APW7393

-1A, -12V Inverting Converter With PSM Mode

Features

- **Operating Input Voltage Range 9V to 14V**
- **Output Current up to -1A**
- **Reference Voltage: 0.8V**
  Efficiency up to 90% at -1A Loading
- **Current Mode with PSM for Fast Response and Higher Efficiency**
- **Fixed 500kHz Switching Frequency**
- **Protections:**
  Input Over Voltage Protections
  Under Voltage Protection and Hiccup Mode
  Current Limited
  Over Temperature Protection
  BST to SW POR Function
- **Internal Soft-Start**

Applications

- **Standard ATX Power Supply**

General Description

APW7393 is an inverting Buck-Boost converter. Integrated 70mΩ high side and 60mΩ low side power MOSFET. Can generating a negative output voltage and provides an output current up to -1A.

The APW7393 is equipped with an automatic PSM/PWM mode operation when MODE pin connecting to VOUT pin. At light load, the IC operates in the PSM mode to reduce the switching losses. At heavy load, APW7393 works in PWM mode with a fixed switching frequency of 500kHz. If MODE pin floating, converter working in force PWM mode.

Built-in EN function reference voltage, can simplify enable function in inverting converter application. Give a voltage more than 2V on EN to GND pin, IC V_{OUT} will turn on with soft-start function.

The APW7393 is also equipped with Power-on-reset, soft-start, enable/disable and whole protections (over-voltage, hiccup mode, over-temperature and current-limit) into a single package.

Simplified Application Circuit

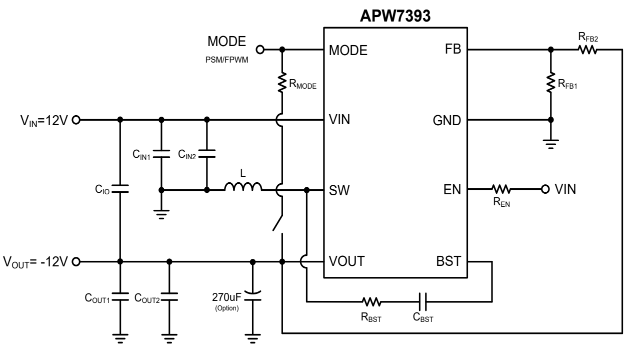


Figure 1. Application Circuit

Pin Configuration

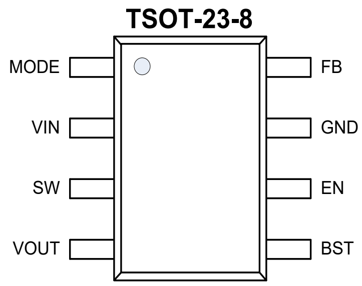
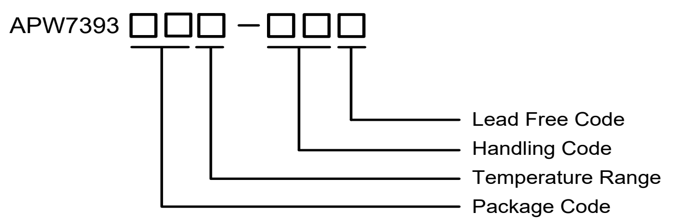


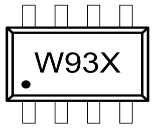
Figure 2. Package PIN Out

ANPEC reserves the right to make changes to improve reliability or manufacturability without notice, and advise customers to obtain the latest version of relevant information to verify before placing orders.

Ordering and Marking Information



Package Code
AZ
Operating Ambient Temperature Range
I : -40°C to 85°C
Handling Code
TR : Tape & Reel
Assembly Material
G : Green Part



X : Date Code

Note: ANPEC's green product compliant RoHS and Halogen free.

Absolute Maximum Ratings (Note 1)

Symbol	Parameter		Rating	Unit
V_{IN}	VIN to GND Voltage	V_{EN}=GND=0V	-0.3 ~ 30	V
		V_{EN} > EN_H	-0.3 ~ 16	V
V_{SW}	SW to VOUT Voltage	> 20ns	-1 ~ V_{IN}+0.3	V
		< 20ns	-3 ~ 18	V
V_{EN}	EN to GND Voltage		-0.3 ~ 15	V
V_{MODE}	MODE to VOUT Voltage		-0.3 ~ 7	V
V_{FB}	FB to VOUT Voltage		-0.3 ~ 7	V
V_{BST}	BST to SW Voltage		-0.3 ~ 6	V
T_J	Junction Temperature		-40 ~ 150	°C
T_{STG}	Storage Temperature		-65 ~ 150	°C
T_{SDR}	Maximum Lead Soldering Temperature (10 Seconds)		260	°C

Note 1: Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
θ_{JA}	Junction-to-ambient resistance in free air (Note 2)	50	°C/W
θ_{JC}	Junction-to-case resistance in free air (Note 2)	20	°C/W

Note 2: θ_{JA} and θ_{JC} is measured with the component mounted on a high effective thermal conductivity test board in free air.

Recommended Operating Conditions (Note 3)

Symbol	Parameter	Range	Unit
V_{IN}	VIN to GND Voltage	9 ~ 14	V
V_{EN}	EN to GND Voltage	-0.3 ~ 14	V
V_{MODE}	MODE to VOUT Voltage	-0.3 ~ 6	V
I_{OUT}	Converter Output Current	0 ~ -1	A
T_A	Ambient Temperature	-40 ~ 85	°C
T_J	Junction Temperature	-40 ~ 125	°C

Note 3: Refer to the typical application circuit.

Electrical Characteristics

Unless otherwise specified, these specifications apply over V_{IN}=12V, T_A=25°C.

Symbol	Parameter	Test Conditions	Specification			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
I_{IN}	V_{IN} supply current	SW=NC, V_{FB}=0.85V	-	150	-	uA
I_{SD}	V_{IN} shutdown current	V_{IN}=12V, V_{EN}=0V	-	-	15	
POWER-ON-RESET						
POR_H	V_{IN} POR threshold voltage	V_{IN} rising	-	6.5	-	V
POR_Hys	V_{IN} POR hysteresis voltage	V_{IN} falling	-	2	-	
REFERENCE						
V_{FB}	Reference voltage		-	0.8	-	V
	Output voltage accuracy	T_A=25°C	-1	-	1	%
		-40°C ≦ T_A ≦ 85°C	-1.5	-	1.5	
Leak_FB	FB leakage current	V_{FB}=0.8V	-	-	1	uA
OSCILLATOR AND DUTY CYCLE						
F_{SW}	System operating frequency	MODE pin=Floating (Force PWM)	-	500	-	kHz
	Frequency accuracy	V_{IN}=12V, I_{OUT}= -1A, T_A=25°C	-10	-	10	%
		V_{IN}=12V, I_{OUT}= -1A, T_A= -40°C~85°C	-15	-	15	
MOSFET						
R_{ON}_H	Upper switch resistance	V_{IN}=12V, I_{SW}=0.5A	-	70	-	mΩ
Leak_H	Upper switch leakage current	V_{IN}=26V, V_{SW}=0V	-	-	1	uA
R_{ON}_L	Lower switch resistance	V_{IN}=V_{SW}=12V, I_{SW}=0.5A	-	60	-	mΩ
ON-TIME CONTROL						
T_{ON}	Minimum on time		-	160	-	ns
SOFT-START, ENABLE AND MODE						
T_{SS}	Soft-start time	V_{OUT} from 0V to -12V	-	7	-	ms
EN_H	EN logic high threshold	V_{EN} rising	2	-	-	V
EN_L	EN logic low threshold	V_{EN} falling	-	-	0.8	V
MODE_H	MODE logic high threshold	MODE to VOUT rising	1.4	-	-	V
MODE_Hys	MODE hysteresis	MODE to VOUT falling	-	200	-	mV
PROTECTIONS						
I_{LIM}_H	High-side MOSFET current limit		-	3.8	-	A
I_{LIM}_L	Low-side MOSFET current limit		-	3	-	
V_{IN}_OVP	Input over voltage protection threshold		-	27-|V_{OUT}|	-	V
	Input over voltage protection threshold hysteresis		-	2	-	
V_{OUT}_OVP	Output over voltage threshold		-	120	-	%V_{FB}
	Output over voltage threshold hysteresis		-	10	-	
UVP	Under voltage threshold		-	50	-	%V_{FB}
T_{Hiccup}	Hiccup delay time		-	8xT_{SS}	-	ms
OTP	Over temperature protection		-	150	-	°C
	Over temperature protection hystersis		-	30	-	
BOOTSTRAP POWER						
Leak_BST	BST leakage current	V_{BST} - GND=12V, V_{SW}=12, GND=0V	-	-	0.1	uA

Typical Operating Characteristics

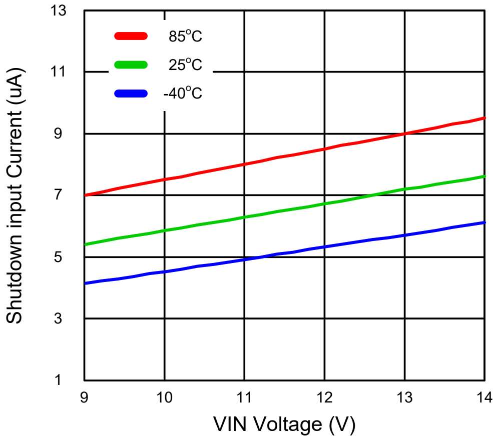


Figure 3. Shutdown Current

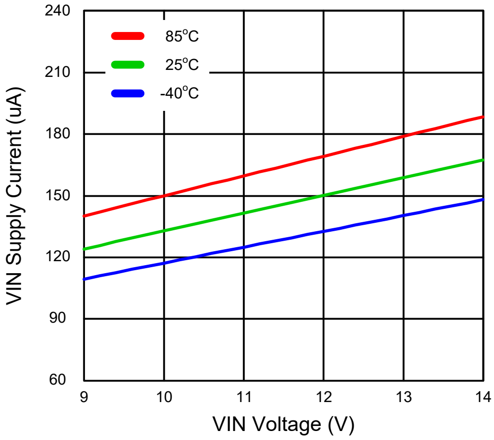


Figure 4. VIN supply Current vs. VIN Voltage

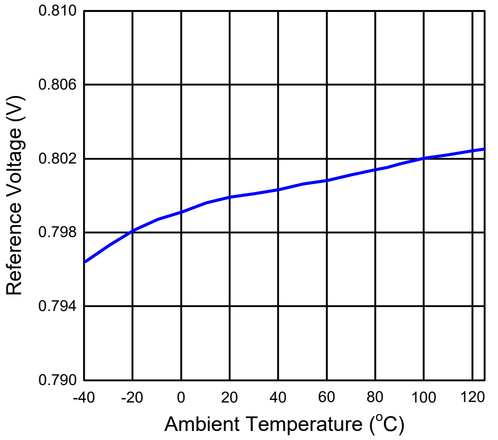


Figure 5. Reference Voltage Accuracy vs. Ambient Temperature

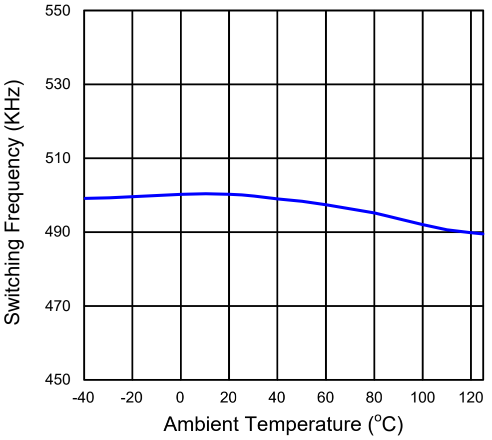


Figure 6. Switching Frequency vs. Ambient Temperature

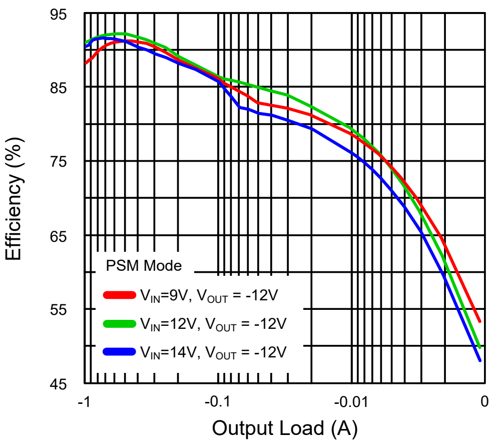
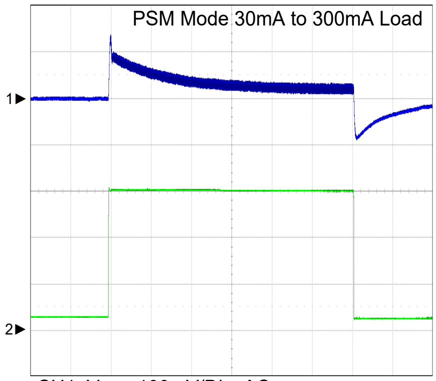


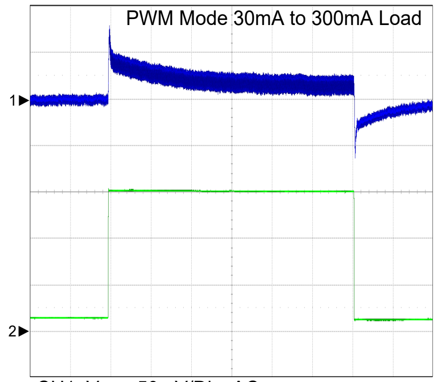
Figure 7. Efficiency

Operating Waveforms



CH1: V_{OUT}, 100mV/Div, AC
CH2: I_L, 100mA/Div, DC
TIME: 200us/Div

Figure 8. PSM Mode 30mA to 300mA Load Transient



CH1: V_{OUT}, 50mV/Div, AC
CH2: I_L, 100mA/Div, DC
TIME: 200us/Div

Figure 9. PWM Mode 30mA to 300mA Load Transient

Typical Application Circuit

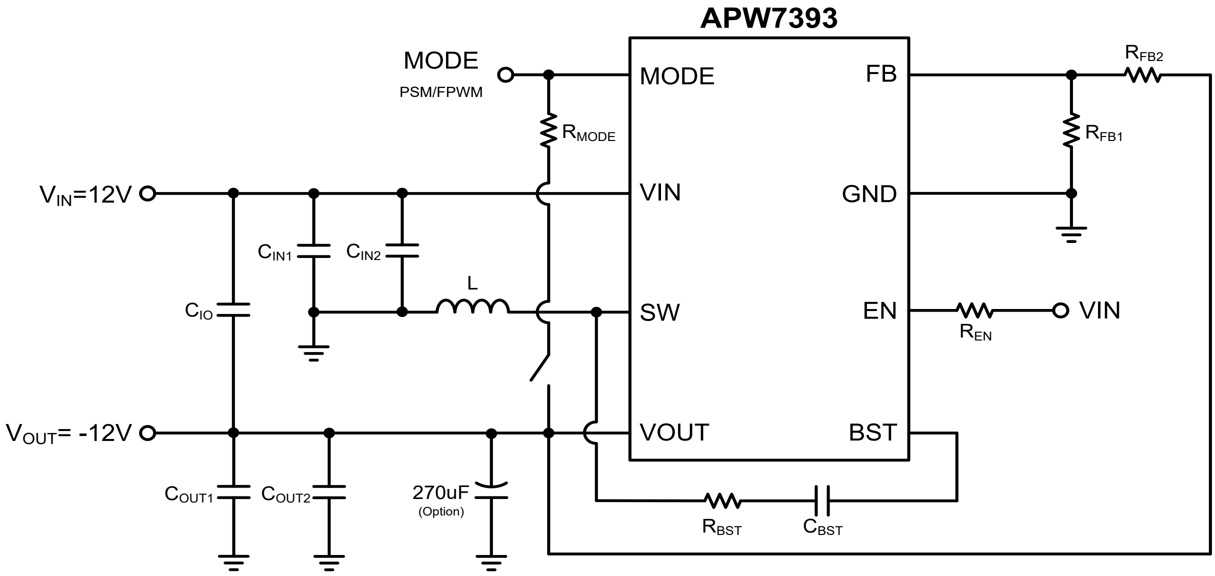


Figure 10. Application Circuit

Components Selection

L	C_{IN1}	C_{IN2}	$C_{OUT1 / OUT2}$	C_{IO}	C_{BST}	R_{BST}	R_{FB1}	R_{FB2}	R_{MODE}	R_{EN}
10uH	10uF/25V	0.1uF/25V	10uF/25V	2.2~10uF/35V	0.1uF/16V	0~10Ω	14kΩ	1kΩ	10kΩ	750kΩ

Pin Descriptions

PIN		FUNCTION
NO.	NAME	
1	MODE	Auto/PWM mode control pin. Floating for force PWM mode, Connecting to V_{OUT} pin for PSM mode.
2	VIN	Power Input. VIN supplies the power to the control circuitry, gate driver. Connecting a ceramic bypass capacitor and suitably large capacitor between VIN and GND eliminates switching noise and voltage ripple on the input to the IC.
3	SW	Power switches output. SW is the source of the N-channel power MOSFET to supply power to the output LC filter.
4	VOUT	Inverting converter output.
5	BST	High-side gate driver boost input. BST supplies the voltage to drive the high-side N-channel MOSFET. At least 0.1uF capacitor should be connected from to BST and supply the high side switch.
6	EN	Enable input. EN is a digital input that turns the regulator on or off. A resistor of 750K must be connected in series to EN pin. EN pin have internal pull low resistor 1MΩ. EN pin can be left floating, the regulator will into shutdown mode.
7	GND	EN signal reference ground.
8	FB	Output voltage feedback input.

Block Diagram

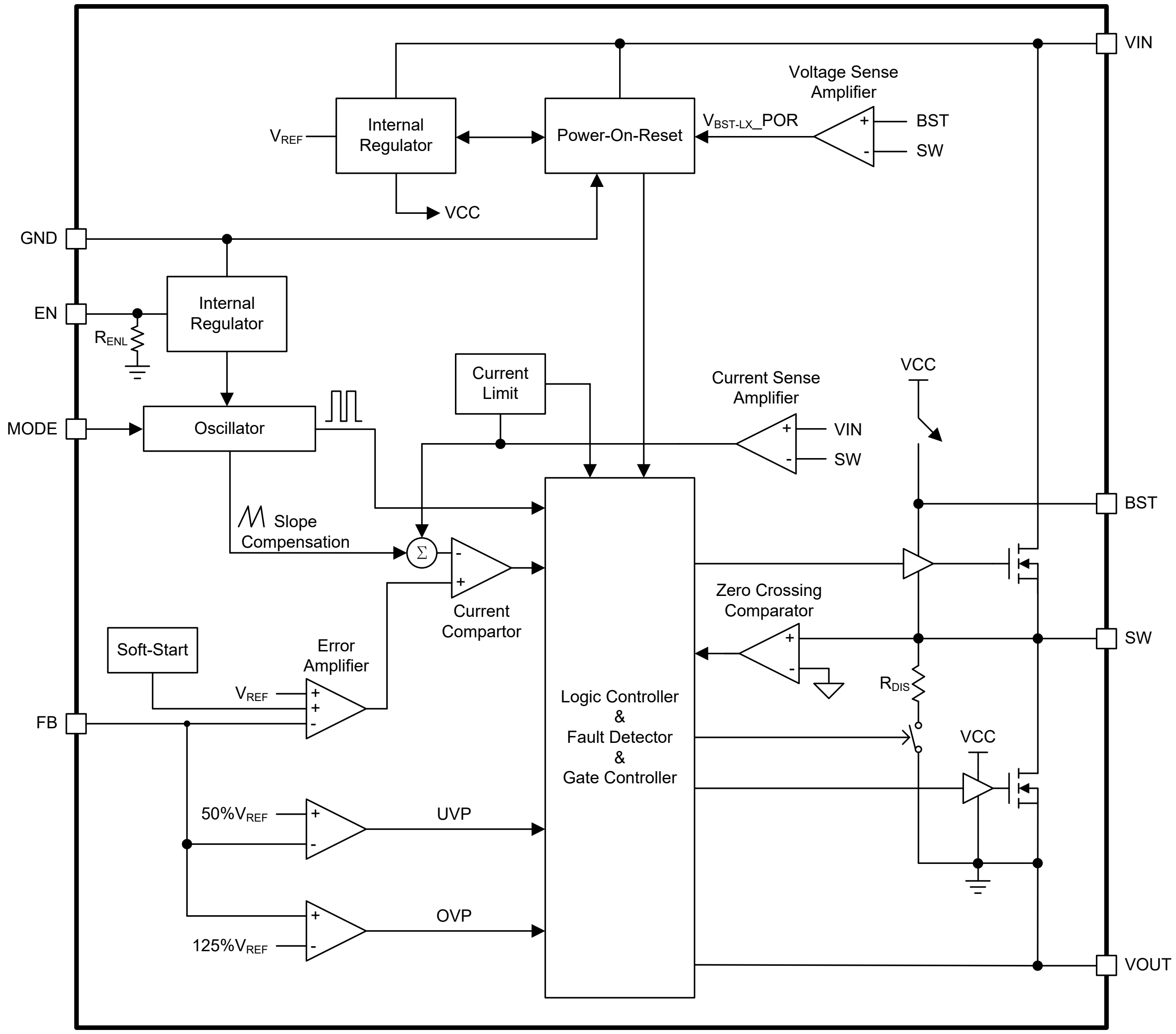


Figure 11. Black Diagram

Function Description

The APW7393 integrates a synchronous PWM controller and high/low side power MOSFETs. It offers the lowest total solution cost that can provide output current up to -1A continuous over wide input supply range from 9V to 14V. The converter runs with current mode PWM operation at high-load condition and automatically reduces frequency to keep excellent efficiency down to several milliamps.

Power-On-Reset

A Power-On-Reset (POR) function is designed to prevent wrong logic controls when the VIN voltage is low. The POR function continually monitors the input supply voltage on the VIN pin if at least one of the enable pins is set high. When the rising VIN voltage reaches the POR_R voltage threshold, the POR signal goes high and the chip initiates soft-start operations. There is a hysteresis to voltage threshold POR_Hys. When VIN voltage drops lower than POR_F, the POR disables the chip.

Soft-Start

The APW7393 has a built-in soft-start function that controls the rise time of the output voltage during start-up to reduce input current surges and prevent output overshoot. The soft-start function will be enabled when any condition that can initiate an output start-up, such as VIN power to the IC and toggle the EN pin, and when the converter is restarted from the OTP, hiccup mode and VIN OVP.

The figure 12 shows V_{OUT} soft-start sequence. When the VIN pin is pulled higher than the VIN_POR voltage, the device initiates a soft-start process to ramp up the output voltage. When VIN initial high, the the EN pin is pulled higher than the EN_H voltage. The device initiates a soft-start process to ramp up the output voltage.

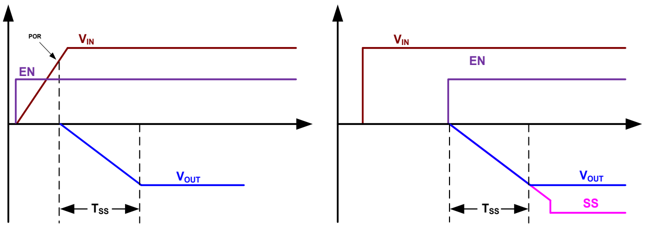


Figure 12. Soft-Start Sequence

Current Limit and Hiccup Protections

The IC monitors the current through the high-side power MOSFET to limits the peak inductor current to prevent IC from being damaged in the event of an overload or short circuit.

The current-limit circuit employs a "peak" current-sensing algorithm (Figure 13). The APW7393 use the internal High-side MOSFET's R_{DS}(ON) of the synchronous rectifier as a current-sensing element. If the magnitude of the current-sense signal at SW pin is above the current limit threshold, the PWM is not allowed to initiate a new cycle. The actual peak current is greater than the current limit threshold by an amount equals to the inductor ripple current. Therefore, the exact current-limit characteristic and maximum load capability are the functions of the sense resistance, inductor value, and input voltage.

The PWM controller uses the internal High-side MOSFETs on-resistance R_{DS}(ON) to monitor the current for protection against shortened outputs. The cycle by cycle current limit threshold is $3.8A_{(Typ)}$ for APW7393.

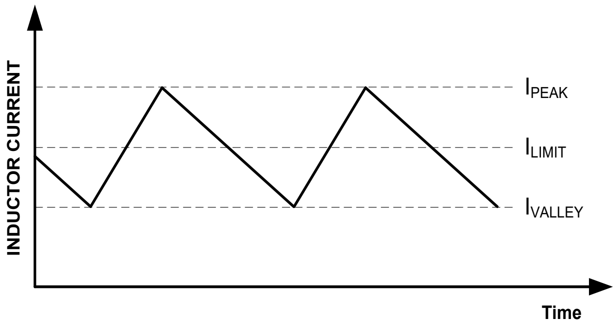


Figure 13. Current Limit Express

When the current limit protection is activated, the output current will be limited and the output voltage will drop. When the output voltage drops below the UVP threshold, UVP is triggered and the converter enters hiccup mode. In hiccup mode, the converter will restart periodically. This protection mode is especially useful when the output is shorted to ground. The average short-circuit current is greatly reduced to alleviate thermal issues and protect he IC. Once the over-current condition is removed, the IC will exit the hiccup mode.

Input and Output Over Voltage Protections (OVP)

The input over-voltage function monitors the input voltage. When VIN rising voltage exceeds the VIN OVP threshold voltage 27-$|V_{OUT}|$, the converter will turn off. If VIN voltage drops lower then VIN OVP hysteresis $2V_{(Typ)}$, converter will be restarted. The output over-voltage function monitors the output voltage by FB pin. Once the voltage V_{FB} exceeds $120\%_{(Typ)}$ of the reference voltage $0.8V_{(Typ)}$, the over-voltage protection comparator forces the high-side and low-side MOSFETs off.

Function Description (Cont.)

Thermal Shutdown

A thermal shutdown circuit limits the junction temperature of APW7393. When the junction temperature exceeds 150°$C_{(Typ)}$, the PWM converter is shut off, allowing the device to cool down. The regulator regulates the output again through initiation of a new soft-start cycle after the junction temperature cools by 30°$C_{(Typ)}$, resulting in a pulsed output during continuous thermal overload conditions. The thermal shutdown designed with a 30°$C_{(Typ)}$ hysteresis lowers the average junction temperature during continuous thermal overload conditions, extending life time of the device.

For normal operation, device power dissipation should be externally limited so that junction temperatures will not exceed 125°C.

Application Information

Input Capacitor Selection

Because converters have a pulsating input current, a low ESR input capacitor is required. This results in the best input voltage filtering, minimizing the interference with other circuits caused by high input voltage spikes.
Also, the input capacitor must be sufficiently large to stabilize the input voltage during heavy load transients. For good input voltage filtering, usually a 10uF input capacitor is sufficient. It can be increased without any limit for better input-voltage filtering. Ceramic capacitors show better performance because of the low ESR value, and they are less sensitive against voltage transients and spikes compared to tantalum capacitors. Place the input capacitor as close as possible to the input and GND of the device for better performance.

Inductor Selection

For high efficiencies, the inductor should have a low DC resistance to minimize conduction losses. Especially at high-switching frequencies, the core material has a higher impact on efficiency. When using small chip inductors, the efficiency is reduced mainly due to higher inductor core losses. This needs to be considered when selecting the appropriate inductor. The inductor value determines the inductor ripple current. Larger the inductor value, smaller the inductor ripple current, lower the conduction losses of the converter. Conversely, larger inductor values cause a slower load transient response. A reasonable starting point for setting ripple current, ΔI_L, is 40% of maximum output current. The recommended inductor value can be calculated as below:

$$L = \frac{V_{IN}}{F_{SW} \times \Delta I_L} \times \frac{|V_{OUT}|}{V_{IN} \times \eta + |V_{OUT}|}$$

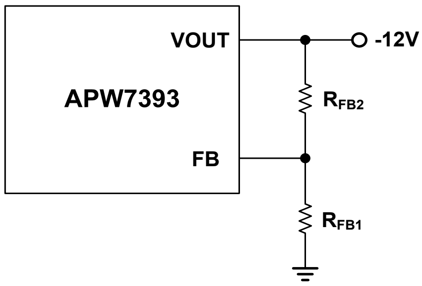
$$\eta = \text{Efficiency}$$

$$I_{L(MAX)} = I_{OUT(MAX)} + \frac{1}{2}\Delta I_L$$

To avoid saturation of the inductor, the inductor should be rated at least for the maximum output current of the converter plus the inductor ripple current.
Recommended inductor part number: MMD-05AH-100M-X2.

Output Voltage Setting

The output voltage is set by a resistive divider. The external resistive divider is connected to the output, allowing remote voltage sensing as shown in “Typical Application Circuits”. A suggestion of maximum value of R2 is 14kΩ to keep the minimum current that provides enough noise rejection ability through the resistor divider. The output voltage can be calculated as below:



$$|-V_{OUT}| = V_{REF} \times \left(1 + \frac{R_{FB1}}{R_{FB2}}\right)$$

Figure 14. Output Voltage Setting

Output Capacitor Selection

The current-mode control scheme of the APW7393 allows the use of tiny ceramic capacitors. The higher capacitor value provides the good load transients response. Ceramic capacitors with low ESR values have the lowest output voltage ripple and are recommended. If required, tantalum capacitors may be used as well. The output ripple is the sum of the voltages across the ESR and the ideal output capacitor. When choosing the output ceramic capacitors, choose the X5R or X7R dielectric formulations. These dielectrics have the best temperature and voltage characteristics of all the ceramics for a given value and size. On the application circuit the need used the bypass capacitor C_{IO} to tightly coupled. Using 2.2uF to 10uF ceramic capacitor is better. It must be noted that, VIN to VOUT voltage is V_{IN}+ $|-V_{OUT}|$. So this C_{IO} need to enough endurance.

Application Information (Cont.)

Layout Considerations

For all switching power supplies, the layout is an important step in the design; especially at high peak currents and switching frequencies. If the layout is not carefully done, the regulator might show noise problems and duty cycle jitter.

1. The input capacitor should be placed close to the VIN and GND. Connecting the capacitor and VIN/GND with short and wide trace without any via holes for good input voltage filtering. The distance between VIN/GND to capacitor less than 2mm respectively is recommended.
2. To minimize copper trace connections that can inject noise into the system, the inductor should be placed as close as possible to the SW pin to minimize the noise coupling into other circuits.
3. The output capacitor should be place closed to converter VOUT and GND.
4. Since the feedback pin and network is a high impedance circuit the feedback network should be routed away from the inductor to minimize noise coupling into this circuit.
5. A star ground connection or ground plane minimizes ground shifts and noise is recommended.

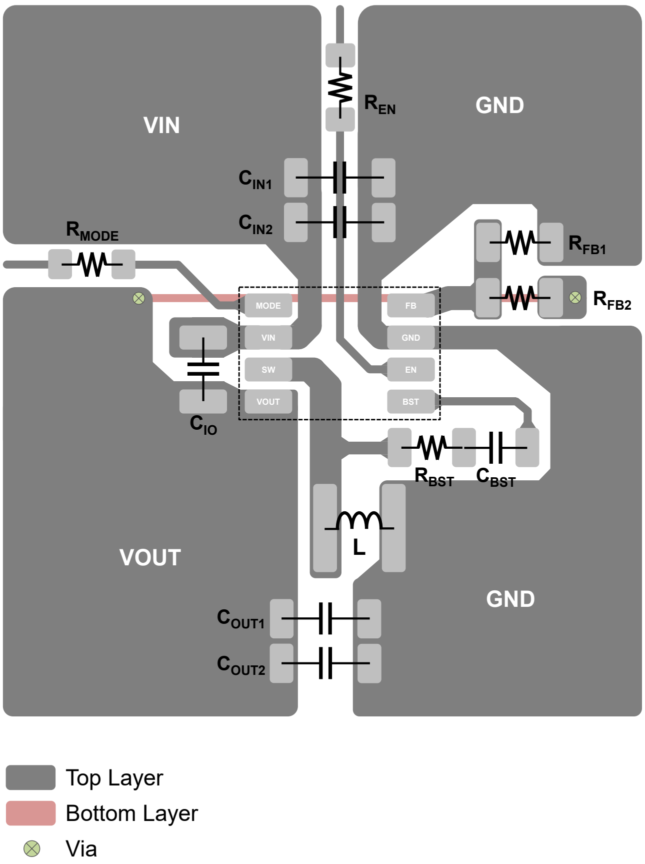
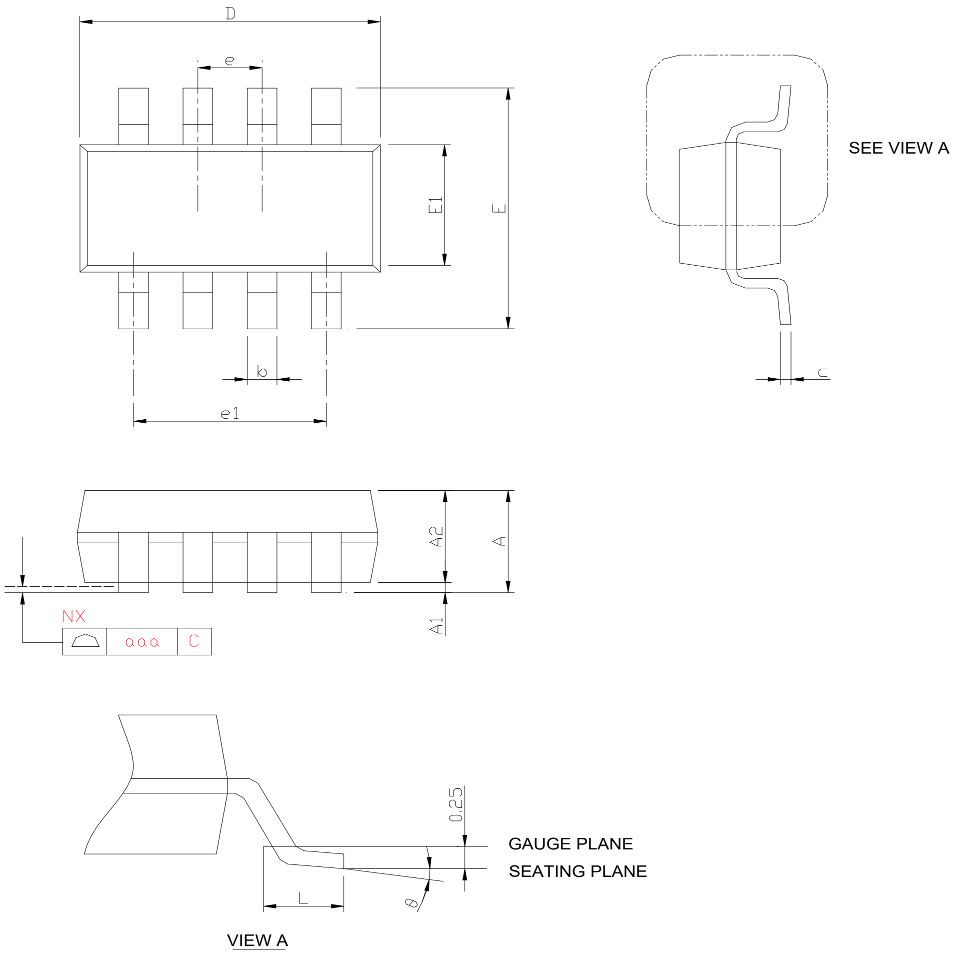


Figure 15. Layout Considerations Top View

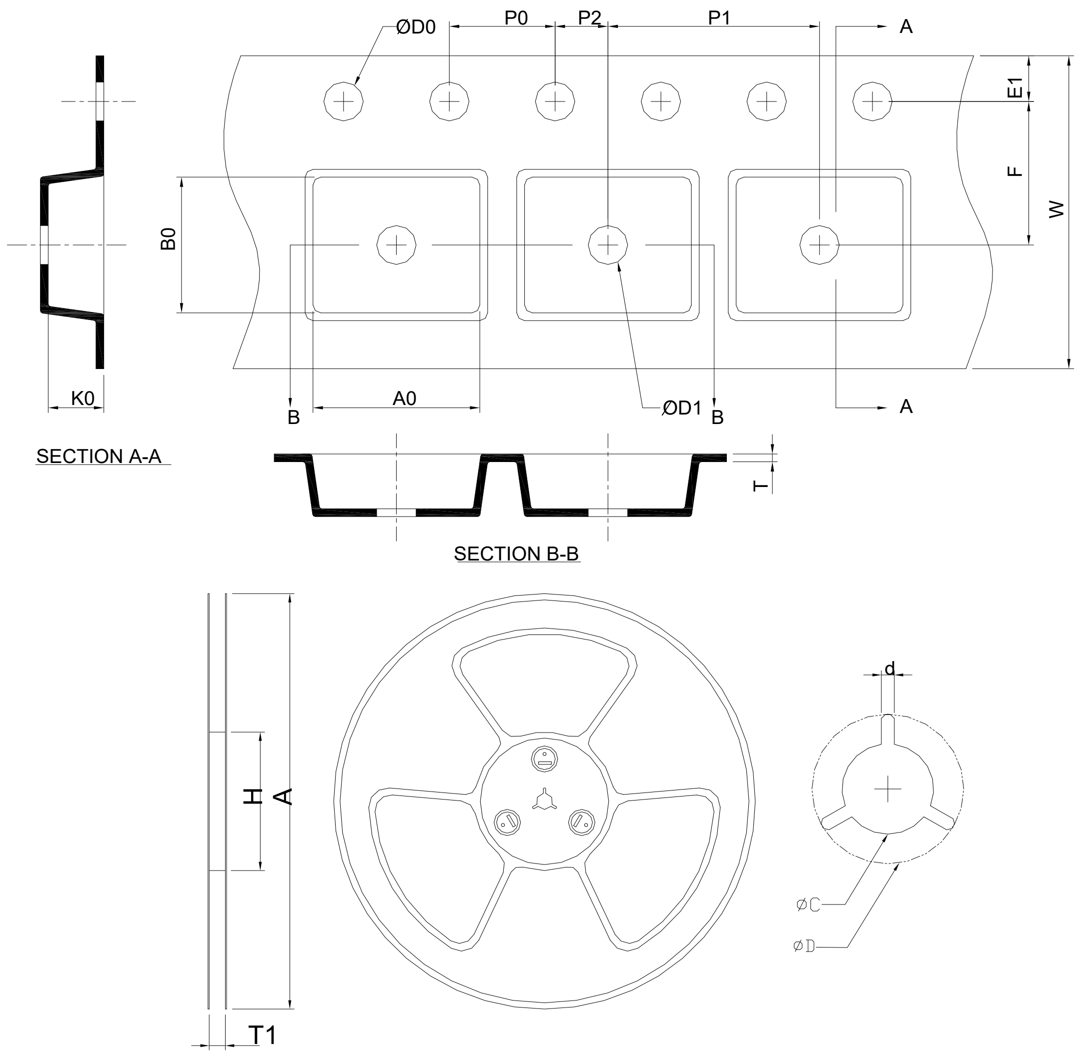
Package Information

TSOT-23-8(A)



SYMBOL	TSOT-23-8A			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	1.00	0.028	0.039
A1	0.01	0.10	0.000	0.004
A2	0.70	0.90	0.028	0.035
b	0.22	0.40	0.009	0.016
c	0.08	0.20	0.003	0.008
D	2.70	3.10	0.106	0.122
E	2.60	3.00	0.102	0.118
E1	1.40	1.80	0.055	0.071
e	0.65 BSC		0.026 BSC	
e1	1.95 BSC		0.077 BSC	
L	0.30	0.60	0.012	0.024
θ	0°	8°	0°	8°
aaa	0.10		0.004	

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
TSOT-23-8	178.0±2.00	50 MIN.	8.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	8.0±0.30	1.75±0.10	3.5±0.05
	P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
	4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.0 MIN.	0.6+0.00 -0.40	3.20±0.20	3.10±0.20	1.20±0.20

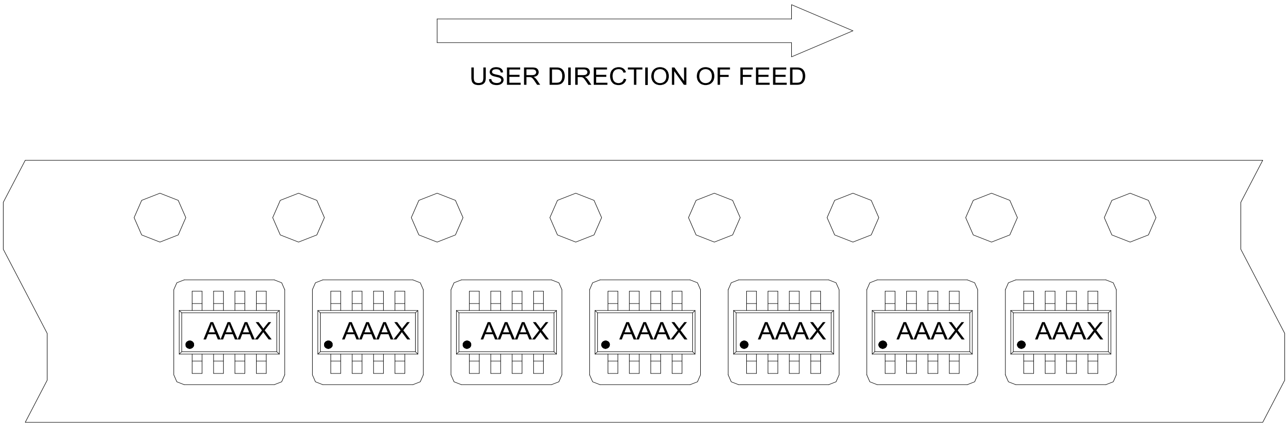
(mm)

Devices Per Unit

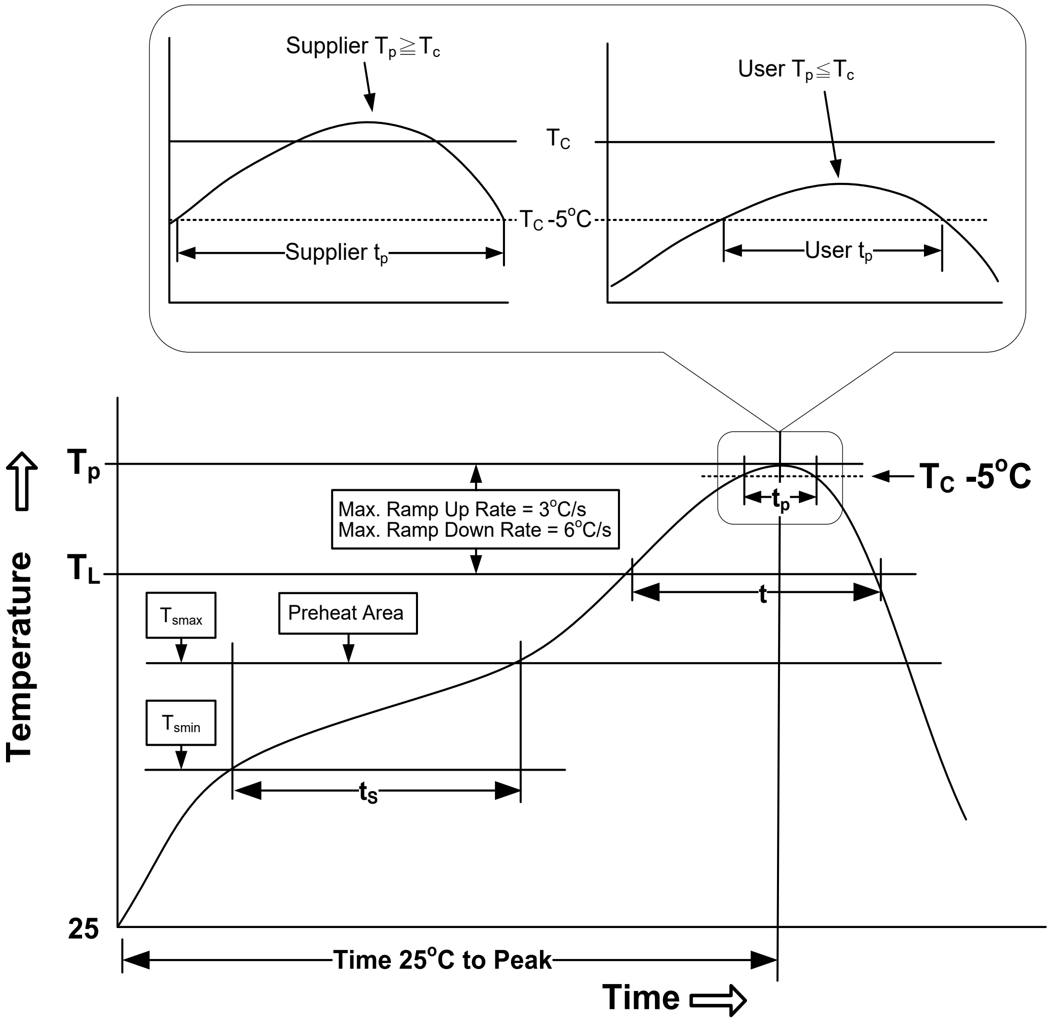
Package type	Packing	Quantity
TSOT-23-8(A)	Tape & Reel	3000

Taping Direction Information

TSOT-23-8(A)



Classification Profile



Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	100°C 150°C 60-120 seconds	150°C 200°C 60-120 seconds
Average ramp-up rate (T_{smax} to T_P)	3°C/second max.	3°C/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	183°C 60-150 seconds	217°C 60-150 seconds
Peak package body Temperature (T_p)*	See Classification Temp in table 1	See Classification Temp in table 2
Time (t_P)** within 5°C of the specified classification temperature (T_c)	20** seconds	30** seconds
Average ramp-down rate (T_p to T_{smax})	6°C/second max.	6°C/second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.
* Tolerance for peak profile Temperature (T_p) is defined as a supplier minimum and a user maximum. ** Tolerance for time at peak profile temperature (t_p) is defined as a supplier minimum and a user maximum.		

Note: ANPEC's green products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature.

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

Package Thickness	Volume mm³ <350	Volume mm³ ≥350
<2.5 mm	235°C	220°C
≥2.5 mm	220°C	220°C

Table 2. Pb-free Process – Classification Temperatures (Tc)

Package Thickness	Volume mm³ <350	Volume mm³ 350-2000	Volume mm³ >2000
<1.6 mm	260°C	260°C	260°C
1.6 mm – 2.5 mm	260°C	250°C	245°C
≥2.5 mm	250°C	245°C	245°C

Reliability Test Program

Test Item	Method	Description
SOLDERABILITY	JESD-22, B102	5 Sec, 245°C
HOLT	JESD-22, A108	1000 Hrs, Bias @ T_j=125°C
PCT	JESD-22, A102	168 Hrs, 100%RH, 2atm, 121°C
TCT	JESD-22, A104	500 Cycles, -65°C~150°C
HBM	MIL-STD-883-3015.7	VHBM ≧ 2KV
MM	JESD-22, A115	VMM ≧ 200V
Latch-Up	JESD-78	10ms, 1_{tr} ≧ 100mA

Customer Service

Anpec Electronics Corp.
Head Office :
No.6, Duxing 1st Rd., East Dist.,
Hsinchu City 300096, Taiwan (R.O.C.)
Tel : 886-3-5642000
Fax : 886-3-5642050

Taipei Branch :
2F, No.11, Ln. 218, Sec. 2, Zhongxing Rd., Xindian Dist.,
New Taipei City 231037, Taiwan (R.O.C.)
Tel : 886-2-2910-3838
Fax : 886-2-2917-3838