$ of $I_{o, max}$ ; $V_o$ within $\pm 1\%$ of steady state) Output Voltage Overshoot (See Figure 11.)	all	$I_{on/off}$	—	—	500	$\mu\text{A}$
	all	$V_{on/off}$	0	—	0.4	V
	all	$V_{on/off}$	—	—	11	V
	all	$I_{on/off}$	—	—	10	$\mu\text{A}$
	all	$V_{on/off}$	—	—	0.4	V
	all	—	—	1.5	2.5	ms
	all	—	—	—	5	%
Output Voltage Sense Range	all	—	—	—	0.5	V
Output Voltage Set Point Adjustment Range	all	—	—	—	0.25	V
Parallel Operation Load Sharing (Current deviation of the unit with respect to the average load current distributed among other units.)	FC020A	—	—	0.2	0.6	A
	FC020B, C	—	—	0.2	0.4	A
Output Overvoltage Clamp	FC020A	$V_{O, clamp}$	5.4	—	7.0	V
	FC020B	$V_{O, clamp}$	13	—	16.0	V
	FC020C	$V_{O, clamp}$	16	—	20.0	V
Synchronization (50% duty cycle): Synchronization Voltage Required Source Current Synchronization Frequency	all	—	4.85	—	5.1	V
	all	—	—	—	6.0	mA
	all	—	325.0	—	345	kHz
Required Output Load for Synchronization	FC020A	$I_o$	0.4	—	—	A
	FC020B, C	$I_o$	0.15	—	—	A

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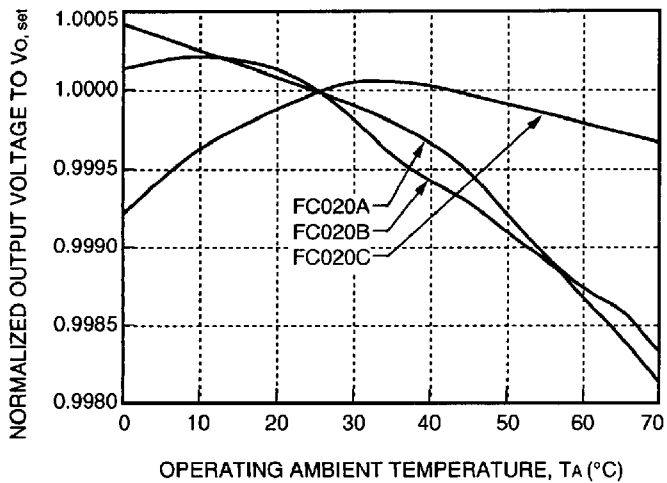
**Characteristic Curves**



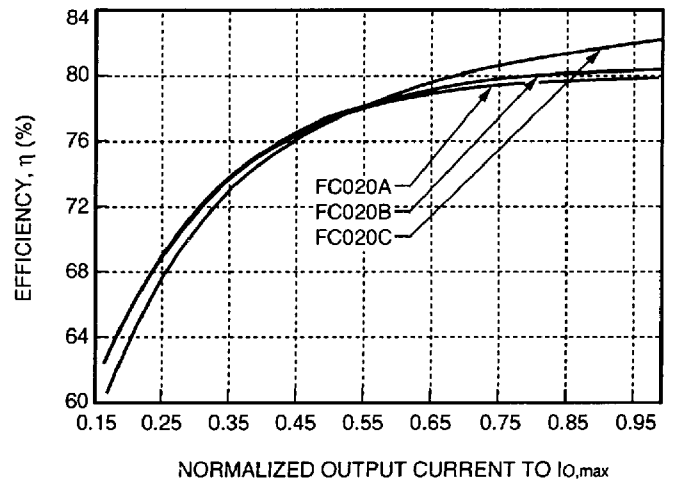
**Figure 1. FC020-Series Typical Input Characteristic with a Resistive Load of  $I_o = I_{o,max}$ ;  $T_A = 25\text{ }^\circ\text{C}$  (Arrows indicate hysteresis)**



**Figure 3. FC020-Series Normalized Output Voltage vs. Normalized Output Current at  $V_i = 28\text{ V}$  and  $T_A = 25\text{ }^\circ\text{C}$**



**Figure 2. FC020-Series Normalized Output Voltage Variation Over Ambient Temperature Range at  $I_o = I_{o,max}$  and  $V_i = 28\text{ V}$**



**Figure 4. FC020-Series Efficiency vs. Normalized Output Current at  $V_i = 28\text{ V}$  and  $T_A = 25\text{ }^\circ\text{C}$**

Characteristic Curves (continued)

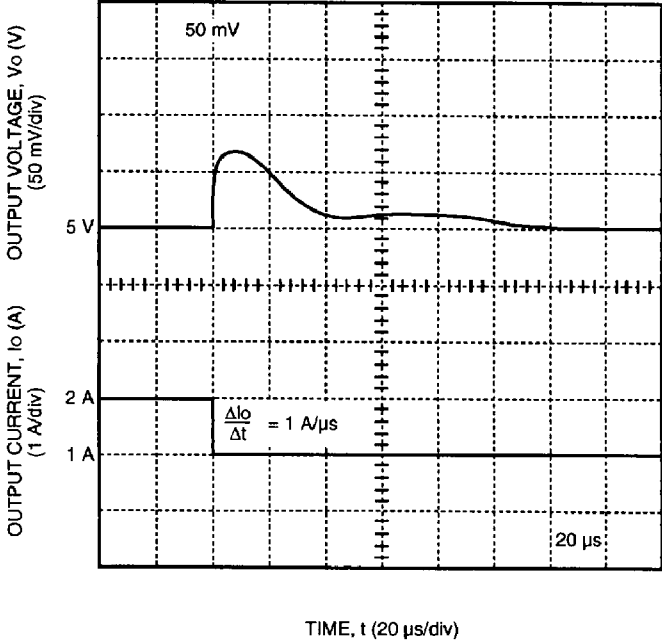


Figure 5. FC020A Typical Output Voltage for a Step Load Change from 50% to 25%

8-240 (C)

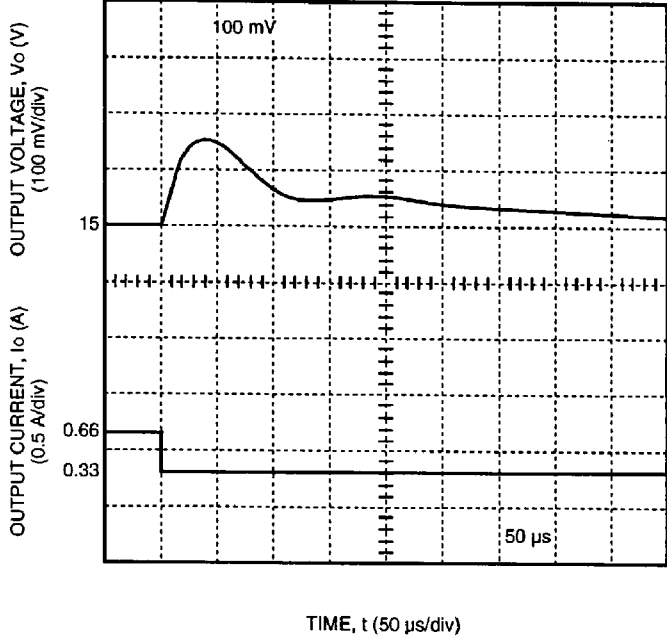


Figure 7. FC020C Typical Output Voltage for a Step Load Change from 50% to 25%

8-1041 (C)

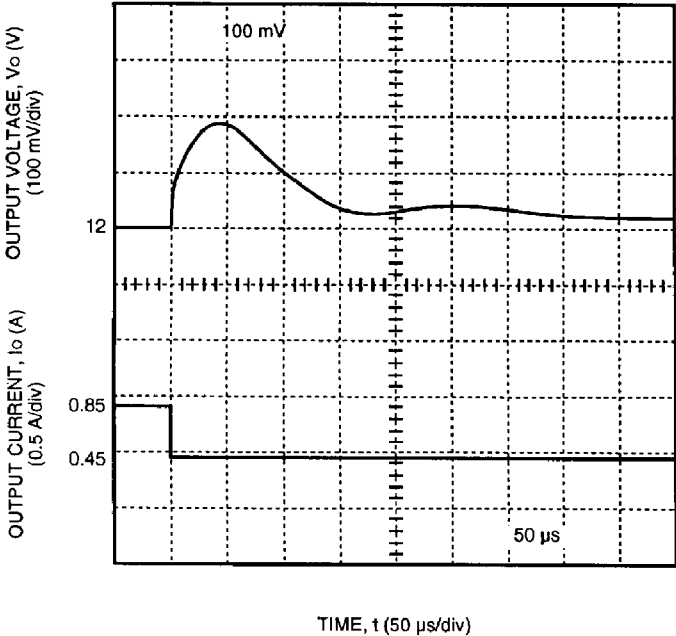


Figure 6. FC020B Typical Output Voltage for a Step Load Change from 50% to 25%

8-1040 (C)

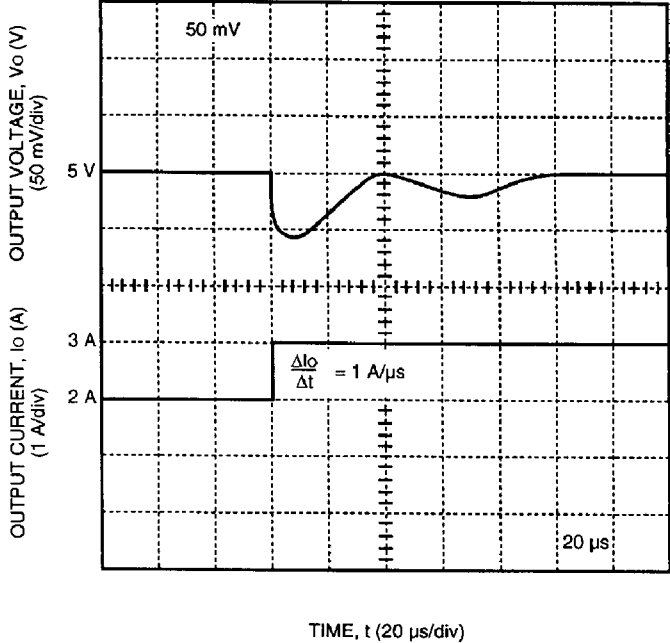
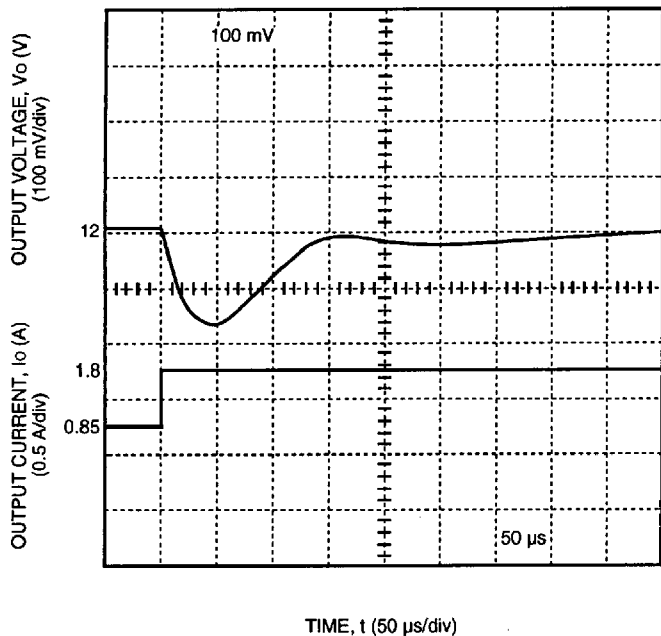


Figure 8. FC020A Typical Output Voltage for a Step Load Change from 50% to 75%

8-239 (C)

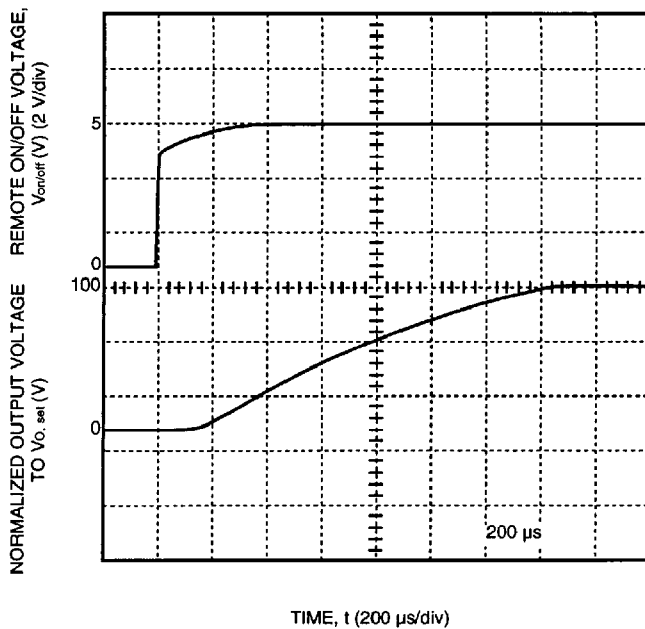
**FC020-Series Power Modules:  
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**Characteristic Curves** (continued)



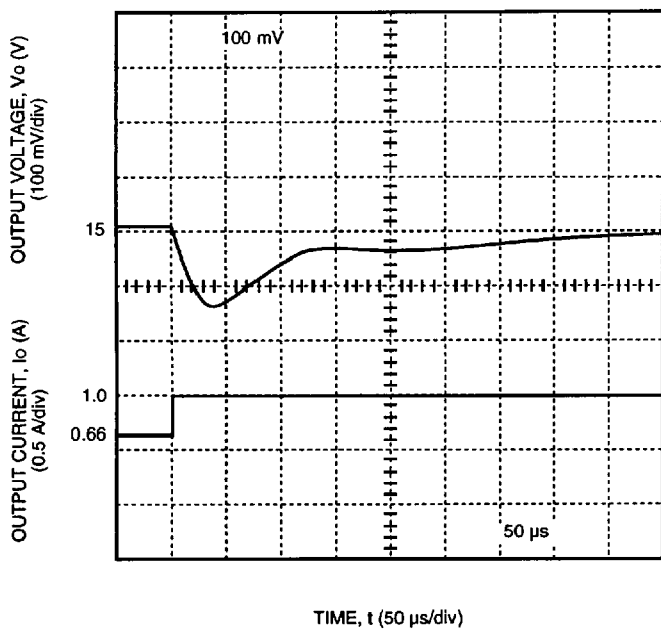
**Figure 9. FC020B Typical Output Voltage for a Step Load Change from 50% to 75%**

8-1043 (C)



**Figure 11. FC020-Series Typical Output Voltage Start-Up at  $V_i = 28\text{ V}$ ,  $I_o = 80\%$  of  $I_{o, \max}$ ,  $T_A = 25\text{ }^\circ\text{C}$**

8-1045 (C)

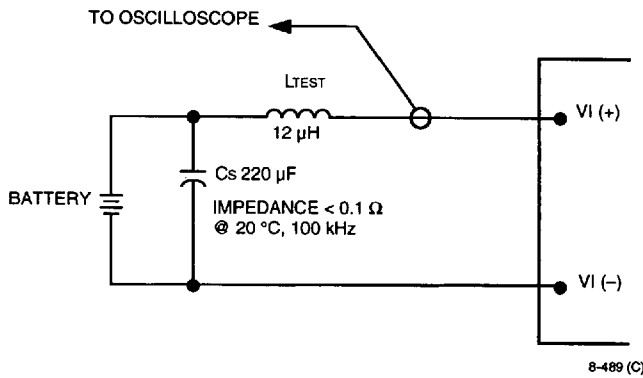


**Figure 10. FC020C Typical Output Voltage for a Step Load Change from 50% to 75%**

8-1044 (C)

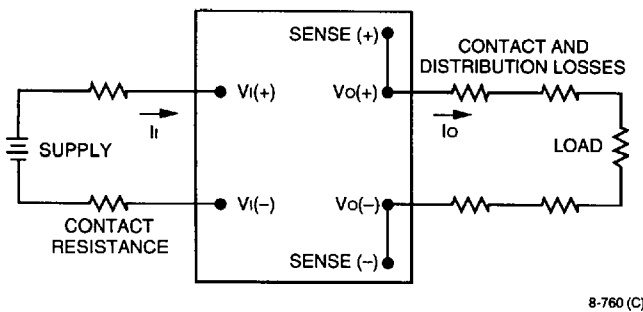


## Test Configurations



Note: Input reflected-ripple current is measured with a simulated source impedance of 12  $\mu$ H. Capacitor Cs offsets possible battery impedance. Current is measured at the input of the module.

**Figure 12. Input Reflected-Ripple Test Setup**



Note: All measurements are taken at the module terminals. When socketing, place Kelvin connections at module terminals to avoid measurement errors due to socket contact resistance.

$$\eta = \left( \frac{[V_{O(+)} - V_{O(-)}] I_o}{[V_{I(+)} - V_{I(-)}] I_i} \right) \times 100$$

**Figure 13. Output Voltage and Efficiency Measurement Test Setup**

## Design Considerations

### Input Source Impedance

The power module should be connected to a low ac-impedance input source. Highly inductive source impedances can affect the stability of the power module. A 33  $\mu$ F electrolytic capacitor (ESR < 0.7  $\Omega$  at 100 kHz) mounted close to the power module helps ensure stability of the unit.

### Safety Considerations

For safety agency approval of the system in which the power module is used, the power module must be installed in compliance with the spacing and separation requirements of the end-use safety agency standard, i.e., UL-1950, CSA 22.2-950, EN 60 950.

For the converter output to be considered meeting the requirements of safety extra low voltage (SELV), one of the following must be true of the dc input:

- All inputs are SELV and floating with the output also floating.
- All inputs are SELV and grounded with the output also grounded.
- Any non-SELV input must be provided with reinforced insulation from any other hazardous voltages, including the ac mains, and must have an SELV reliability test performed on it in combination with the converters.

The power module has extra low voltage (ELV) outputs when all inputs are ELV.

The input to these power units are to be provided with a maximum 5 A normal blown fuse in the ungrounded lead.

## Feature Descriptions

### Output Overvoltage Clamp

The output overvoltage clamp consists of control circuitry, which is independent of the primary regulation loop, that monitors the voltage on the output terminals. The control loop of the clamp has a higher voltage set point than the primary loop (see Feature Specifications table). This provides a redundant voltage-control that reduces the risk of output overvoltage.

### Current Limit

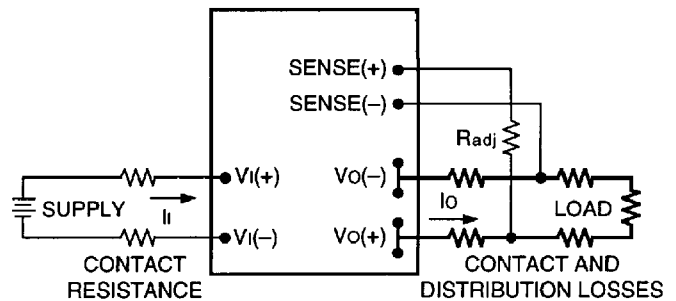
To provide protection in a fault (output overload) condition, the unit is equipped with internal current-limiting circuitry and can endure current limiting for an unlimited duration. At the point of current-limit inception, the unit shifts from voltage control to current control. If the output voltage is pulled very low during a severe fault, the current-limit circuit can exhibit either foldback or tailout characteristics (output-current decrease or increase). The unit operates normally once the output current is brought back into its specified range.

### Remote Sense

Remote sense minimizes the effects of distribution losses by regulating the voltage at the remote-sense connections. The output voltage specifications refer to measurements taken at remote-sense connections. The voltage between the remote-sense pins and the output terminals must not exceed the output voltage sense range given in the Feature Specifications table, i.e.:

$$\left[ V_{O(+)} - V_{O(-)} \right] - \left[ \text{SENSE (+)} - \text{SENSE (-)} \right] \leq 0.5 \text{ V}$$

See Figure 14.



8-710.a (C)

**Figure 14. Effective Circuit Configuration for Single-Module Remote Sense Operation**

### Parallel Operation

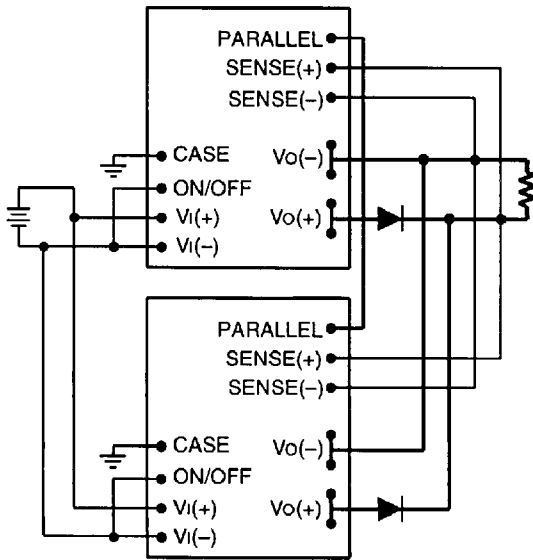
For either redundant operation or additional power requirements, the power modules can be configured for parallel operation with forced load sharing (see Figure 15). For a typical redundant configuration, Schottky diodes or an equivalent should be used to protect against short-circuit conditions. Because of the remote sense, the forward-voltage drops across the Schottky diodes do not affect the set point of the voltage applied to the load. For additional power requirements, where multiple units are used to develop combined power in excess of the rated maximum, the Schottky diodes are not needed.

To implement forced load sharing, the following connections must be made, and good layout techniques should be observed for noise immunity:

- The parallel pins of all units must be connected together. The paths of these connections should be as direct as possible.
- All remote-sense pins should be connected to the power bus at the same point, i.e., connect all remote-sense (+) pins to the (+) side of the power bus at the same point and all remote-sense (-) pins to the (-) side of the power bus at the same point. Close proximity and directness are necessary for good noise immunity.

**Feature Descriptions** (continued)

**Parallel Operation** (continued)



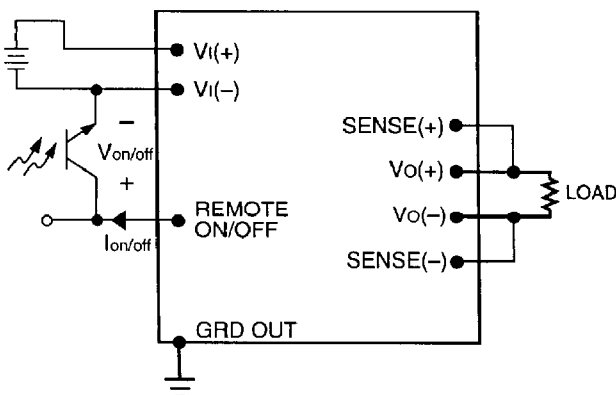
8-581 (C)

**Figure 15. Wiring Configuration for Redundant Parallel Operation**

**Remote On/Off**

To turn the power module on and off, the user must supply a switch to control the voltage between the on/off terminal and the  $V_{i(-)}$  terminal ( $V_{on/off}$ ). The switch can be an open collector or equivalent (see Figure 16). A logic low is  $V_{on/off} = 0$  V to 1.2 V, during which the module is off. The maximum  $I_{on/off}$  during a logic low is 1 mA. The switch should maintain a logic low voltage while sinking 1 mA.

During a logic high, the maximum  $V_{on/off}$  generated by the power module is 6 V. The maximum allowable leakage current of the switch at  $V_{on/off} = 6$  V is 50  $\mu$ A.

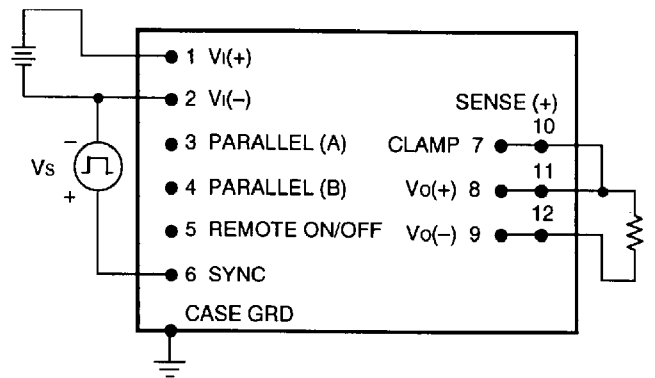


8-720 (C)

**Figure 16. Remote On/Off Implementation**

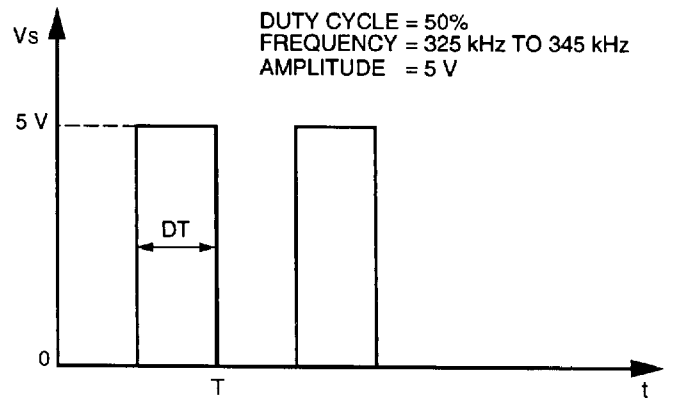
**Synchronization**

The power module must be synchronized to an external clock for applications where synchronization is required. A square-wave voltage capable of delivering 6 mA must be placed between terminals 2 and 6 (see Figure 17).



8-1144 (C)

**Figure 17. Connection Diagram**



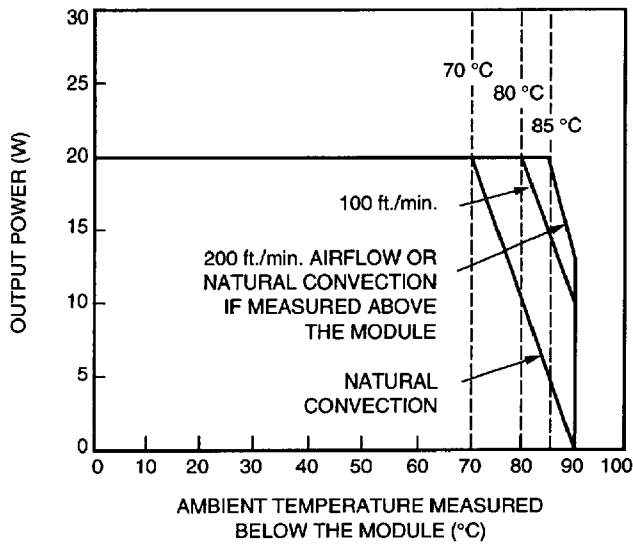
8-097 (C)

**Figure 18. Synchronization Waveform**

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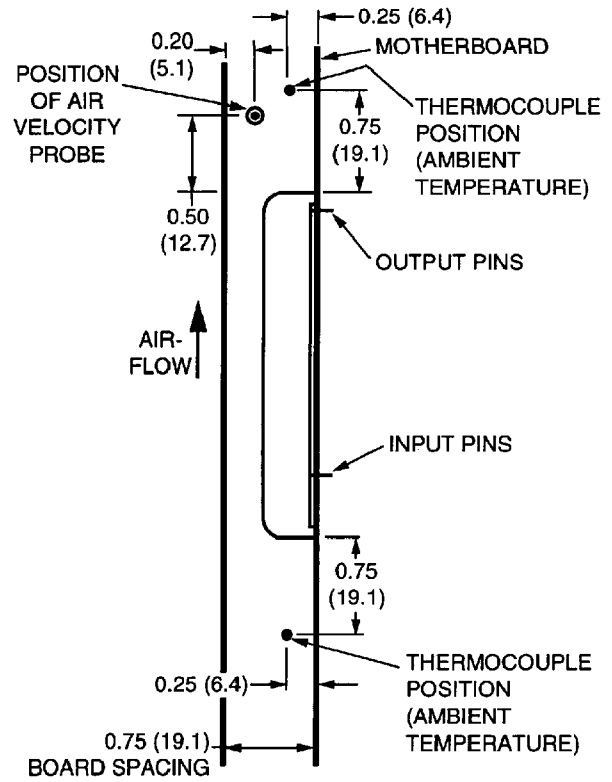
**Thermal Management**

Figure 19 shows the output derating curves for units mounted vertically on boards spaced 3/4 in. apart with natural convection, 100 ft./min., and 200 ft./min. forced-air conditions. Air velocity is measured 0.5 in. above the unit and the adjacent board (see Figure 20). To ensure proper operation in other environments, the user must not allow the case temperature to exceed 100 °C. Refer to Figure 21 for the location of the case temperature measurements.



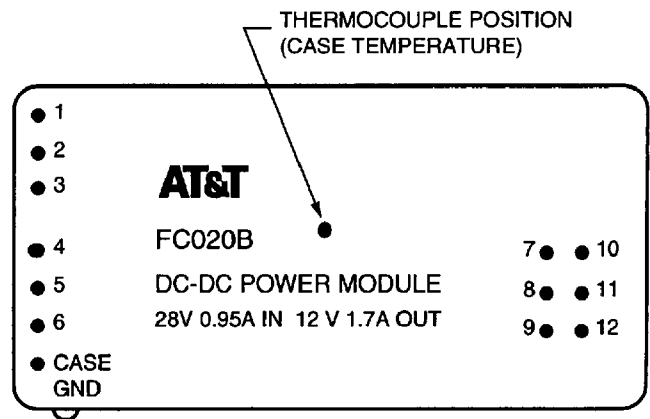
**Figure 19. Thermal Derating Curves for FC020A Power Module**

8-1145 (C)



8-607 (C)

**Figure 20. Power Module Orientation in Test Chamber**



8-608 (C)

**Figure 21. Thermocouple Location**

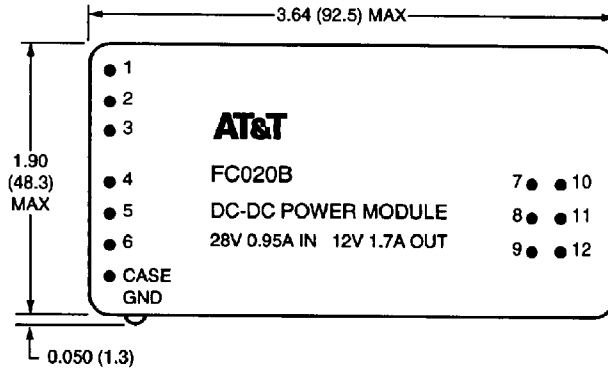
## Outline Diagram

Dimensions are in inches and (millimeters).

Copper paths must not be routed beneath the power module standoffs.

Tolerances: x.xx ± 0.03 in. (0.76 mm), x.xxx ± 0.015 in. (0.38 mm)

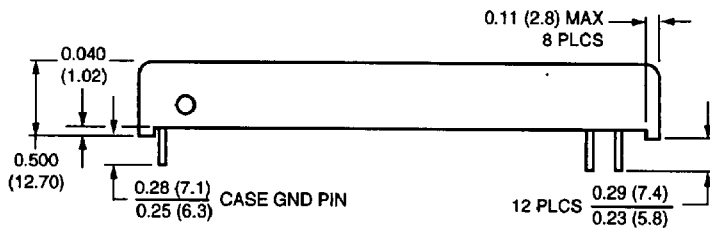
### Top View



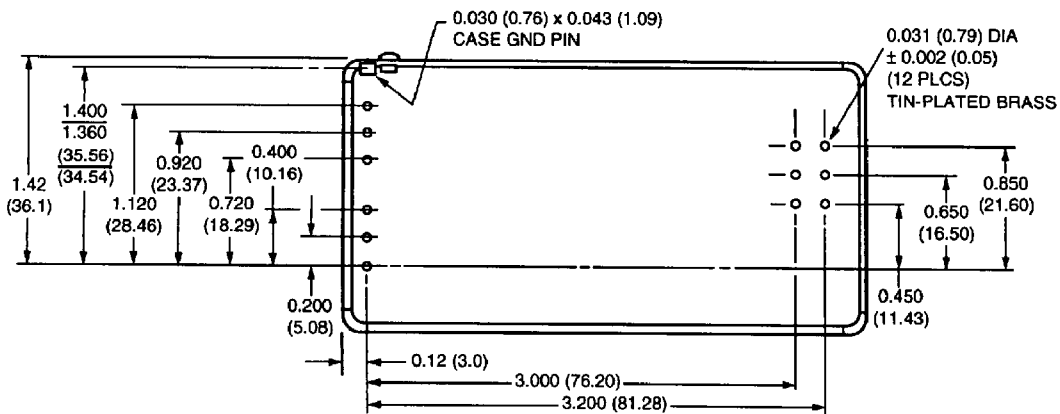
### Pin Descriptions

Pin	Description
1	Vi (+)
2	Vi (-)
3	Parallel (A)
4	Parallel (B)
5	Remote On/Off
6	Synchronization
7	Clamp
8	Vo (+)
9	Vo (-)
10	Remote Sense (+)
11	Vo (+)
12	Vo (-)

### Side View



### Bottom View

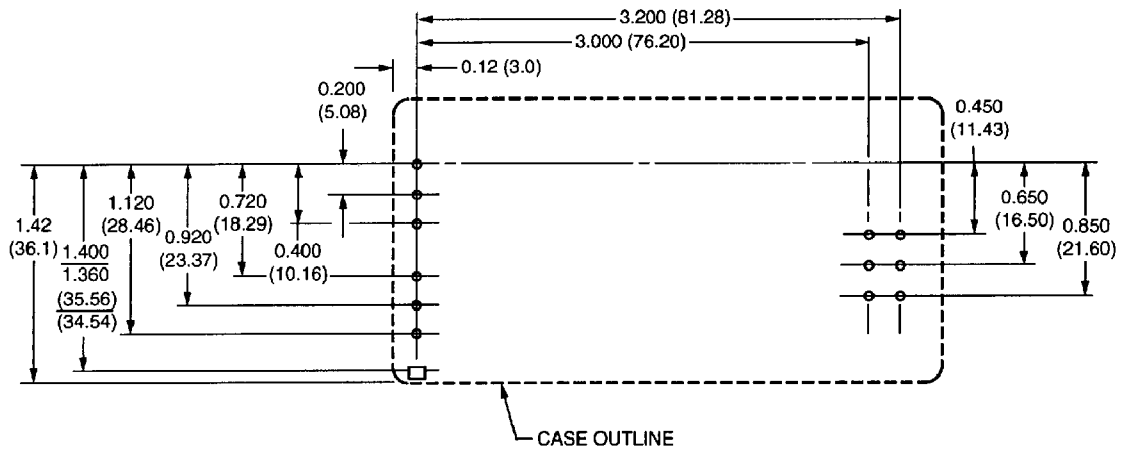


# FC020-Series Power Modules: dc-dc Converters; 28 Vdc Input, 20 W

## Recommended Hole Pattern

Component-side footprint.

Dimensions are in inches and (millimeters).



## **Ordering Information**

For assistance in ordering options, please contact your AT&T Account Manager or Application Engineer.

<b>Input Voltage</b>	<b>Output Voltage</b>	<b>Output Power</b>	<b>Device Code</b>	<b>Comcode</b>
18 V—36 V	5 V	20 W	FC020A	105558191
18 V—36 V	12 V	20 W	FC020B	105558209
18 V—36 V	15 V	20 W	FC020C	105558225