Data Sheet
August 1996

microelectronics group

Lucent Technologies
Bell Labs Innovations

MK010-Series Power Modules: 36 Vdc to 75 Vdc Input

The MK010-Series Power Modules are encapsulated in aluminum cases measuring 2.00 in. long, 1.69 in. wide, and 0.50 in. high.

Features

- Small size: 2.00 in. x 1.69 in. x 0.50 in.
- Metal case with ground pin
- Wide input voltage range: 36 Vdc to 75 Vdc
- Output overvoltage clamp
- Input undervoltage lockout
- Input-to-output isolation
- No external filtering required
- Operating ambient temperature range: –40 °C to +85 °C
- Remote on/off
- Within FCC and VDE Class A radiated limits
- High reliability
- *UL** recognized; VDE and *CSA*† certified
- CE mark meets 73/23/EEC and 93/68/EEC directives‡

Options

- Higher accuracy output voltage set point
- Plastic case (MW010-Series)
- Long pins (0.230 in. ± 0.020 in.)

Applications

- Telecommunications
- Distributed power architecture

* *UL* is a registered trademark of Underwriters Laboratories, Inc.
† *CSA* is a registered trademark of the Canadian Standards Association.
‡ This product is intended for integration into end-use equipment. All the required procedures for CE marking of end-use equipment should be followed. (The CE mark is placed on selected products.)

Description

The MK010A1, N1, E4, D1, and F1 Power Modules are dc-dc converters that operate over a wide input voltage range of 36 Vdc to 75 Vdc and provide precisely regulated dc outputs of 5.0 V, 5.2 V, 2.32 V, 2.0 V, and 3.3 V respectively. The outputs are fully isolated from the inputs, allowing versatile polarity configurations and grounding connections. The MK010A1 and N1 have maximum power ratings of 10 W at a typical full-load efficiency of 80%. The MK010E4, D1, and F1 have maximum output current ratings of 2.0 A at a typical full-load efficiency of 69%. The remote on/off allows the modules to be controlled with an open-collector logic signal.

The modules are encapsulated in aluminum cases with ground pins. In a natural convection environment, the modules are rated to full load at 85 °C with no heat sinking or external filtering.

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 Continuous Transient (2 ms)	 V_I V_I	 — —	 80 100	 V V
I/O Isolation Voltage dc Transient (1 minute)	 — —	 — —	 500 850	 V V
Operating Ambient Temperature (natural convection, derate 0.1 W/°C beyond 70 °C; see Design Considerations section.)	T_A	–40	85	°C
Storage Temperature	T_{stg}	–40	100	°C

Electrical Specifications

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

Table 1. Input Specifications

Parameter	Device	Symbol	Min	Typ	Max	Unit
Operating Input Voltage	all	V_I	36	48	75	Vdc
Maximum Input Current (V_I = 0 V to 75 V; I_O = $I_{O, max}$; T_A = 25 °C): (See Figures 1, 2, and 3.)	MK010A1, N1 MK010E4, D1 MK010F1	$I_{I, max}$	—	—	625 370 470	mA mA mA
Inrush Transient	all	i^2t	—	0.3	1.0	A^2s
Input Reflected-ripple Current, Peak-to-peak (5 Hz to 20 MHz, 12 µH source impedance, T_A = 25 °C) (See Figure 12 and Design Considerations section.)	MK010A1, N1 MK010E4, D1 F1	— —	— —	25 10	— —	mA p-p mA p-p
Input Ripple Rejection (120 Hz)	all	—	—	50	—	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 *Underwriters Laboratories Conditions of Acceptability* requires a normal-blow, dc fuse with a maximum rating of 5 A in series with the input. 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. See Figure 13.)	MK010A1	V_o	4.85	—	5.15	Vdc
	MK010N1	V_o	5.05	—	5.35	Vdc
	MK010E4	V_o	2.20	—	2.44	Vdc
	MK010D1	V_o	1.88	—	2.12	Vdc
	MK010F1	V_o	3.11	—	3.46	Vdc
Output Voltage Set Point (V_I = 48 V; I_o = $I_{o,max}$; T_A = 25 °C)	MK010A1	$V_{o,set}$	4.90	5.0	5.10	Vdc
	MK010N1	$V_{o,set}$	5.10	5.2	5.30	Vdc
	MK010E4	$V_{o,set}$	2.25	2.32	2.39	Vdc
	MK010D1	$V_{o,set}$	1.94	2.00	2.06	Vdc
	MK010F1	$V_{o,set}$	3.20	3.30	3.40	Vdc
Output Regulation:						
Line (V_I = 36 Vdc to 75 Vdc)	MK010A1, N1	—	—	0.02	0.10	%
	MK010E4, D1, F1	—	—	0.05	0.3	%
Load (I_o = $I_{o,min}$ to $I_{o,max}$)	MK010A1, N1	—	—	0.05	0.15	%
	MK010E4, D1, F1	—	—	0.1	0.7	%
Temperature (T_A = –40 °C to +85 °C)	MK010A1, N1	—	—	15	70	mV
	MK010E4, D1, F1	—	—	10	50	mV
Output Ripple and Noise Voltage: (See Figure 14.):						
RMS	MK010A1, N1	—	—	—	10	mVrms
	MK010E4, D1, F1	—	—	—	12	mVrms
Peak-to-peak (5 Hz to 20 MHz)	MK010A1, N1	—	—	—	70	mVp-p
	MK010E4, D1, F1	—	—	—	50	mVp-p
Output Current: (At less than minimum load, the converter may exceed its output ripple specification.)	MK010N1	I_o	0.1	—	1.92	A
	all others	I_o	0.1	—	2.0	A
Output Current-limit Inception (V_o = 90%, $V_{o,nom}$) (See Figures 4 and 5.)	MK010A1	—	—	3.7	5.5	A
	MK010N1	—	—	3.6	5.5	A
	MK010E4, D1, F1	—	—	3.7	5.8	A
Output Current Limit (V_o = 1.0 V)	all	—	—	—	6.3	A
Output Short-circuit Current (V_o = 250 mV; see Figures 4 and 5.)	MK010A1, N1	—	—	3.5	7.0	A
	MK010E4, D1, F1	—	—	4.3	6.9	A
Efficiency (See Figure 13.) (V_I = 48 V, I_o = $I_{o,max}$, T_A = 25 °C) See also Figures 6, 7, and 8.	MK010A1, N1	η	77	80	—	%
	MK010E4, D1, MK010F1	η	66	69	—	%
		η	69	72	—	%

Electrical Specifications (continued)

Table 2. Output Specifications (continued)

Parameter	Min	Typ	Max	Unit
Dynamic Response ($\Delta Io/\Delta t$ = 1 A/10 µs, V_I = 48 V, T_A = 25 °C): Load Change from Io = 50% to 75% of $Io_{,max}$				
Peak Deviation	—	140	—	mV
Settling Time (See Figure 9.) (Vo < 10% of peak deviation)	—	3	—	ms
Load Change from Io = 50% to 25% of $Io_{,max}$				
Peak Deviation	—	140	—	mV
Settling Time (See Figure 10.) (Vo < 10% of peak deviation)	—	3	—	ms

Table 3. Isolation Specifications

Specifications apply to all devices.

Parameter	Min	Typ	Max	Unit
Isolation Capacitance	—	1200	—	pF
Isolation Resistance	10	—	—	MΩ

General Specifications

Parameter	Device	Min	Typ	Max	Unit
Calculated MTBF (80% of full load; Tc = 40 °C)	MK010A1, N1 MK010E4, D1, F1		2,500,000 4,000,000		hours hours
Weight	all	—	—	1.8 (51)	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 sections for further information.

Parameter	Device	Symbol	Min	Typ	Max	Unit
Remote On/Off (0 V < V_I < 75 V; open collector or equivalent compatible; signal referenced to V_I(–) terminal; see Figure 15 and Feature Descriptions.): Logic Low — Module On Logic High — Module Off						
Module Specifications:						
On/Off Current — Logic Low	all	$I_{on/off}$	—	—	1.0	mA
On/Off Voltage:						
Logic Low	all	$V_{on/off}$	0	—	1.2	V
Logic High ($I_{on/off}$ = 0)	all	$V_{on/off}$	—	—	18	V
Open Collector Switch Specifications:						
Leakage Current During Logic High ($V_{on/off}$ = 18 V)	all	$I_{on/off}$	—	—	50	µA
Output Low Voltage During Logic Low ($V_{on/off}$ = 1 mA)	all	$V_{on/off}$	—	—	1.2	V
Turn-on Time; see Figure 11.	MK010A1, N1	—	—	5	—	ms
(@ 80% of full load, T_A = 25 °C,	MK010E4,	—	—	1	—	ms
V_O within ±1% of steady state)	D1, F1					
Output Overvoltage Clamp	MK010A1, N1	$V_{O, clamp}$	5.4	—	7.0	V
	MK010E4, D1	$V_{O, clamp}$	2.5	—	5.1	V
	MK010F1	$V_{O, clamp}$	3.5	—	5.4	V
Input Undervoltage Lockout:						
Module On	all	—	—	28	36	V
Module Off	all	—	20	24	—	V

Characteristic Curves

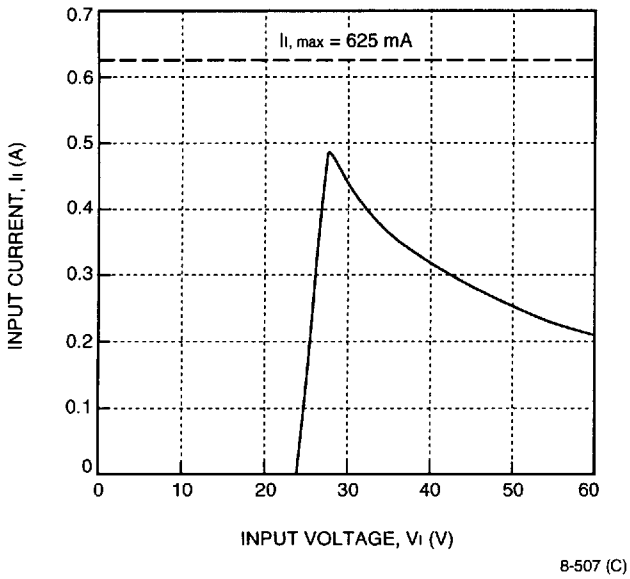


Figure 1. MK010, N1 Typical Input Characteristic; Io = Io, max; TA = 25 °C

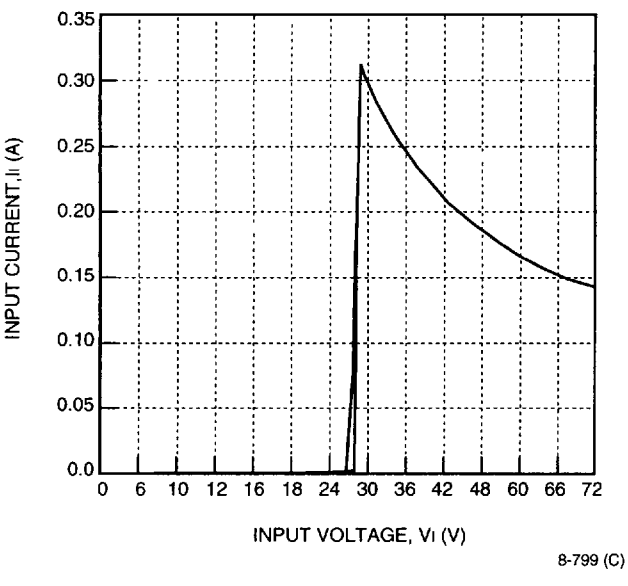


Figure 2. MK010F1 Typical Input Characteristic; Io = Io, max; TA = 25 °C

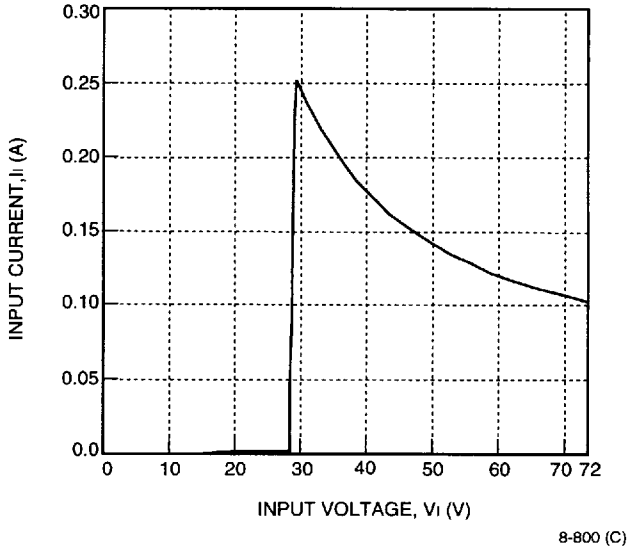


Figure 3. MK010D1, E4 Typical Input Characteristic; Io = Io, max; TA = 25 °C

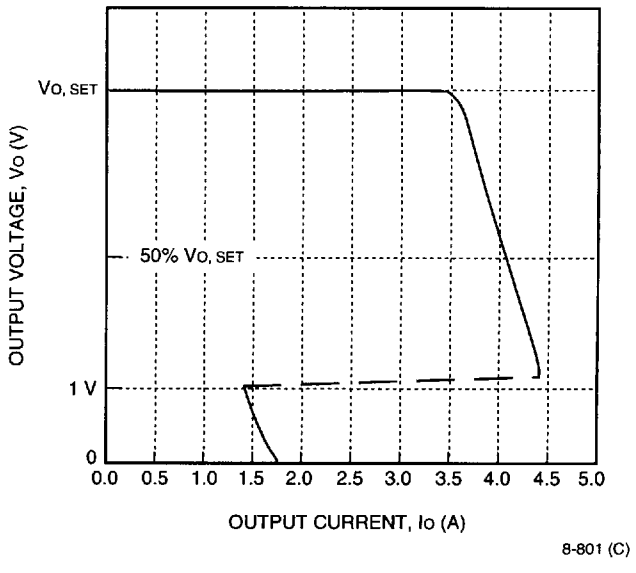


Figure 4. MK010A1, N4 Typical Output Characteristic; VI = 48 V; TA = 25 °C

Characteristic Curves (continued)

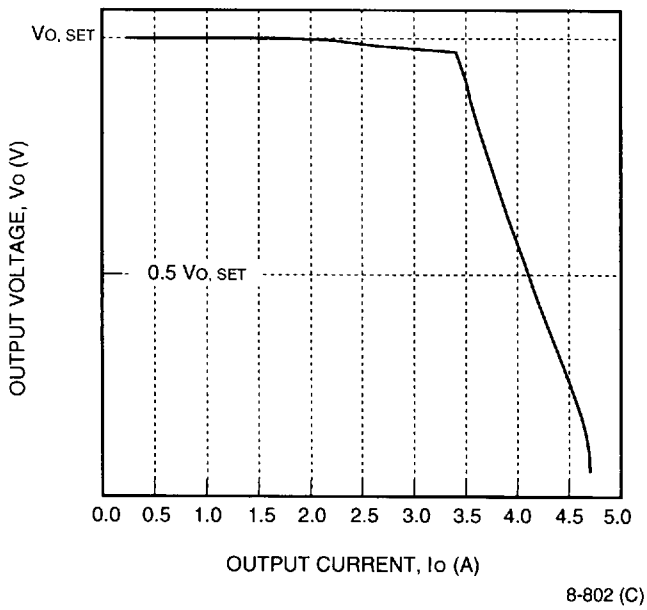


Figure 5. MK010D1, F1, E4 Typical Output Characteristic; V_I = 48 V; T_A = 25 °C

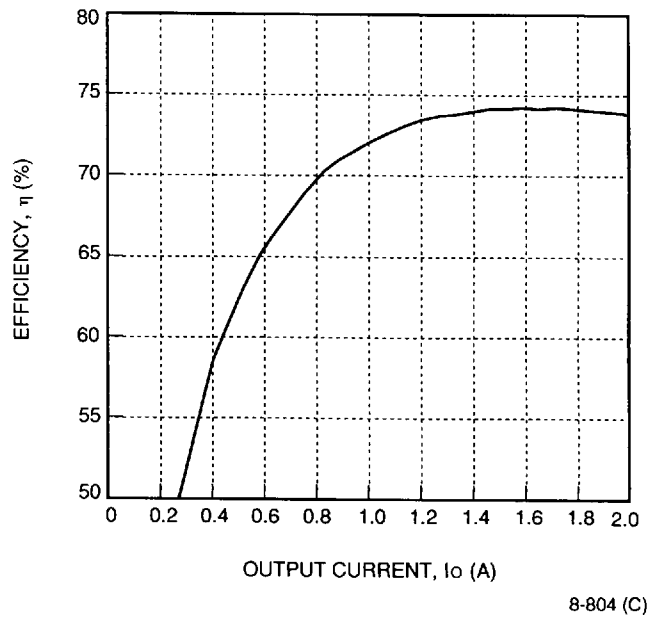


Figure 7. MK010F1, Typical Converter Efficiency as a Function of Output Current; V_I = 48 V; T_A = 25 °C

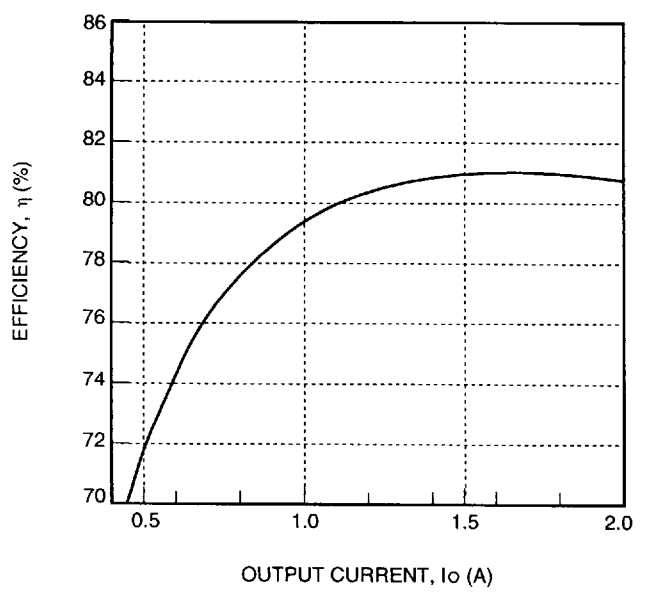


Figure 6. MK010A1, N1 Typical Converter Efficiency as a Function of Output Current; V_I = 48 V; T_A = 25 °C

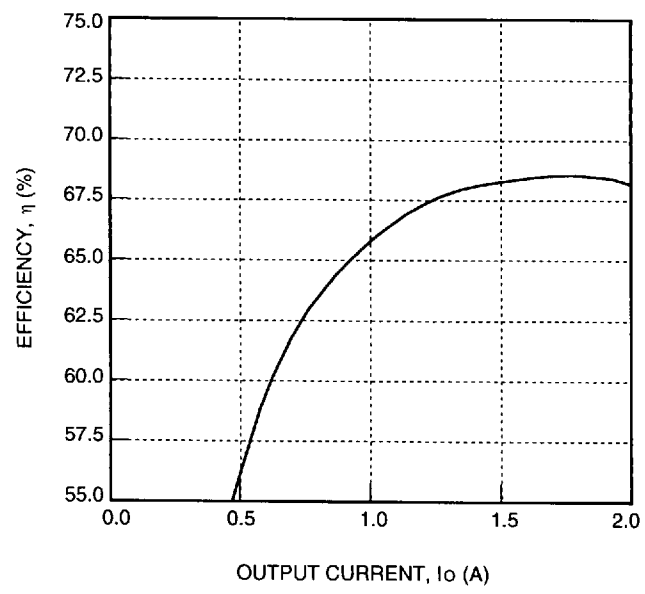


Figure 8. MK010D1, E4 Typical Converter Efficiency as a Function of Output Current; V_I = 48 V; T_A = 25 °C

Characteristic Curves (continued)

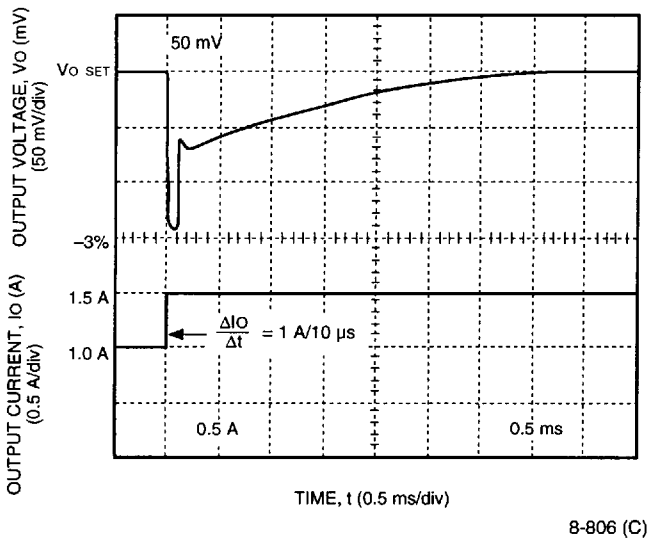


Figure 9. MK010 Typical Output Voltage Waveform for a Step Load Change from 50% to 75% of $I_{O,max}$; V_I = 48 V; T_A = 25 °C

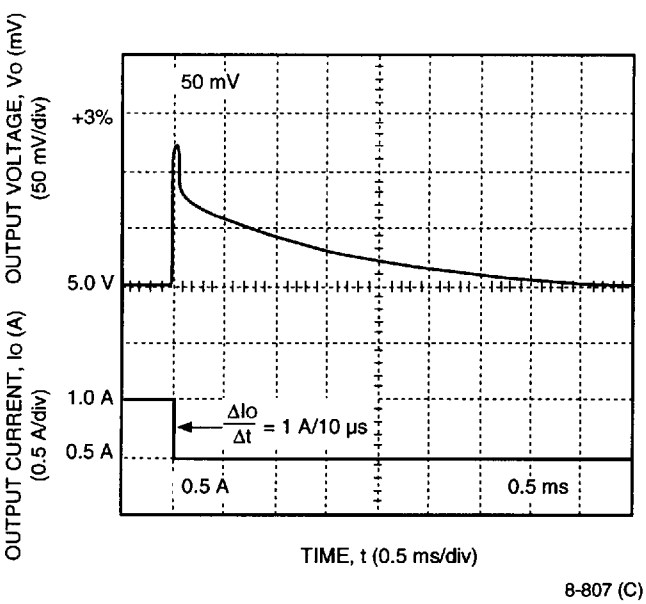


Figure 10. MK010 Typical Output Voltage Waveform for a Step Load Change from 50% to 25% of $I_{O,max}$; V_I = 48 V; T_A = 25 °C

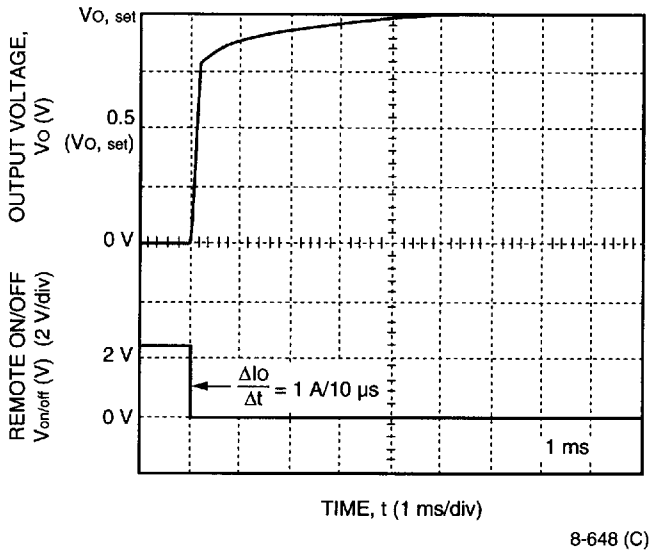
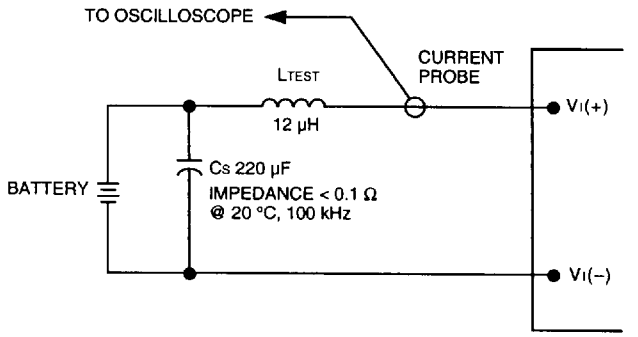


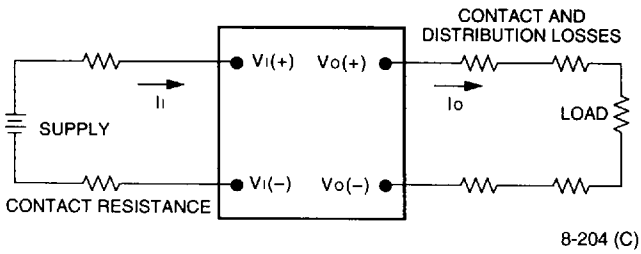
Figure 11. MK010 Typical Output Voltage Start-Up Waveform with Remote On/Off; I_O = 0.8 ($I_{O,max}$); V_I = 48 V; T_A = 25 °C

Test Configurations



Note: Input reflected-ripple current is measured with a simulated source impedance (LTEST) of 12 µH. Capacitor Cs offsets possible battery impedance. Current is measured at the input of the module.

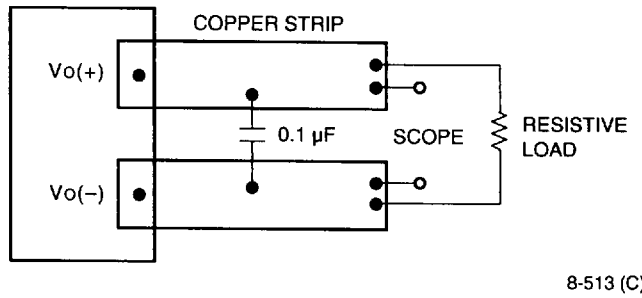
Figure 12. Input Reflected-Ripple Test Setup



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.

$$h = \left(\frac{[VO(+) - (VO(-))]IO}{[VI(+) - (VI(-))]II}\right) \times 100$$

Figure 13. Output Voltage and Efficiency Measurement Test Setup



Note: Use a 0.1 µF ceramic capacitor. Scope measurement should be made using a BNC socket. Position the load between 2 in. and 3 in. from the module.

Figure 14. Output Noise Measurement Test Setup

Feature Descriptions

Output Overvoltage Clamp

The output overvoltage clamp consists of control circuitry, independent of the primary regulation loop, that monitors the voltage on the output terminals. The control loop of the clamp has a set point that is higher than the set point of 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 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.

Feature Descriptions (continued)

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 15). A logic low is $V_{on/off}$ = 0 V to 1.2 V, during which the module is on. 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 18 V. The maximum allowable leakage current of the switch at $V_{on/off}$ = 18 V is 50 µA.

Note: A PWB trace between the on/off terminal and the $V_I(-)$ terminal can be used to override the remote on/off.

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.

Design Considerations

Remote On/Off

Either the user-supplied switch or the override jumper should be wired into the circuit via individual traces not common with the V_I power current path. Connect the switch or jumper at the power module terminals (see Figure 15). Configuring the switch connection in this way prevents noise from falsely triggering the remote on/off. Also, a 0.01 µF ceramic capacitor across remote on/off pin and $V_I(-)$ pin is recommended to eliminate high frequency noise.

Top view.

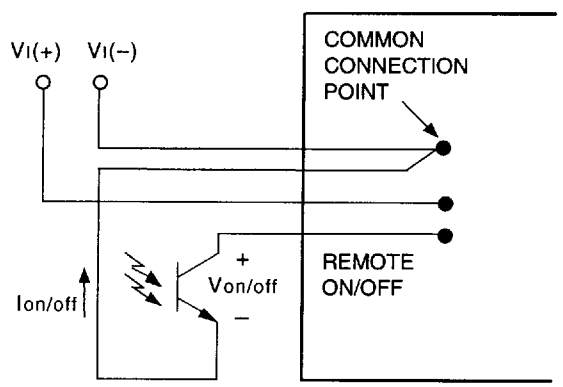


Figure 15. Remote On/Off Wiring Configuration

Input Reflected-Ripple Current

An internal aluminum electrolytic capacitor is used for filtering; therefore, input ripple increases as temperature decreases. (There is approximately two times more ripple at 0 °C than at 25 °C and eight times more ripple at –40 °C than at 25 °C.) The power module functions properly down to –40 °C with no additional filtering. If needed, an external capacitor across the input with an impedance of 0.3 Ω at 100 kHz over the desired temperature range can be added to limit the input ripple current to the typical level given in the Input Specifications table.

Output Voltage Reversal

CAUTION: Applying a reverse voltage across the module output forward biases an internal diode. Attempting to start the module under this condition can damage the module.

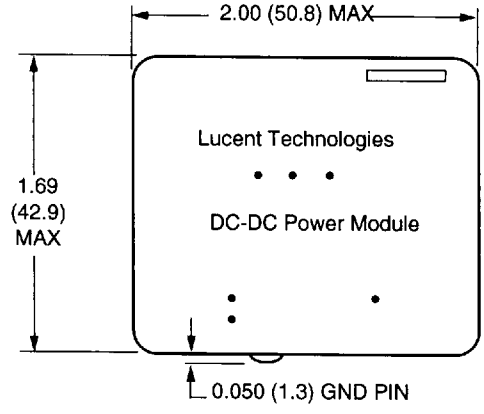
Outline Diagrams

Dimensions are in inches and (millimeters).

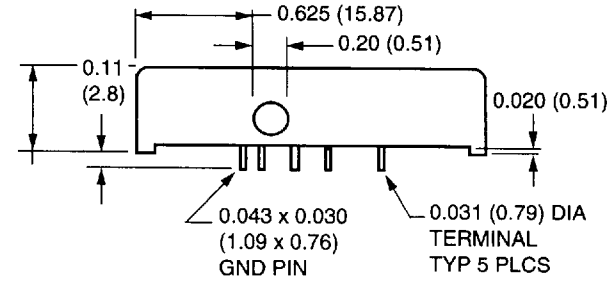
Module tolerances, unless otherwise indicated: x.xx ± 0.02 in. (0.5 mm), x.xxx ± 0.010 in. (0.25 mm).

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

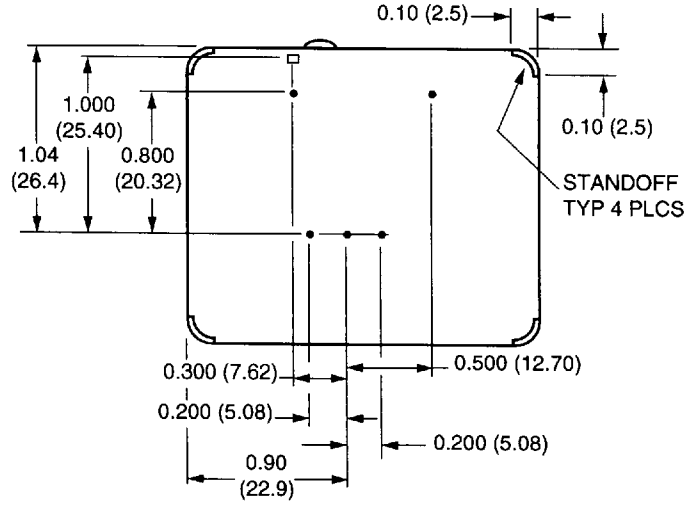
Top View



Side View



Bottom View

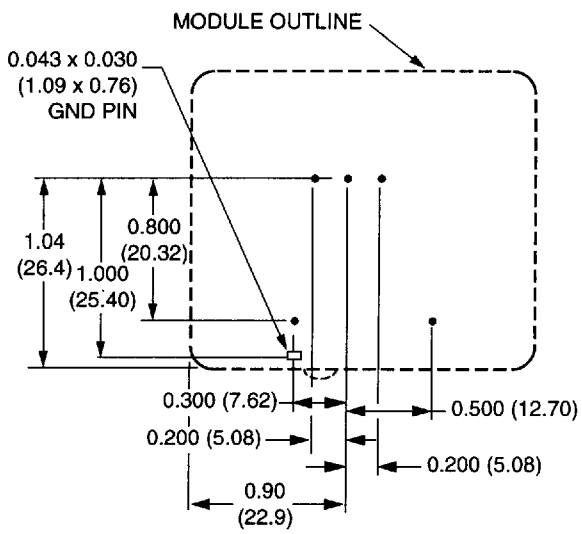


8-602 (C)

Recommended Hole Patterns

Component-side footprint.

Dimensions are in inches and (millimeters).



8-602 (C)

Ordering Information

For assistance in ordering, contact your Microelectronics Group Account Manager.

Power Module Description		Device Code	Comcode
Input Voltage (V)	Output Voltage		
36—75	5.0 V	MK010A1	106224793
36—75	5.2 V	MK010N1	106224785
36—75	2.32 V	MK010E4	106302839
36—75	2.0 V	MK010D1	106741515
36—75	3.3 V	MK010F1	106741523
36 V to 75 V	15.0 V −15.0 V	MK005CL4	106194616

For additional information, contact your Microelectronics Group Account Manager or the following:
U.S.A.: Microelectronics Group, Lucent Technologies Inc., 555 Union Boulevard, Room 30L-15P, Allentown, PA 18103
1-800-372-2447, FAX 610-712-4106 (In CANADA: **1-800-553-2448**, FAX 610-712-4106)
ASIA PACIFIC: Microelectronics Group, Lucent Technologies Singapore Pte. Ltd., 14 Science Park Drive, #03-02A/04 The Maxwell, Singapore 0511
Tel. (65) 778 8833, FAX (65) 777 7495
JAPAN: Microelectronics Group, Lucent Technologies Japan Ltd., 7-18, Higashi-Gotanda 2-chome, Shinagawa-ku, Tokyo 141, Japan
Tel. (81) 3 5421 1600, FAX (81) 3 5421 1700
For data requests in Europe:
MICROELECTRONICS GROUP DATALINE: **Tel. (44) 1734 324 299**, FAX (44) 1734 328 148
For technical inquiries in Europe:
CENTRAL EUROPE: **(49) 89 95086 0** (Munich), NORTHERN EUROPE: **(44) 1344 865 900** (Bracknell UK),
FRANCE: **(33) 1 47 67 47 67** (Paris), SOUTHERN EUROPE: **(39) 2 6601 1800** (Milan) or **(34) 1 807 1700** (Madrid)

August 1996
DS96-049EPS (Replaces DS93-038EPS)