TEN 60 Series

Application Note

DC/DC Converter 18 to 36Vdc or 36 to 75Vdc Input
3.3 to 15Vdc Single Outputs, 60W

E188913

Complete TEN 60 datasheet can be downloaded at:
http://www.tracopower.com/products/ten60.pdf

Features

- Single output current up to 14A
- 60 watts maximum output power
- 2:1 wide input voltage range of 18-36 and 36-75VDC
- Six-sided continuous shield
- Case grounding
- High efficiency up to 90%
- Low profile: 50.8×50.8×10.2 mm (2.00×2.00×0.40 inch)
- Fixed switching frequency
- RoHS directive compliant
- Input to output isolation: 1500Vdc, 1min
- Over-temperature protection
- Input under-voltage protection
- Output over-voltage protection
- Over-current protection, auto-recovery
- Output short circuit protection, auto-recovery
- Remote ON/OFF

Options

- Heat sinks available for extended operation

Applications

- Distributed power architectures
- Workstations
- Computer equipment
- Communications equipment

General Description

The TEN 60 series offer 60 watts output power from a 50.8 × 50.8 × 10.2 mm (2.00 x 2.00 x 0.4 inch) package. This product has a 2:1 wide input voltage range of 18-36VDC and 36-75VDC with an I/O isolation test voltage of 1500Vdc, indefinite short-circuit protection and over-voltage protection, as well as six sided shielding. All models are particularly suited to telecommunications, industrial, mobile telecom and test equipment applications.

Table of Contents

Absolute Maximum Rating				
Parameter	**Model**	**Min**	**Max**	**Unit**
Input Voltage Continuous	TEN 60-24xx TEN 60-48xx		36 75	Vdc
Input Voltage Transient (100ms)	TEN 60-24xx TEN 60-48xx		50 100	Vdc
Input Voltage Variation (Complies With EST300 132 Part 4.4)	All		5	V/ms
Operating Ambient Temperature (With Derating)	All	-40	85	°C
Operating Case Temperature	All		110	°C
Storage Temperature	All	-55	125	°C

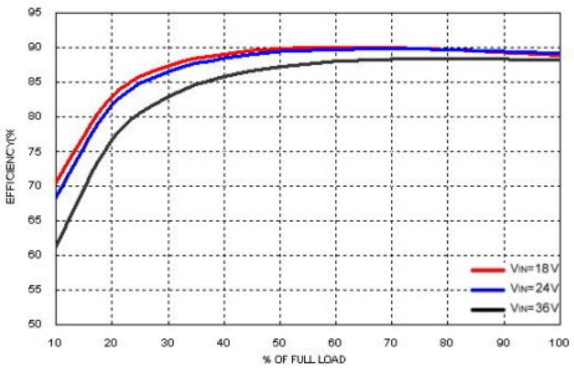
Output Specification					
Parameter	**Model**	**Min**	**Typ**	**Max**	**Unit**
Output Voltage (V_{in} = $V_{in\,nom}$; Full Load ; T_A=25°C)	TEN 60-xx10 TEN 60-xx11 TEN 60-xx12 TEN 60-xx13	3.267 4.95 11.88 14.85	3.3 5 12 15	3.333 5.05 12.12 15.15	Vdc
Voltage Adjustability(See Page 28)	All	-10		+10	%
Output Regulation Line ($V_{in\,min}$ to $V_{in\,max}$ at Full Load) Load (0% to 100% of Full Load)	All	 -0.2 -0.5		 +0.2 +0.5	%
Output Ripple & Noise Peak-to-Peak (5Hz to 20MHz Bandwidth)	TEN 60-xx10 TEN 60-xx11 TEN 60-xx12 TEN 60-xx13			75 75 100 100	mV pk-pk
Temperature Coefficient	All	-0.02		+0.02	%/°C
Output Voltage Overshoot (V_{in} = $V_{in\,min}$ to $V_{in\,max}$; Full Load ; T_A=25°C)	All		0	3	% Vo
Dynamic Load Response (V_{in} = $V_{in\,nom}$; T_A = 25°C) Load Step Change From 75% to 100% or 100 to 75% of Full Load Peak Deviation Setting Time (V_{out} < 10% Peak Deviation)	 All All		 200 250		 mV µs
Output Current	TEN 60-xx10 TEN 60-xx11 TEN 60-xx12 TEN 60-xx13	0 0 0 0		14 12 5 4	A
Output Over Voltage Protection (Voltage Clamped)	TEN 60-xx10 TEN 60-xx11 TEN 60-xx12 TEN 60-xx13		3.9 6.2 15 18		Vdc
Max Capacitive Load	TEN 60-xx10 TEN 60-xx11 TEN 60-xx12 TEN 60-xx13			36'000 20'400 3'550 2'300	µF
Output Over Current Protection	All		150		% FL.
Output Short Circuit Protection	All	Hiccup, Automatics Recovery			

Input Specification					
Parameter	**Model**	**Min**	**Typ**	**Max**	**Unit**
Operating Input Voltage	TEN 60-24xx TEN 60-48xx	18 36	24 48	36 75	Vdc
Input Current (Maximum Value at $V_{in} = V_{in\ nom}$; Full Load)	TEN 60-2410 TEN 60-2411 TEN 60-2412 TEN 60-2413 TEN 60-4810 TEN 60-4811 TEN 60-4812 TEN 60-4813			2264 2941 2907 2907 1132 1453 1453 1453	mA
Input Standby Current (Typical Value at $V_{in} = V_{in\ nom}$; No Load)	TEN 60-2410 TEN 60-2411 TEN 60-2412 TEN 60-2413 TEN 60-4810 TEN 60-4811 TEN 60-4812 TEN 60-4813		100 130 150 150 80 90 100 100		mA
Under Voltage Lockout Turn-on Threshold	TEN 60-24xx TEN 60-48xx		17 34		Vdc
Under Voltage Lockout Turn-off Threshold	TEN 60-24xx TEN 60-48xx		15 32		Vdc
Input Reflected Ripple Current (5 to 20MHz, 12µH Source Impedance)	All		20		mA pk-pk
Start Up Time ($V_{in} = V_{in\ nom}$ and Constant Resistive Load) Power Up Remote ON/OFF	All		 20 20		ms
Remote ON/OFF Control (The ON/OFF pin voltage is referenced to $-V_{IN}$) Positive Logic DC-DC ON(Open) DC-DC OFF(Short)	All	 3 0		 12 1.2	Vdc
Remote Off Input Current	ALL		4		mA
Input Current of Remote Control Pin	ALL	-0.5		1	mA

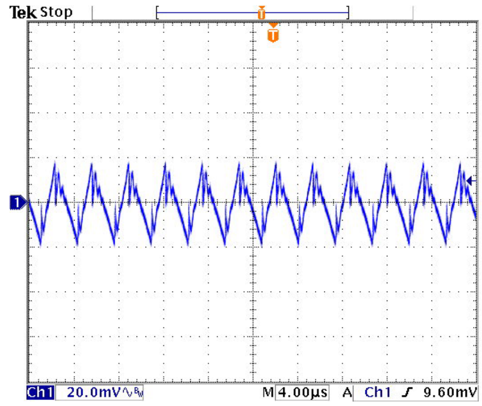
General Specification					
Parameter	**Model**	**Min**	**Typ**	**Max**	**Unit**
Efficiency (V_{in} = $V_{in\,nom}$; Full Load ; T_A=25°C)	TEN 60-2410 TEN 60-2411 TEN 60-2412 TEN 60-2413 TEN 60-4810 TEN 60-4811 TEN 60-4812 TEN 60-4813		89.0 90.0 90.0 90.0 89.0 90.0 90.0 90.0		%
Isolation Voltage (Functional Insulation) Input to Output (60 seconds) Input to Case, Output to Case (60 seconds)	All	1500			Vdc
Isolation Resistance	All	1			GΩ
Isolation Capacitance	All			1500	pF
Switching Frequency	All		300		KHz
Weight	All		60.0		g
MTBF Bellcore TR-NWT-000332, TC=40°C MIL-STD-217F	All		1.093×10^6 1.096×10^5		hours

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2410

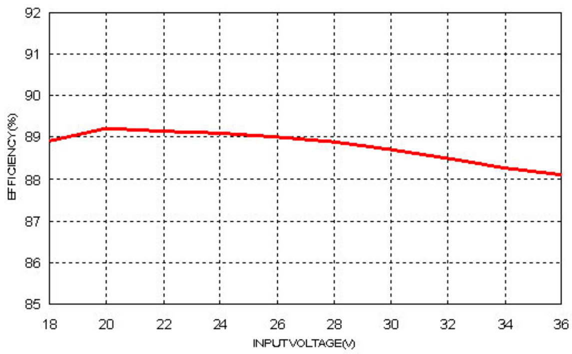


Efficiency Versus Output Current

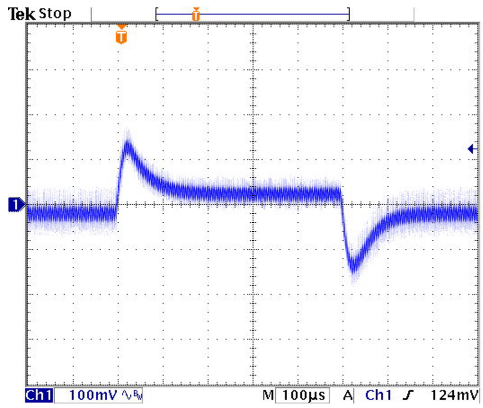


Typical Output Ripple and Noise.

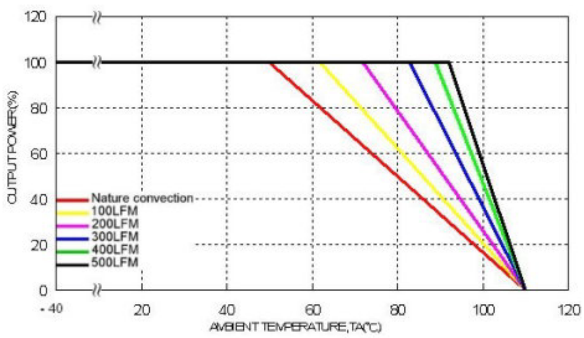
$V_{in} = V_{in\,nom}$, Full Load



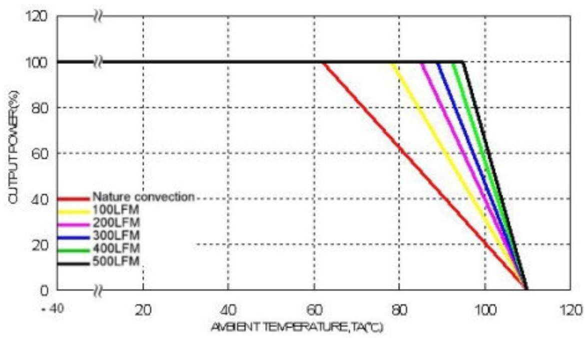
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; $V_{in} = V_{in\,nom}$



Derating Output Current Versus Ambient Temperature and Airflow $V_{in} = V_{in\,nom}$

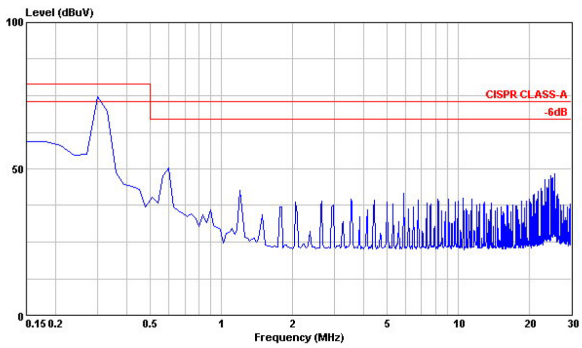


Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow

$V_{in} = V_{in\,nom}$

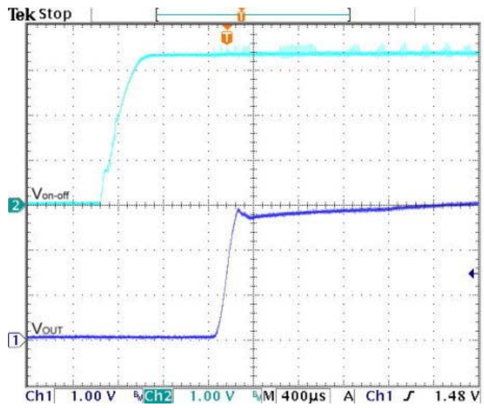
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2410 (Continued)



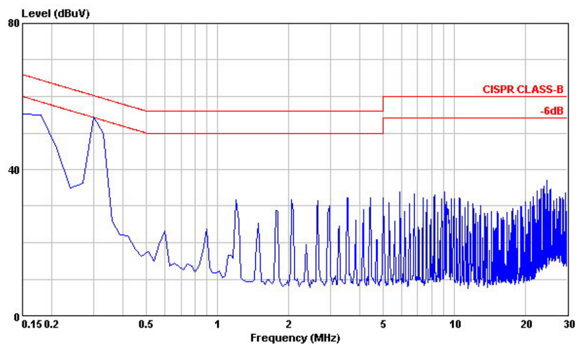
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\,nom}$, **Full Load**



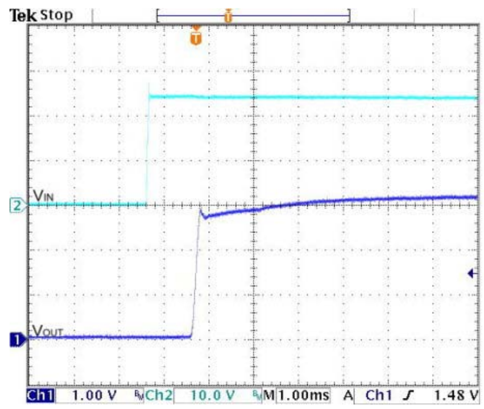
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\,nom}$, **Full Load**



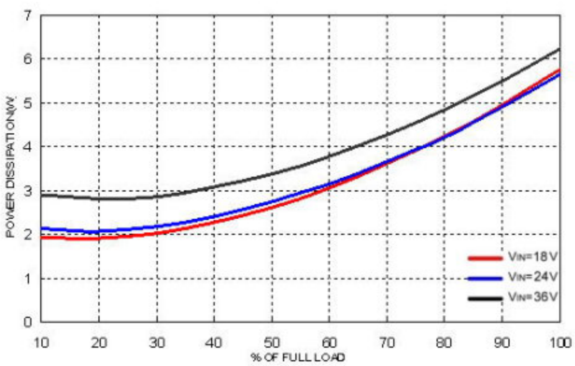
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\,nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

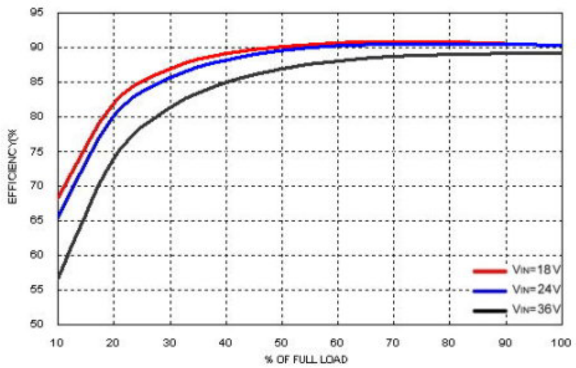
$V_{in} = V_{in\,nom}$, **Full Load**



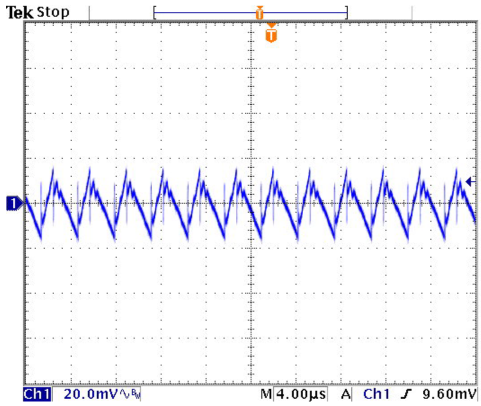
Power Dissipation Versus Output Current

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2411

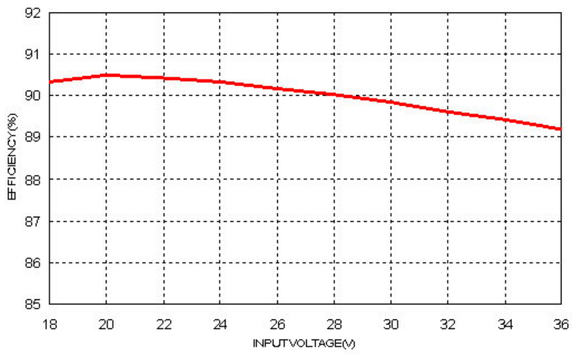


Efficiency Versus Output Current

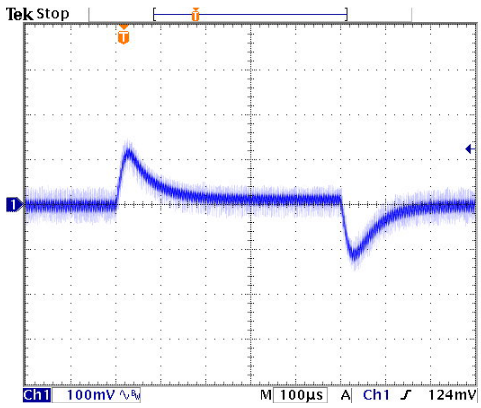


Typical Output Ripple and Noise.

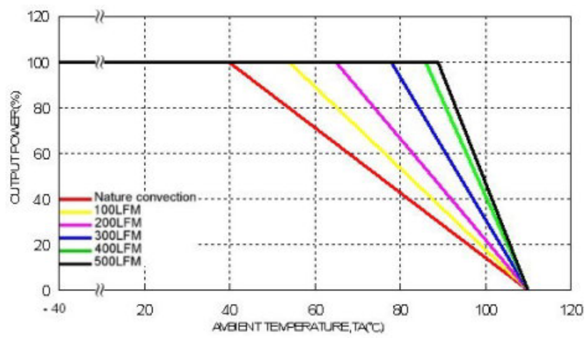
$V_{in} = V_{in\,nom}$, **Full Load**



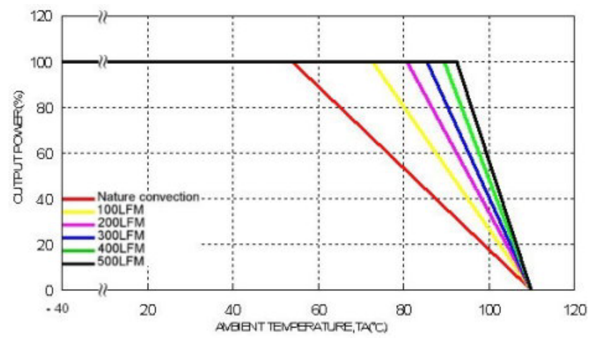
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; $V_{in} = V_{in\,nom}$



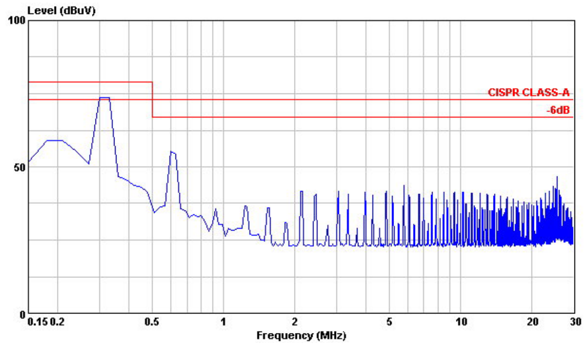
Derating Output Current Versus Ambient Temperature and Airflow $V_{in} = V_{in\,nom}$



Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow $V_{in} = V_{in\,nom}$

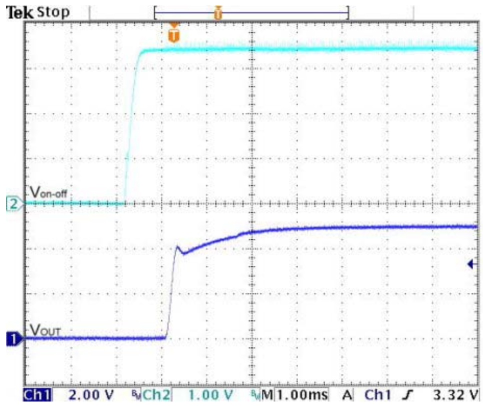
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2411 (Continued)



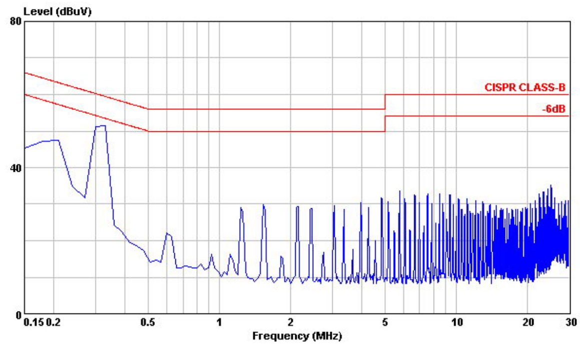
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\,nom}$, **Full Load**



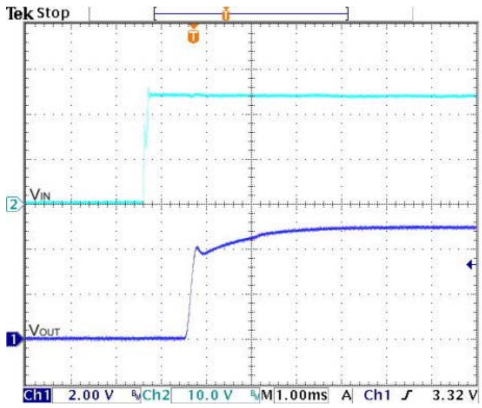
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\,nom}$, **Full Load**



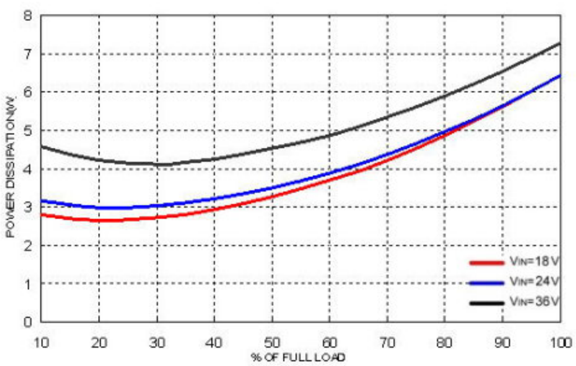
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\,nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

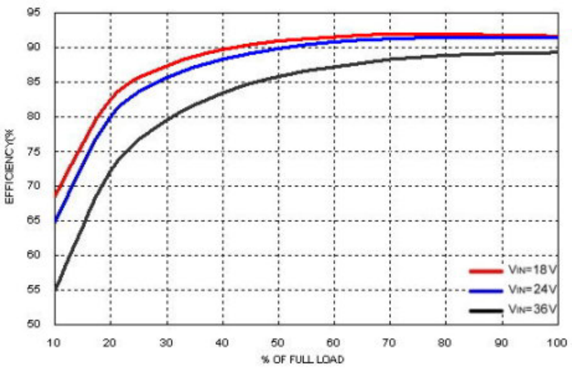
$V_{in} = V_{in\,nom}$, **Full Load**



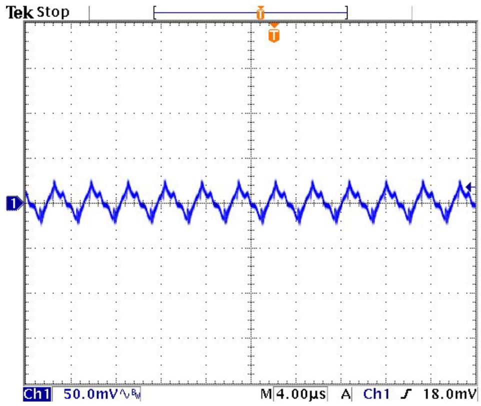
Power Dissipation Versus Output Current

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2412

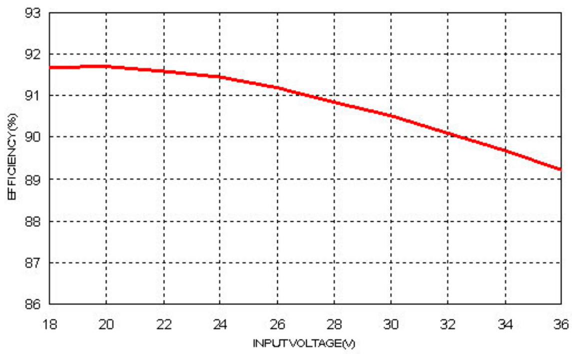


Efficiency Versus Output Current

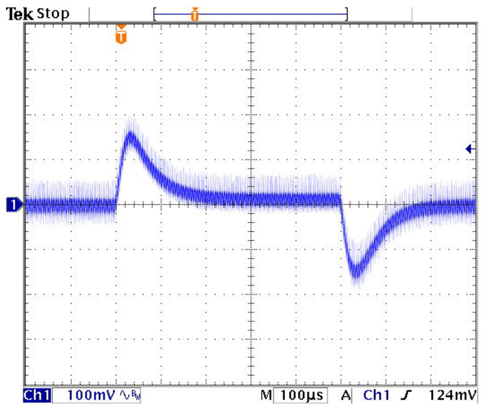


Typical Output Ripple and Noise.

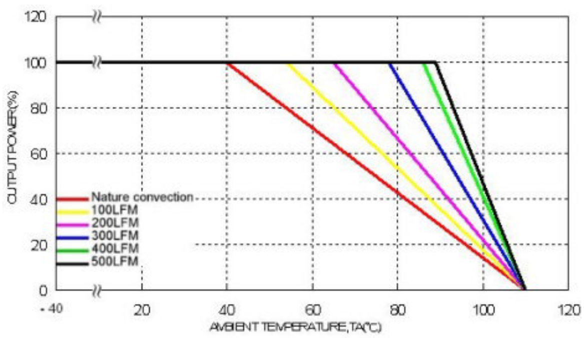
$V_{in} = V_{in\,nom}$, **Full Load**



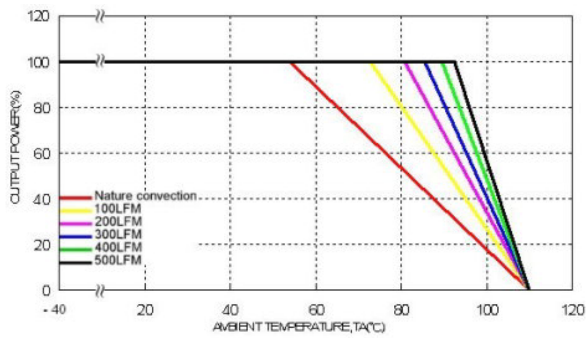
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; $V_{in} = V_{in\,nom}$



Derating Output Current Versus Ambient Temperature and Airflow $V_{in} = V_{in\,nom}$

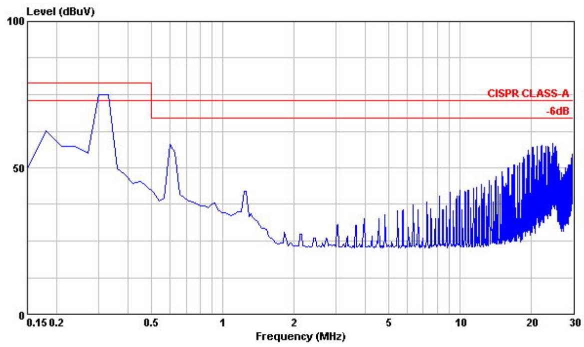


Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow

$V_{in} = V_{in\,nom}$

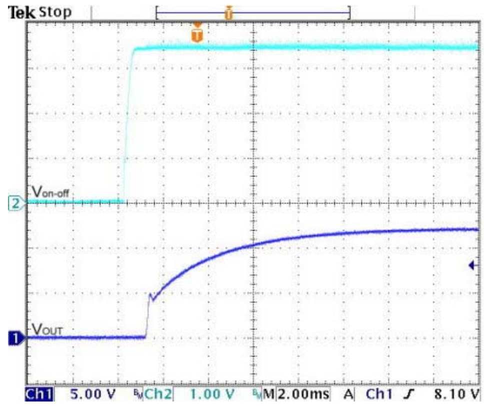
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2412 (Continued)



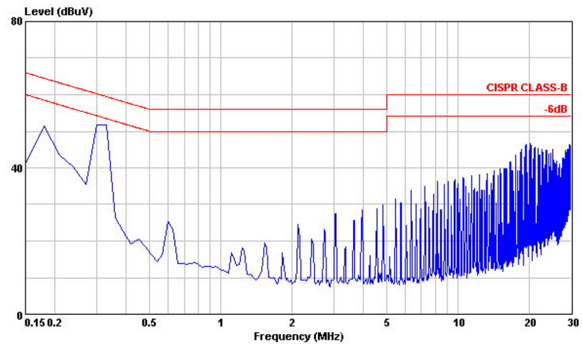
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\ nom}$, **Full Load**



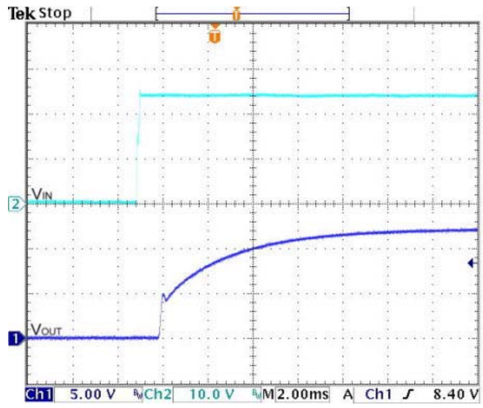
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\ nom}$, **Full Load**



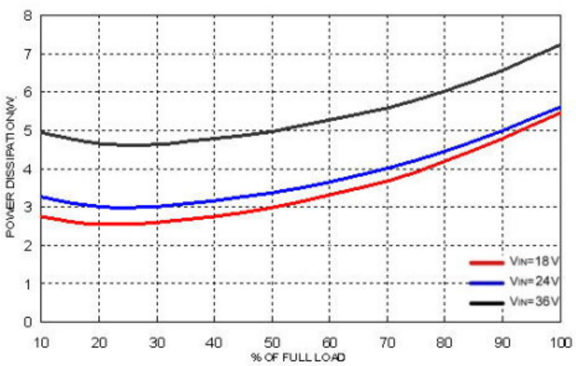
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\ nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

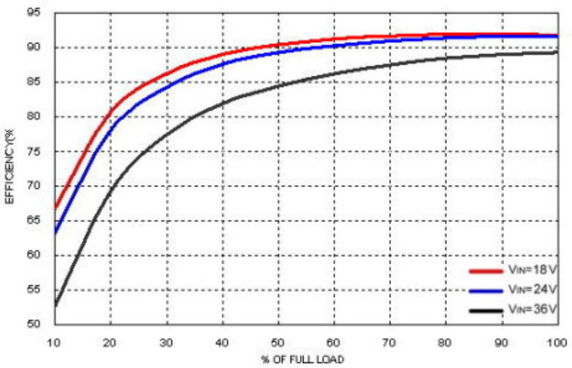
$V_{in} = V_{in\ nom}$, **Full Load**



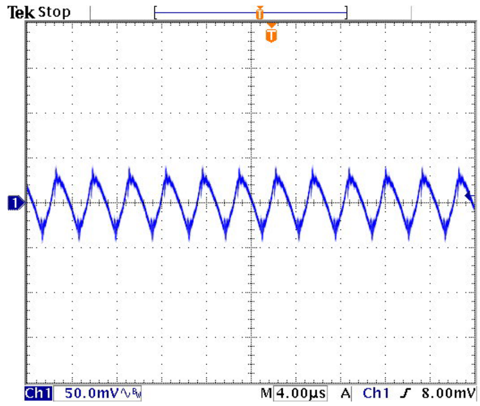
Power Dissipation Versus Output Current

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2413

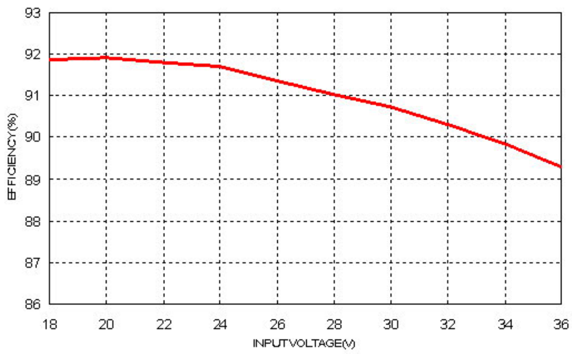


Efficiency Versus Output Current

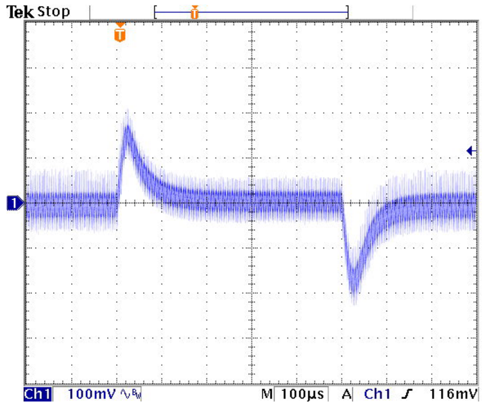


Typical Output Ripple and Noise.

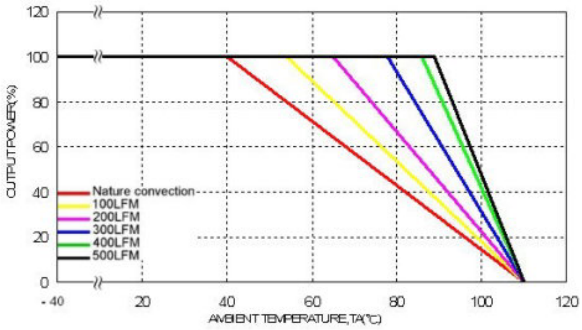
$V_{in} = V_{in\,nom}$, **Full Load**



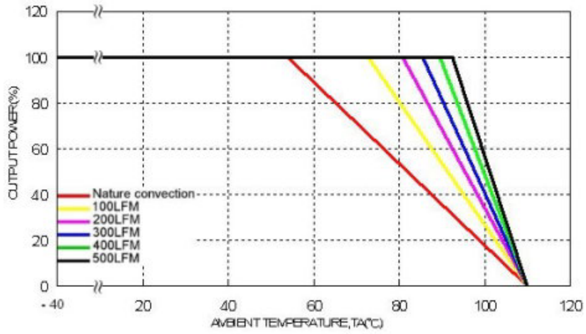
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; $V_{in} = V_{in\,nom}$



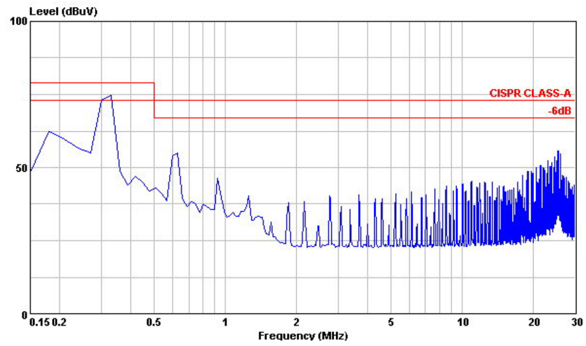
Derating Output Current Versus Ambient Temperature and Airflow $V_{in} = V_{in\,nom}$



Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow $V_{in} = V_{in\,nom}$

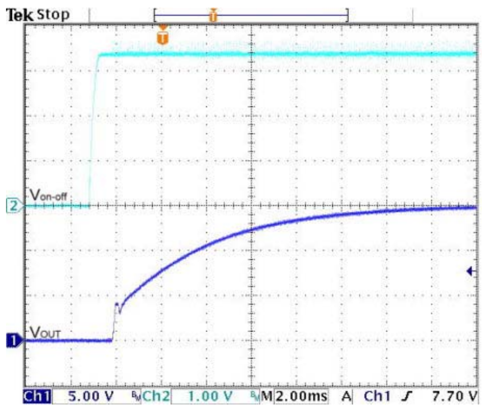
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-2413 (Continued)



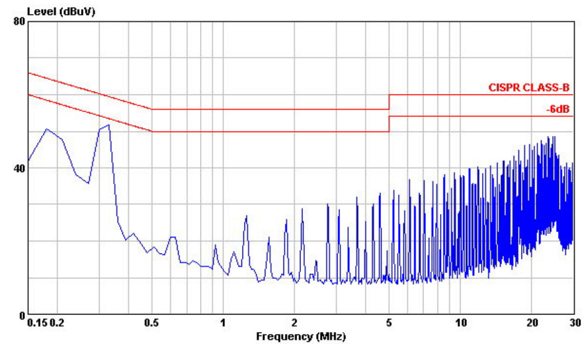
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\,nom}$, **Full Load**



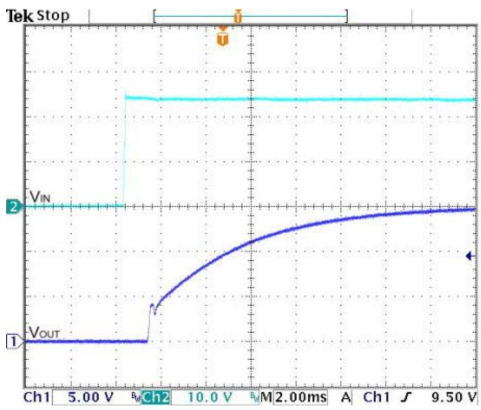
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\,nom}$, **Full Load**



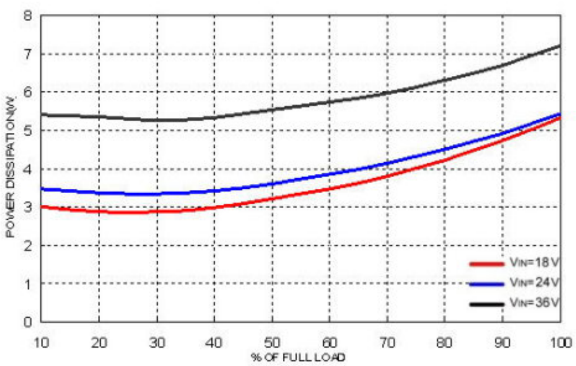
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\,nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

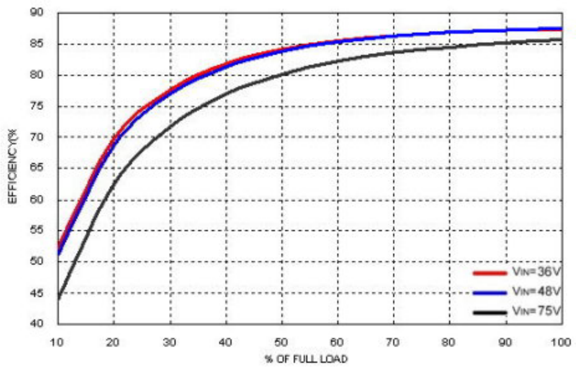
$V_{in} = V_{in\,nom}$, **Full Load**



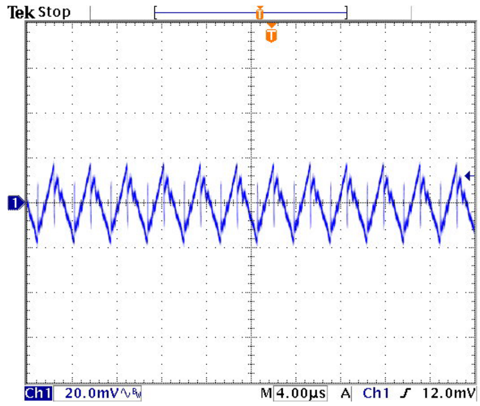
Power Dissipation Versus Output Current

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4810

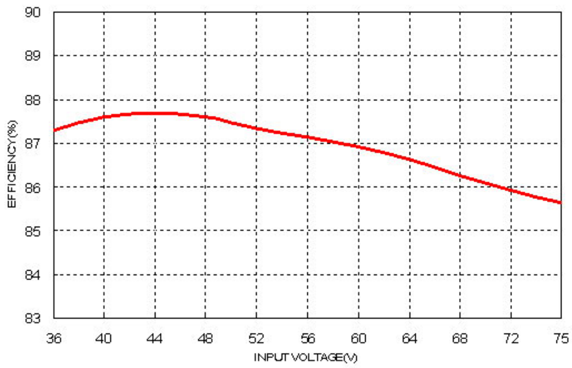


Efficiency Versus Output Current

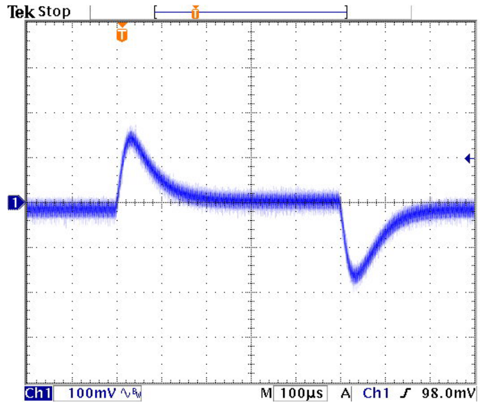


Typical Output Ripple and Noise.

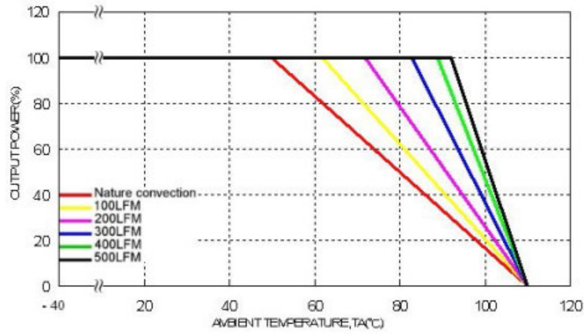
$V_{in} = V_{in\,nom}$, Full Load



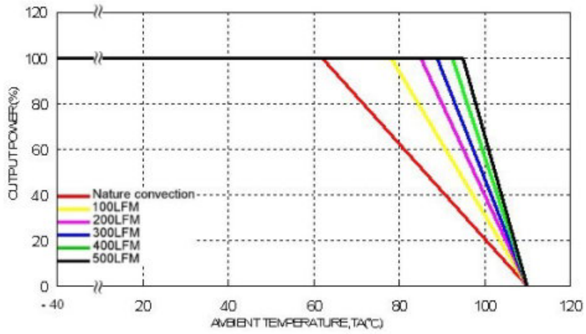
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; $V_{in} = V_{in\,nom}$



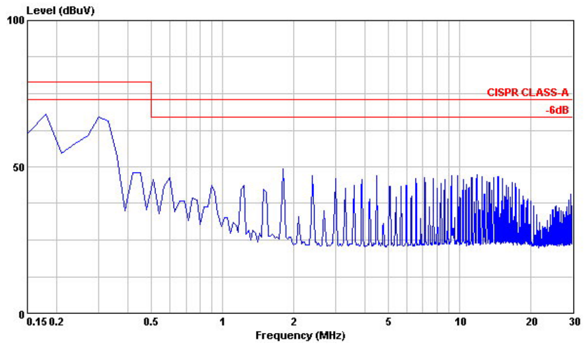
Derating Output Current Versus Ambient Temperature and Airflow $V_{in} = V_{in\,nom}$



Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow $V_{in} = V_{in\,nom}$

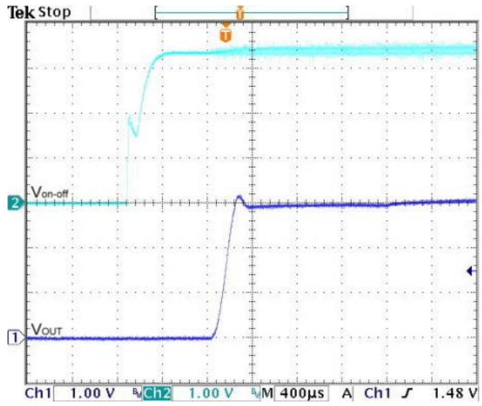
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4810 (Continued)



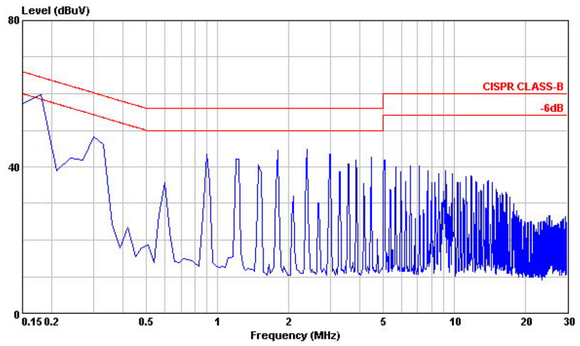
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\,nom}$, **Full Load**



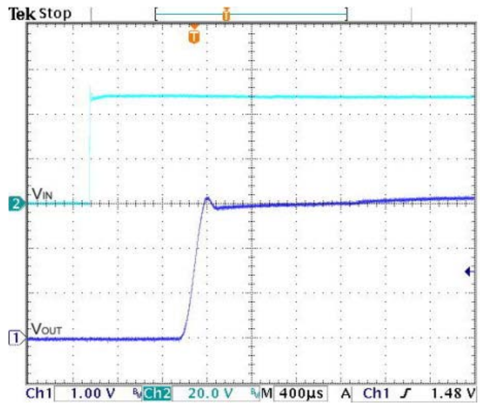
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\,nom}$, **Full Load**



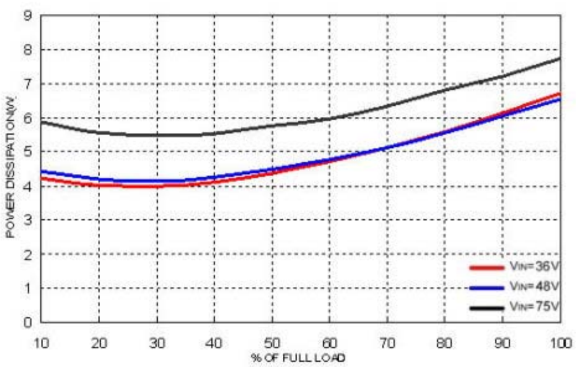
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\,nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

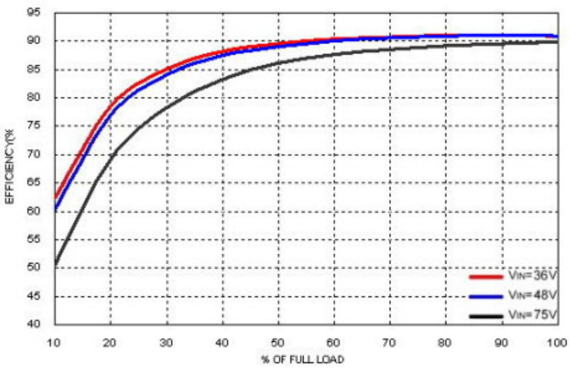
$V_{in} = V_{in\,nom}$, **Full Load**



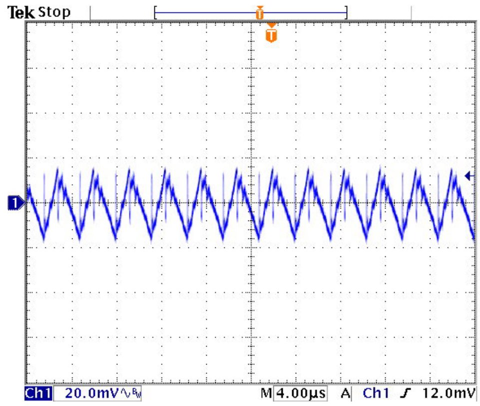
Power Dissipation Versus Output Current

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4811

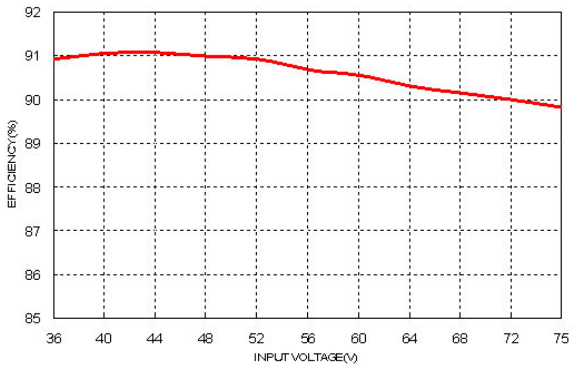


Efficiency Versus Output Current

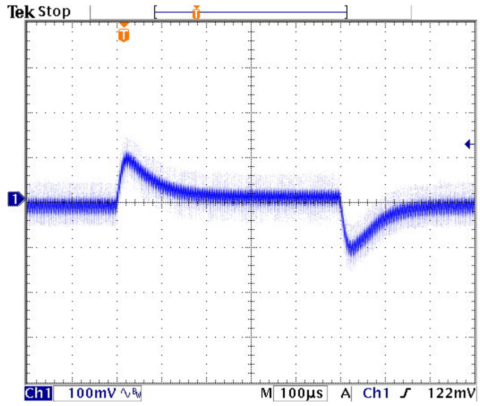


Typical Output Ripple and Noise.

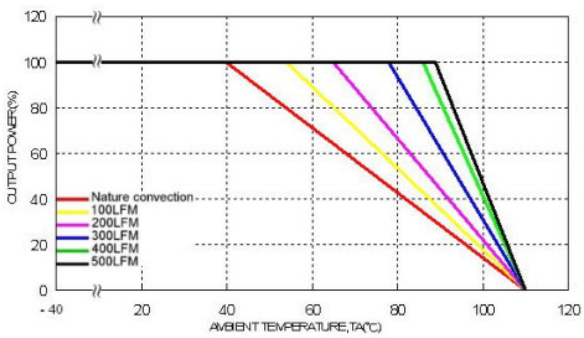
$V_{in} = V_{in\,nom}$, **Full Load**



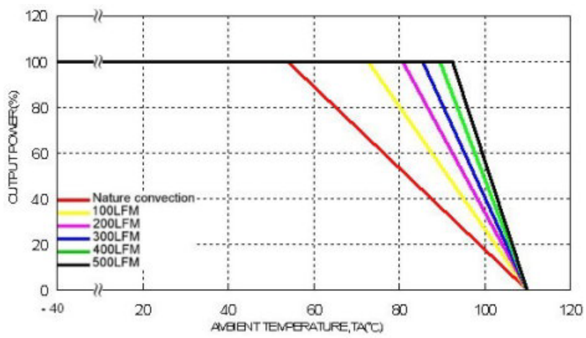
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; $V_{in} = V_{in\,nom}$



Derating Output Current Versus Ambient Temperature and Airflow $V_{in} = V_{in\,nom}$

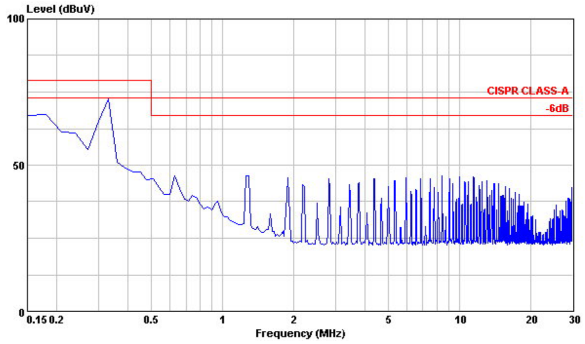


Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow

$V_{in} = V_{in\,nom}$

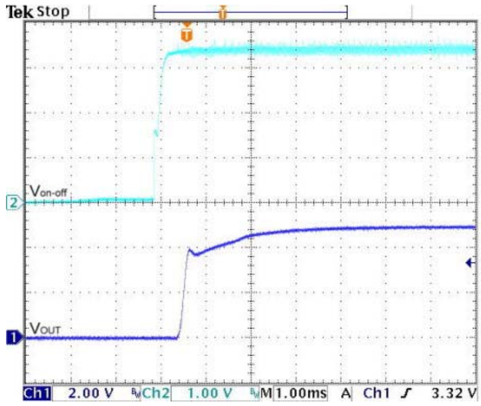
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4811 (Continued)



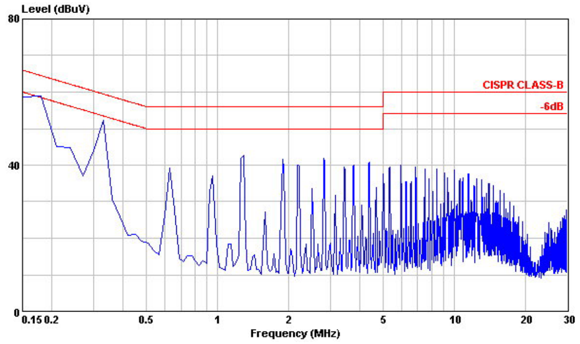
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\,nom}$, **Full Load**



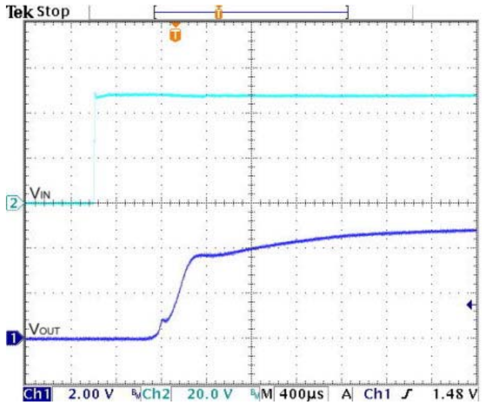
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\,nom}$, **Full Load**



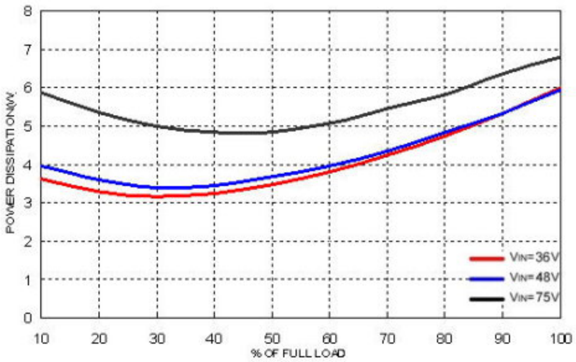
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\,nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

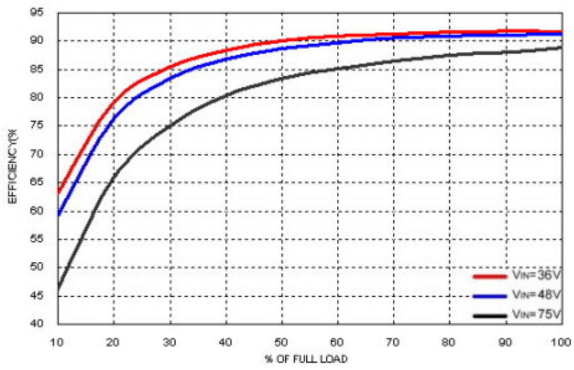
$V_{in} = V_{in\,nom}$, **Full Load**



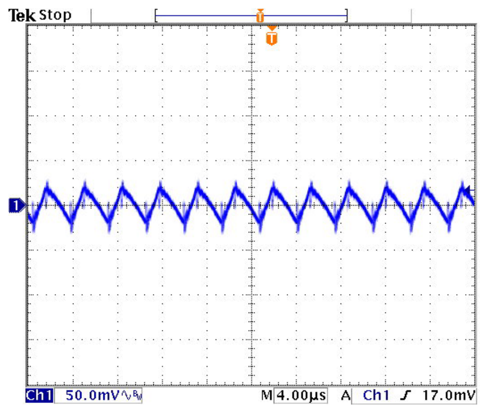
Power Dissipation Versus Output Current

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4812

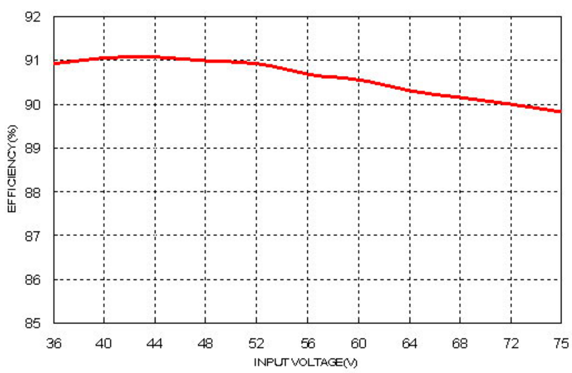


Efficiency Versus Output Current

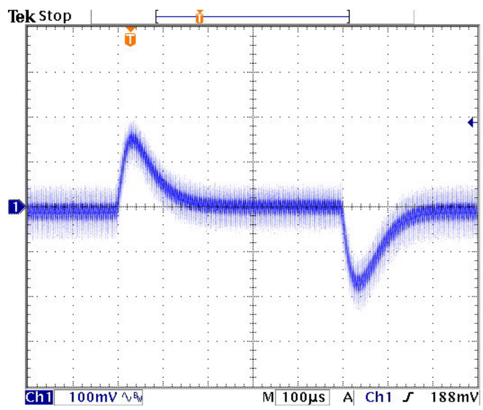


Typical Output Ripple and Noise.

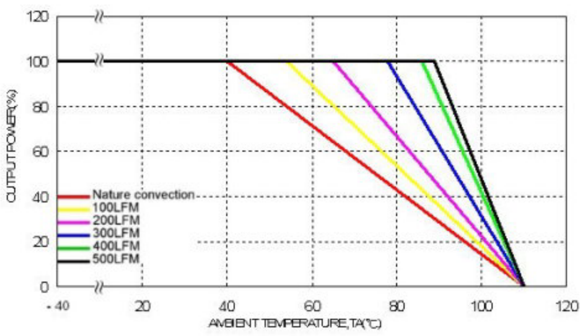
V_{in} = $V_{in\,nom}$, Full Load



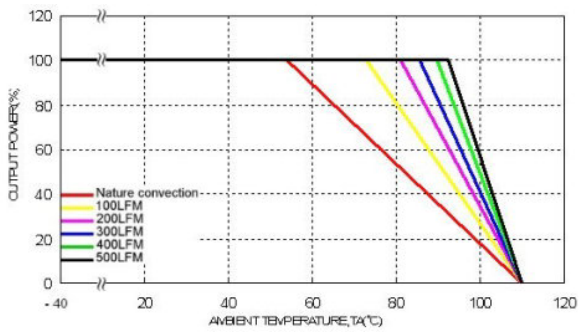
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; V_{in} = $V_{in\,nom}$



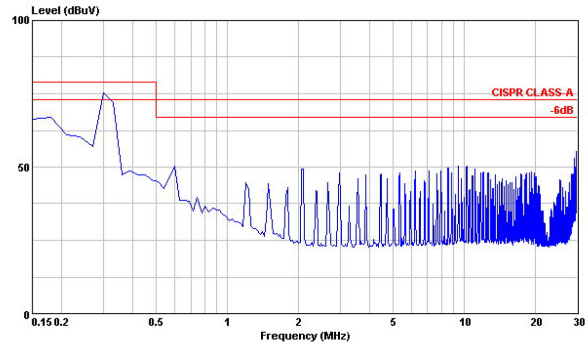
Derating Output Current Versus Ambient Temperature and Airflow V_{in} = $V_{in\,nom}$



Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow V_{in} = $V_{in\,nom}$

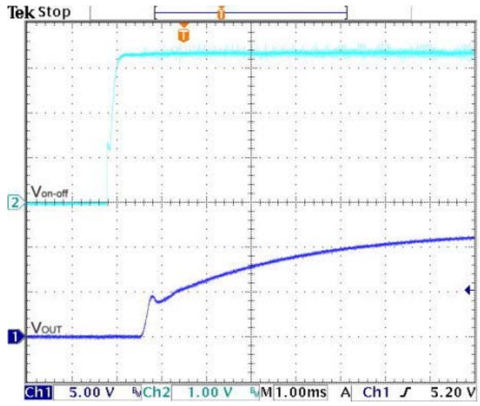
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4812 (Continued)



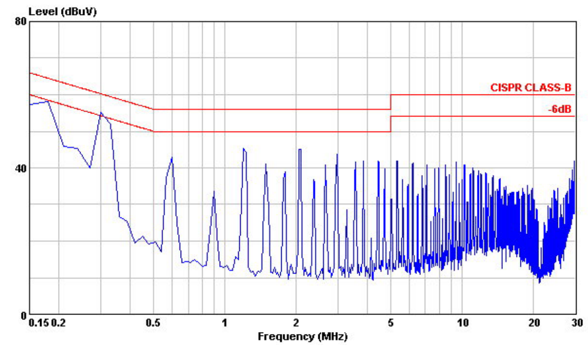
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\,nom}$, **Full Load**



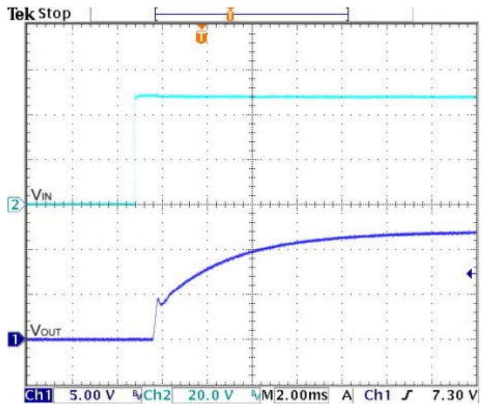
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\,nom}$, **Full Load**



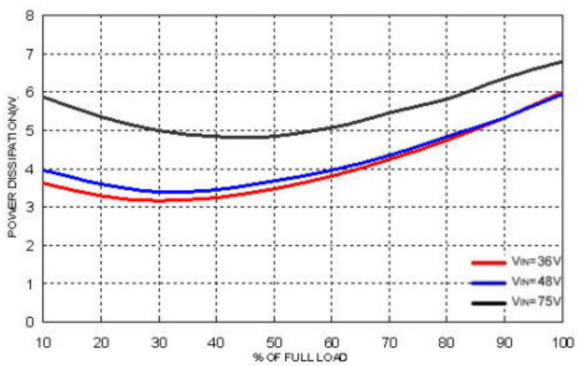
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\,nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

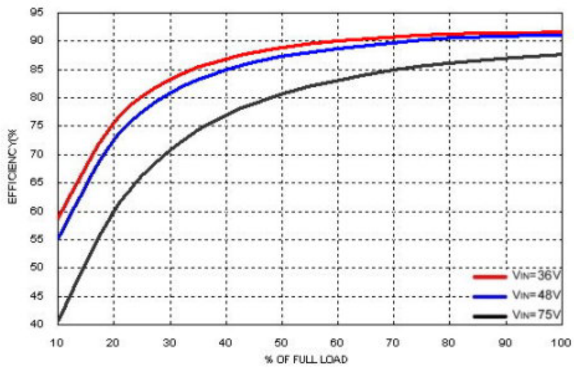
$V_{in} = V_{in\,nom}$, **Full Load**



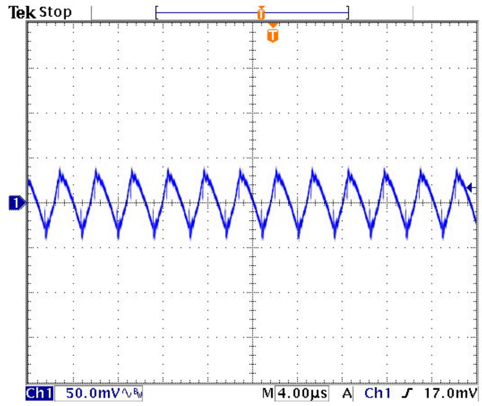
Power Dissipation Versus Output Current

Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4813

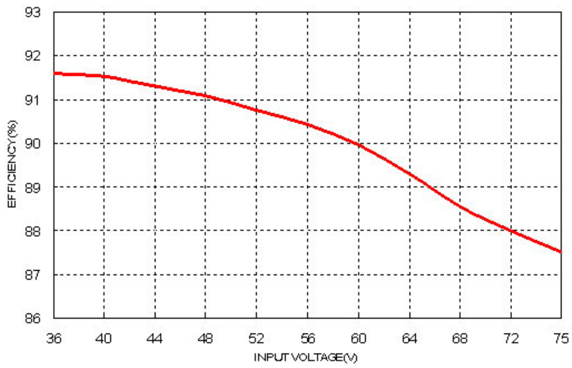


Efficiency Versus Output Current

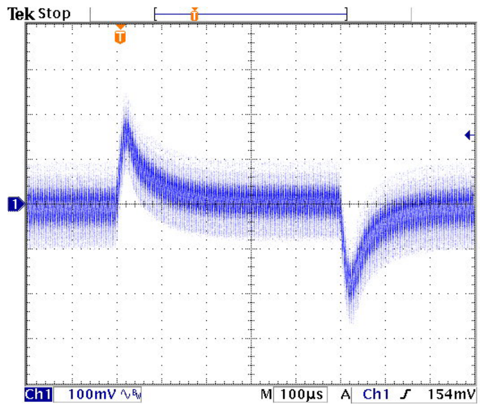


Typical Output Ripple and Noise.

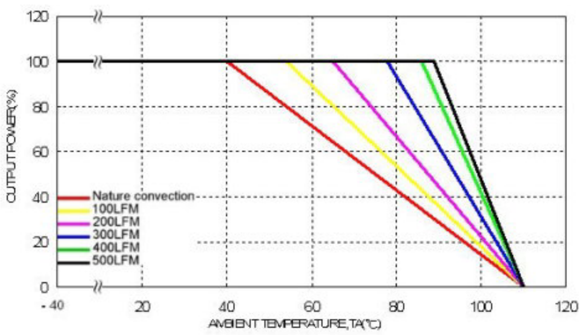
$V_{in} = V_{in\,nom}$, **Full Load**



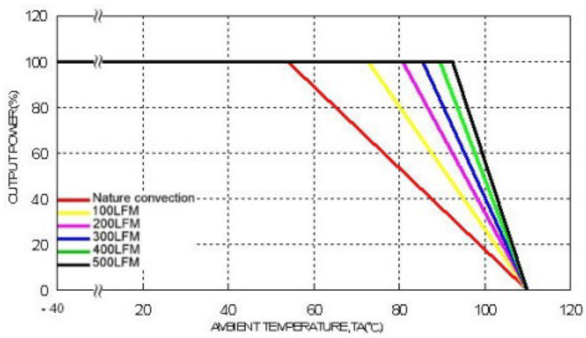
Efficiency Versus Input Voltage. Full Load



Transient Response to Dynamic Load Change from 100% to 75% to 100% of Full Load ; $V_{in} = V_{in\,nom}$



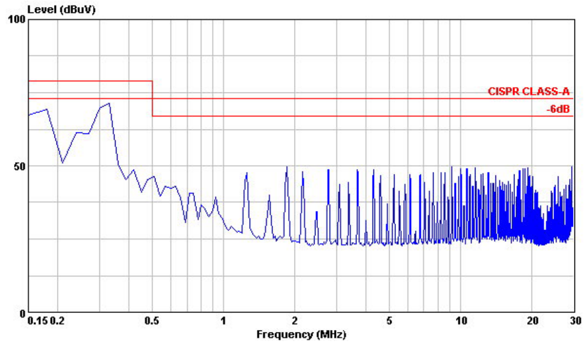
Derating Output Current Versus Ambient Temperature and Airflow $V_{in} = V_{in\,nom}$



Derating Output Current Versus Ambient Temperature with Heat-Sink and Airflow $V_{in} = V_{in\,nom}$

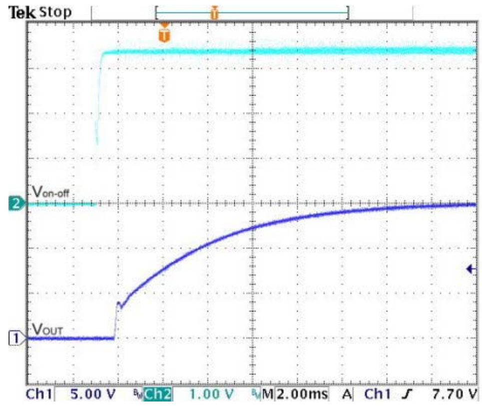
Characteristic Curves

All test conditions are at 25°C. The figures are identical for TEN 60-4813 (Continued)



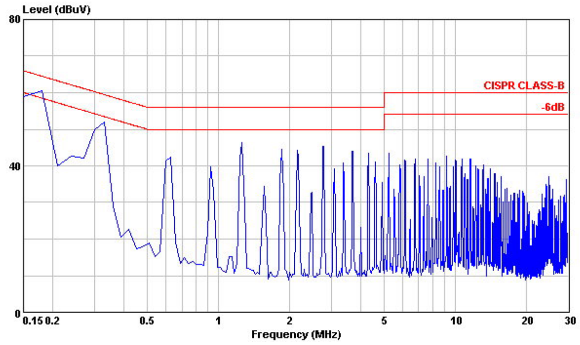
Conduction Emission of EN55022 Class A

$V_{in} = V_{in\,nom}$, **Full Load**



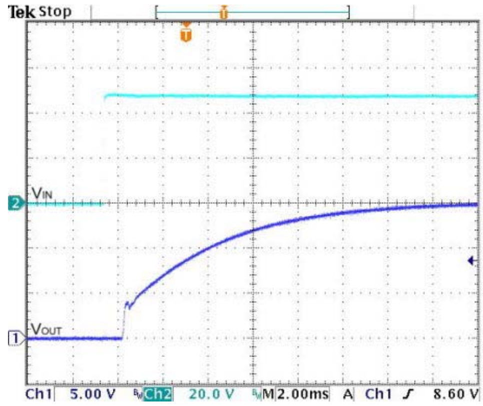
Using ON/OFF Voltage Start-Up and V_{out} Rise Characteristic

$V_{in} = V_{in\,nom}$, **Full Load**



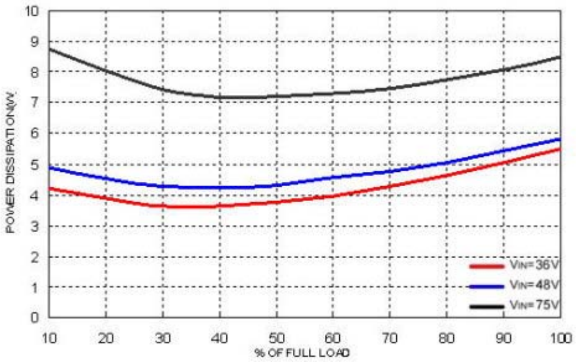
Conduction Emission of EN55022 Class B

$V_{in} = V_{in\,nom}$, **Full Load**



Typical Input Start-Up and Output Rise Characteristic

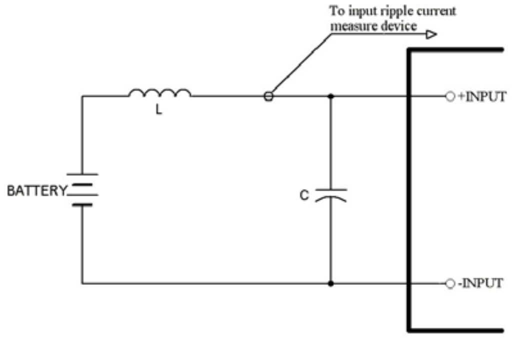
$V_{in} = V_{in\,nom}$, **Full Load**



Power Dissipation Versus Output Current

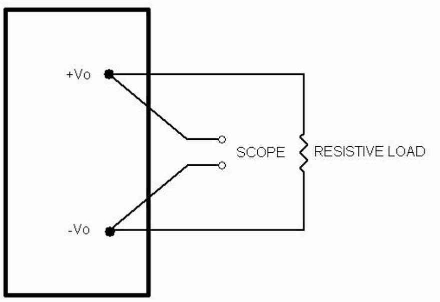
Testing Configurations

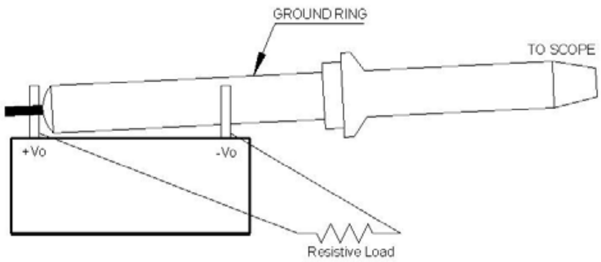
Input reflected-ripple current measurement test up



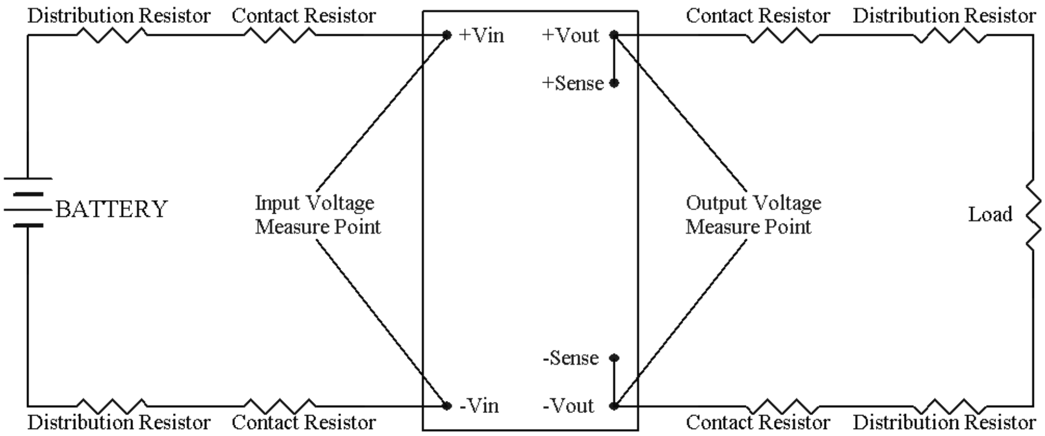
Component	Value	Voltage	Reference
L	12µH	—	—
C	47µF	100V	Aluminum Electrolytic Capacitor

Peak-to-peak output ripple & noise measurement test up





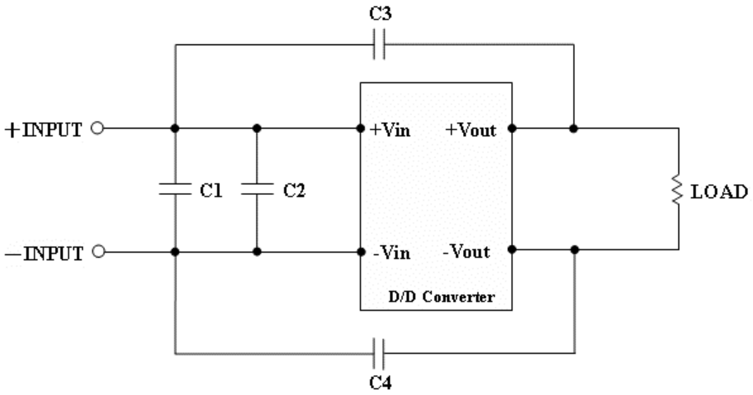
Output voltage and efficiency measurement test up



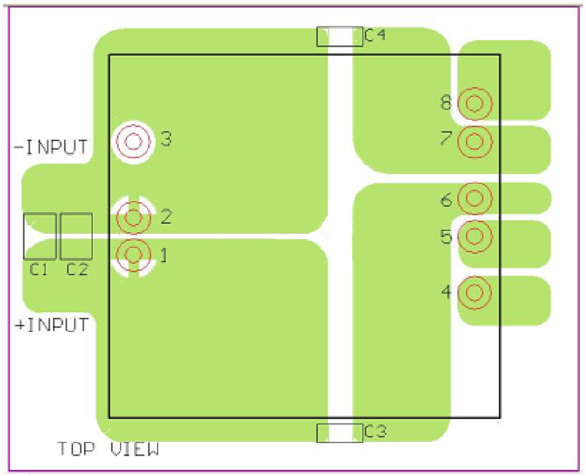
Note: All measurements are taken at the module terminals.

$$Efficiency = \left(\frac{V_o \times I_o}{V_{in} \times I_{in}} \right) \times 100\%$$

EMC considerations



Suggested Schematic to comply with EN55022 Class A Conducted Noise



Recommended Layout with Input Filter

Following components are needed to comply with EN55022 Class A conducted noise:

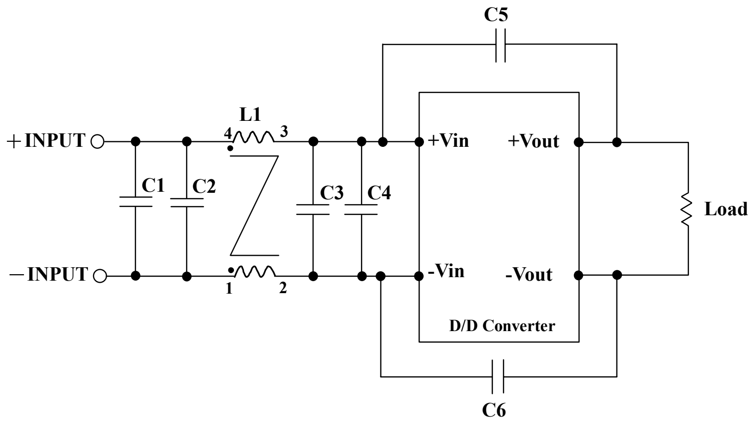
TEN 60-24xx

Component	Value	Voltage	Reference
C2	6.8uF	50V	1812 MLCC
C3、C4	1000pF	2KV	1808MLCC

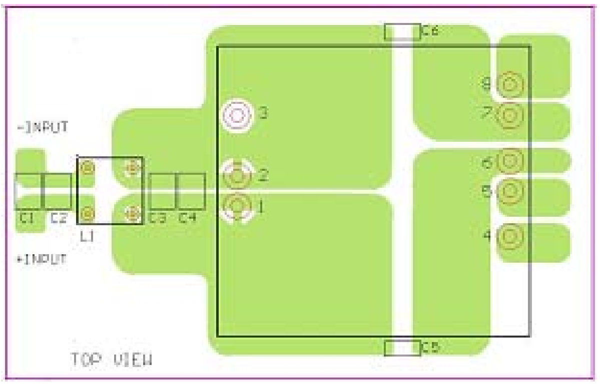
TEN 60-48xx

Component	Value	Voltage	Reference
C1、C2	2.2uF	100V	1812 MLCC
C3、C4	1000pF	2KV	1808 MLCC

EMC considerations (Continued)



Suggested Schematic to comply with EN55022 Class B Conducted Noise



Recommended Layout with Input Filter

Following components are needed to comply with EN55022 Class B conducted noise:

TEN 60-24xx

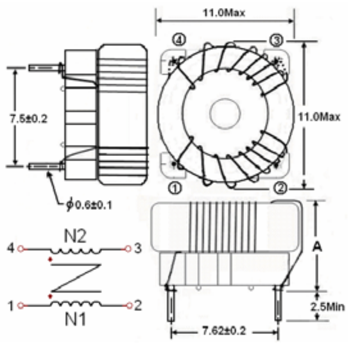
Component	Value	Voltage	Reference
C1、C3	4.7uF	50V	1812 MLCC
C5、C6	1000pF	2KV	1808 MLCC
L1	450uH	—	Common Choke, P/N: TCK-048

TEN 60-48xx

Component	Value	Voltage	Reference
C1、C2、C3	2.2uF	100V	1812 MLCC
C5、C6	1000pF	2KV	1808MLCC
L1	830uH	—	Common Choke, P/N: TCK-053

This Common Choke L1 has been define as follow：

- ■ TCK-048
- L：450µH±35% / DCR：25mΩ, max
- **A** height：9.8 mm, Max
- ■ TCK-053
- L：830µH±35% / DCR：31mΩ, max
- **A** height：8.8 mm, Max
- ■ Test condition：100KHz / 100mV
- ■ Recommended through hole：Φ0.8mm
- ■ All dimensions in millimeters



Input Source Impedance

The power module should be connected to a low impedance input source. Highly inductive source impedance can affect the stability of the power module. Input external L-C filter is recommended to minimize input reflected ripple current. The inductor is simulated source impedance of 12µH and capacitor is Nippon Chemi-con KZE series 47µF/100V. The capacitor should be equipped as close as possible to the input terminals of the TEN 60 converter for lower impedance.

Output Over Current Protection

When excessive output currents occur in the system, circuit protection is required on all converers. Normally, overload current is maintained at approximately 150 percent of rated current for TEN 60 series.

Hiccup-mode is a method of operation in a converter whose purpose is to protect the power supply from being damaged during an over-current fault condition. It also enables the converter to restart when the fault is removed.

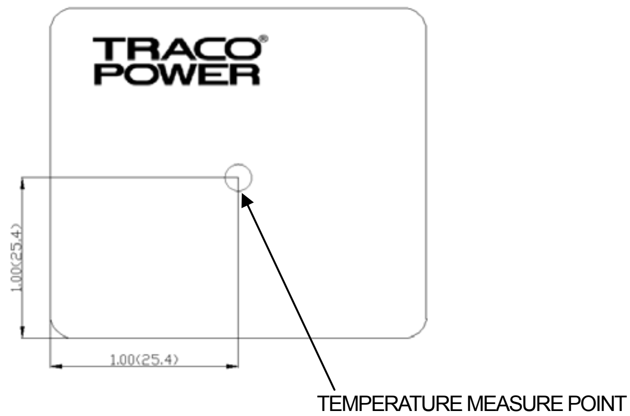
One of the problems resulting from over current is that excessive heat may be generated in the TEN 60 converter; especially MOSFET and Schottky diodes and the temperature of those devices may exceed their specified limits. A protection mechanism has to be used to prevent those power devices from being damaged.

Output Over Voltage Protection

The output over-voltage protection consists of a Zener diode that monitors the output voltage on the feedback loop. If the voltage on the output terminals exceeds the over-voltage protection threshold, then the Zener diode will send a current signal to the control IC to limiting the output voltage.

Thermal Consideration

The TEN 60 operates in a variety of thermal environments. However, sufficient cooling should be provided to ensure reliable operation of the unit. Heat is removed by conduction, convection, and radiation to the surrounding environment. Proper cooling can be verified by measuring the point as shown in the figure below. The temperature at this point should not exceed 110°C. When operating, adequate cooling must be provided to maintain the test point temperature at or below 110°C. Although the maximum point temperature of the power modules is 110°C, you can limit this temperature to a lower value for higher reliability.

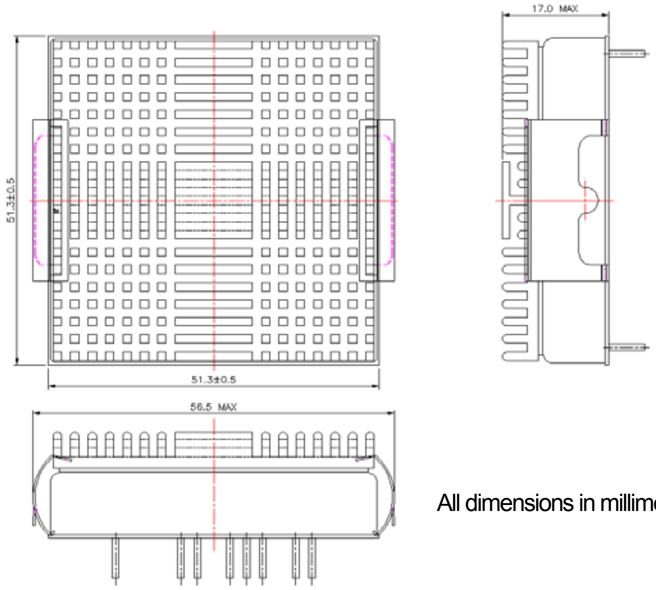


Measurement shown in inches and (millimeters)

TOP VIEW

Heat Sink Consideration

Equip heat-sink for lower temperature and higher reliability of the module. Considering space and air-flow is the way to choose which heat-sink is needed. Order Code: TEN-HS3

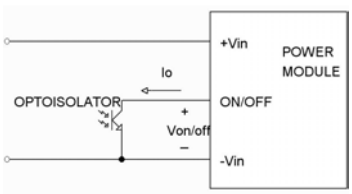


All dimensions in millimeters

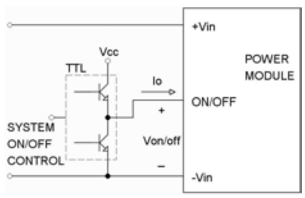
Remote ON/OFF Control

The Remote ON/OFF Pin is to to turn on and off the TEN 60 converter; the user must use a switch to control the logic voltage high or low level of the pin referenced to -Vin. The switch can be open collector transistor, FET and Photo-Couple. The switch must be capable of sinking up to 1 mA at low-level logic voltage. High-level logic of the ON/OFF signal maximum voltage is allowable. Leakage current of the switch at 15V is 50 µA.

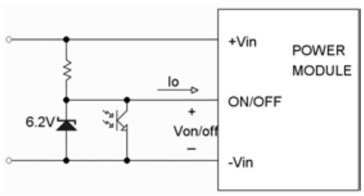
Remote ON/OFF Implementation Circuits



Isolated-Closure Remote ON/OFF

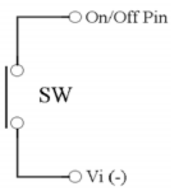


Level Control using TTL Output

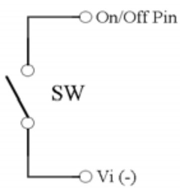


Level Control using Line Voltage

a. The Positive logic structure turned on of the DC/DC module when the ON/OFF pin is at high-level logic and low-level logic is turned off it.

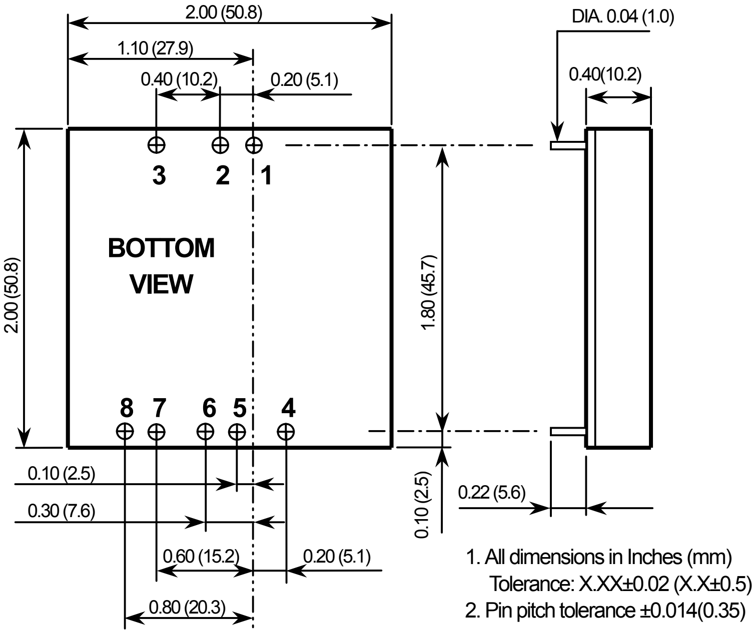


When TEN 60 module is turned off at Low-level logic



When TEN 60 module is turned on at High-level logic

Mechanical Data

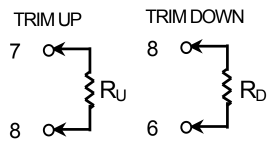


PIN CONNECTION

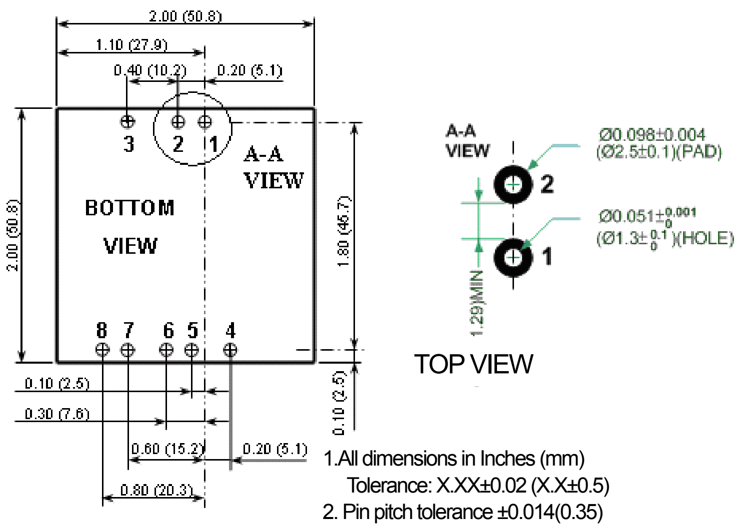
PIN	SINGLE
1	+INPUT
2	-INPUT
3	CTRL
4	-SENSE
5	+SENSE
6	+OUTPUT
7	-OUTPUT
8	TRIM

EXTERNAL OUTPUT TRIMMING

Output can be externally trimmed by using the method shown below.

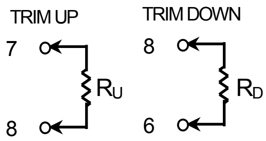


Recommended Pad Layout



Output Voltage Adjustment

Output voltage set point adjustment allows the user to increase or decrease the output voltage set point of a module. This is accomplished by connecting an external resistor between the TRIM pin and either the SENSE(+) or SENSE(-) pins. With an external resistor between the TRIM and SENSE(-) pin, the output voltage set point increases. With an external resistor between the TRIM and SENSE(+) pin, the output voltage set point decreases.



TRIM TABLE

TEN 60-xx10

Trim up (%)	1	2	3	4	5	6	7	8	9	10
V_{OUT} (Vdc)	3.333	3.366	3.399	3.432	3.465	3.498	3.531	3.564	3.597	3.630
R_U (kΩ)	57.930	26.165	15.577	10.283	7.106	4.988	3.476	2.341	1.459	0.753
Trim down (%)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
V_{OUT} (Volts)	3.267	3.234	3.201	3.168	3.135	3.102	3.069	3.036	3.003	2.970
R_D (kΩ)	69.470	31.235	18.490	12.117	8.294	5.745	3.924	2.559	1.497	0.647

TEN 60-xx11

Trim up (%)	1	2	3	4	5	6	7	8	9	10
V_{OUT} (Volts)	5.050	5.100	5.150	5.200	5.250	5.300	5.350	5.400	5.450	5.500
R_U (kΩ)	36.570	16.580	9.917	6.585	4.586	3.253	2.302	1.588	1.032	0.588
Trim down (%)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
V_{OUT} (Volts)	4.950	4.900	4.850	4.800	4.750	4.700	4.650	4.600	4.550	4.500
R_D (kΩ)	45.533	20.612	12.306	8.152	5.660	3.999	2.812	1.922	1.230	0.676

TEN 60-xx12

Trim up (%)	1	2	3	4	5	6	7	8	9	10
V_{OUT} (Volts)	12.120	12.240	12.360	12.480	12.600	12.720	12.840	12.960	13.080	13.200
R_U (kΩ)	367.910	165.950	98.636	64.977	44.782	31.318	21.701	14.488	8.879	4.391
Trim down (%)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
V_{OUT} (Volts)	11.880	11.760	11.640	11.520	11.400	11.280	11.160	11.040	10.920	10.800
R_D (kΩ)	460.990	207.950	123.600	81.423	56.118	39.249	27.199	18.162	11.132	5.509

TEN 60-xx13

Trim up (%)	1	2	3	4	5	6	7	8	9	10
V_{OUT} (Volts)	15.150	15.300	15.450	15.600	15.750	15.900	16.050	16.200	16.350	16.500
R_U (kΩ)	404.180	180.590	106.060	68.796	46.437	31.531	20.883	12.898	6.687	1.718
Trim down (%)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
V_{OUT} (Volts)	14.850	14.700	14.550	14.400	14.250	14.100	13.950	13.800	13.650	13.500
R_D (kΩ)	499.820	223.410	131.270	85.204	57.563	39.136	25.974	16.102	8.424	2.282

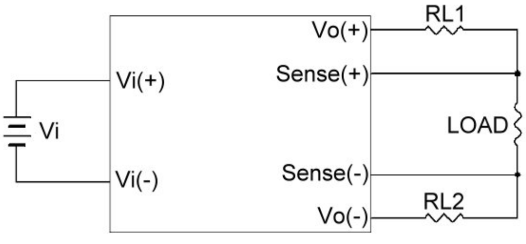
Remote Sense Application Circuit

The Remote Sense function can regulate the voltage at the load when output current through the line resistor causes voltage drop. The Remote Sense voltage range cannot be over 10% V_{out}, i.e.:

$$[+V_{out} \text{ to } -V_{out}] - [+\text{Sense to } -\text{Sense}] \leqq 10\% V_{out}$$

If the Remote Sense function is not used, then the +SENSE has to be connected to $+V_{out}$ and the -SENSE has to be connected to $-V_{out}$.

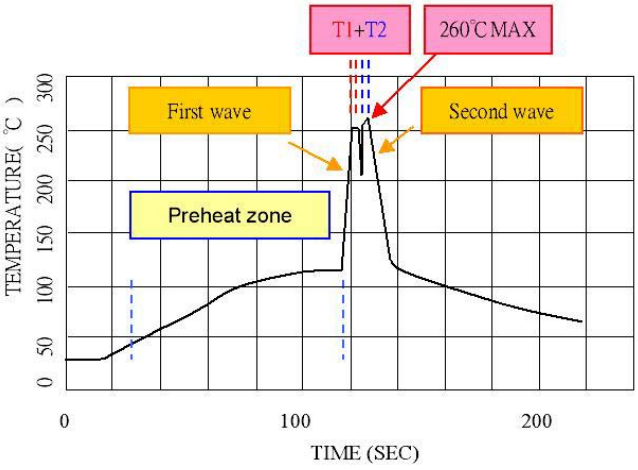
RL1 and RL2 are conduction losses



Operation Output Voltage with Sense Function Used

Soldering and Reflow Considerations

Lead free wave solder profile for TEN 60



Zone	Reference Parameter
Preheat zone	Rise temp. speed : 3°C/ sec max. Preheat temp. : 100~130°C
Actual heating	Peak temp. : 250~260°C Peak time (T1+T2 time) : 4~6 sec

Reference Solder : Sn-Ag-Cu ; Sn-Cu

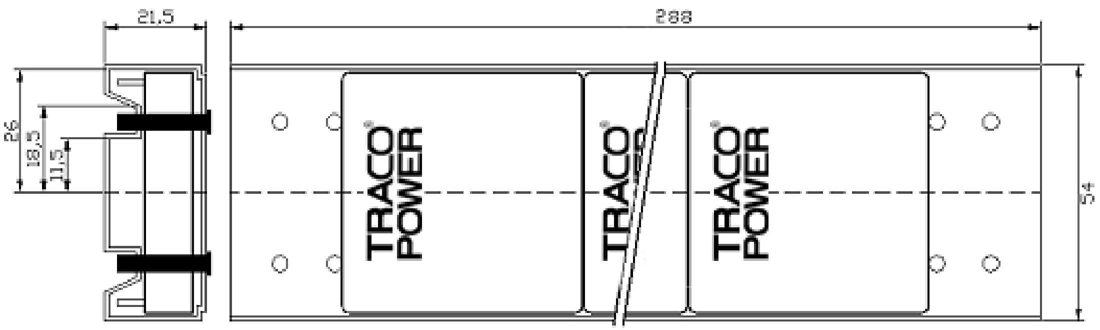
Hand Soldering :

Soldering iron : Power 90W

Welding Time : 2~4 sec

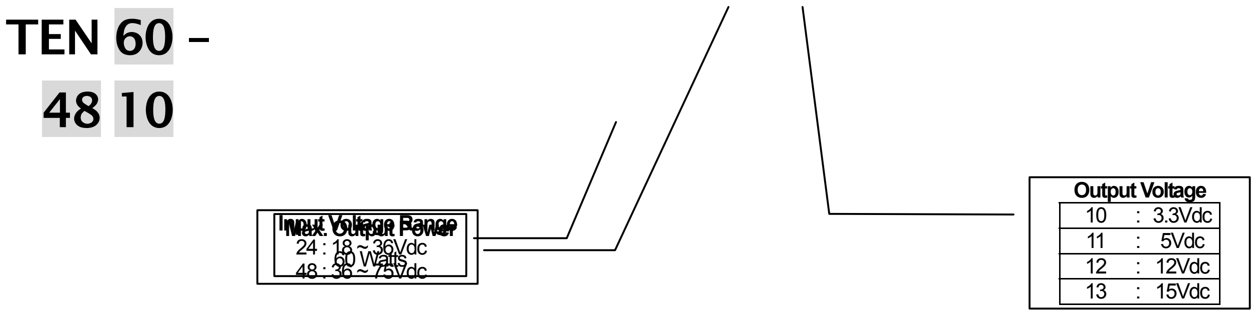
Temp. : 380~400℃

Packaging Information



5 PCS per TUBE

Part Number Structure



Model Number	Input Range	Output Voltage	Output Current	Input Current	Eff [(2)] (%)
			Max. Load	Full Load[(1)]	
TEN 60-2410	18 – 36 VDC	3.3 VDC	14'000mA	2264mA	89
TEN 60-2411	18 – 36 VDC	5 VDC	12'000mA	2941mA	90
TEN 60-2412	18 – 36 VDC	12 VDC	5'000mA	2907mA	90
TEN 60-2413	18 – 36 VDC	15 VDC	4'000mA	2907mA	90
TEN 60-4810	36 – 75 VDC	3.3 VDC	14'000mA	1132mA	89
TEN 60-4811	36 – 75 VDC	5 VDC	12'000mA	1453mA	90
TEN 60-4812	36 – 75 VDC	12 VDC	5'000mA	1453mA	90
TEN 60-4813	36 – 75 VDC	15 VDC	4'000mA	1453mA	90

Note 1. Maximum value at nominal input voltage and full load of standard type.
Note 2. Typical value at nominal input voltage and full load.

Safety and Installation Instruction

Fusing Consideration

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 sophisticated power architecture. To 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 fuse with maximum rating of 5A for TEN 60-24xx modules and 3A for TEN 60-48xx modules. Based on the information provided in this data sheet on Inrush energy and maximum DC input current; the same type of fuse with lower rating can be used. Refer to the fuse manufacturer's data for further information.

MTBF and Reliability

The MTBF of TEN 60 series of DC/DC converters has been calculated using

Bellcore TR-NWT-000332 Case I: 50% stress, Operating temperature at 40°C (Ground fixed and controlled environment). The MTBF is: 1.093×10^6 hours.

MIL-HDBK 217F NOTICE2 FULL LOAD, Operating temperature at 25°C. The MTBF is: 1.096×10^5 hours.