1.8MHZ,1A,SYNCHRONOUS SWITCHING BUCK REGULATOR

FEATURES

- **Up to 95% Efficiency**
- **2.5V to 5.5V Input Voltage Range**
- **1.8MHz Switching Frequency**
- **25μA Ultra Low Sleep Mode Quiescent**
- **<1μA Shutdown Current**
- **Internal Compensation Circuit**
- **500μs Soft Start Period**
- **160°C Built-in Thermal Shutdown Protection**

APPLICATIONS

- **Portable Navigation Device**
- **Digital Photo Frame**
- **Digital Still Camera**
- **E-Book**

GENERAL DESCRIPTION

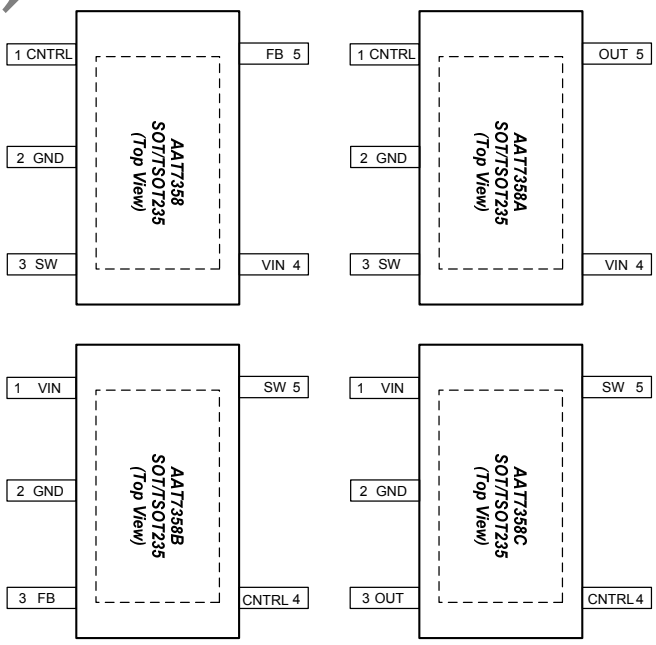
The AAT7358/ AAT7358A/ AAT7358B/ AAT7358C device is a 1.8MHz, high efficiency, synchronous buck regulator incorporating both Light Load Mode and PWM mode operation.

With an automatic Light Load Mode / PWM mode switching mechanism, the AAT7358/ AAT7358A/ AAT7358B/ AAT7358C device provides 80% efficiency under light load operation and up to 90% efficiency during heavy load condition.

The featured input voltage range of AAT7358/ AAT7358A/ AAT7358B/ AAT7358C provides flexibility for different applications.

The AAT7358/ AAT7358A/ AAT7358B/ AAT7358C is implemented in a 5-pin SOT23-5 /TSOT23-5 package.

PIN CONFIGURATION



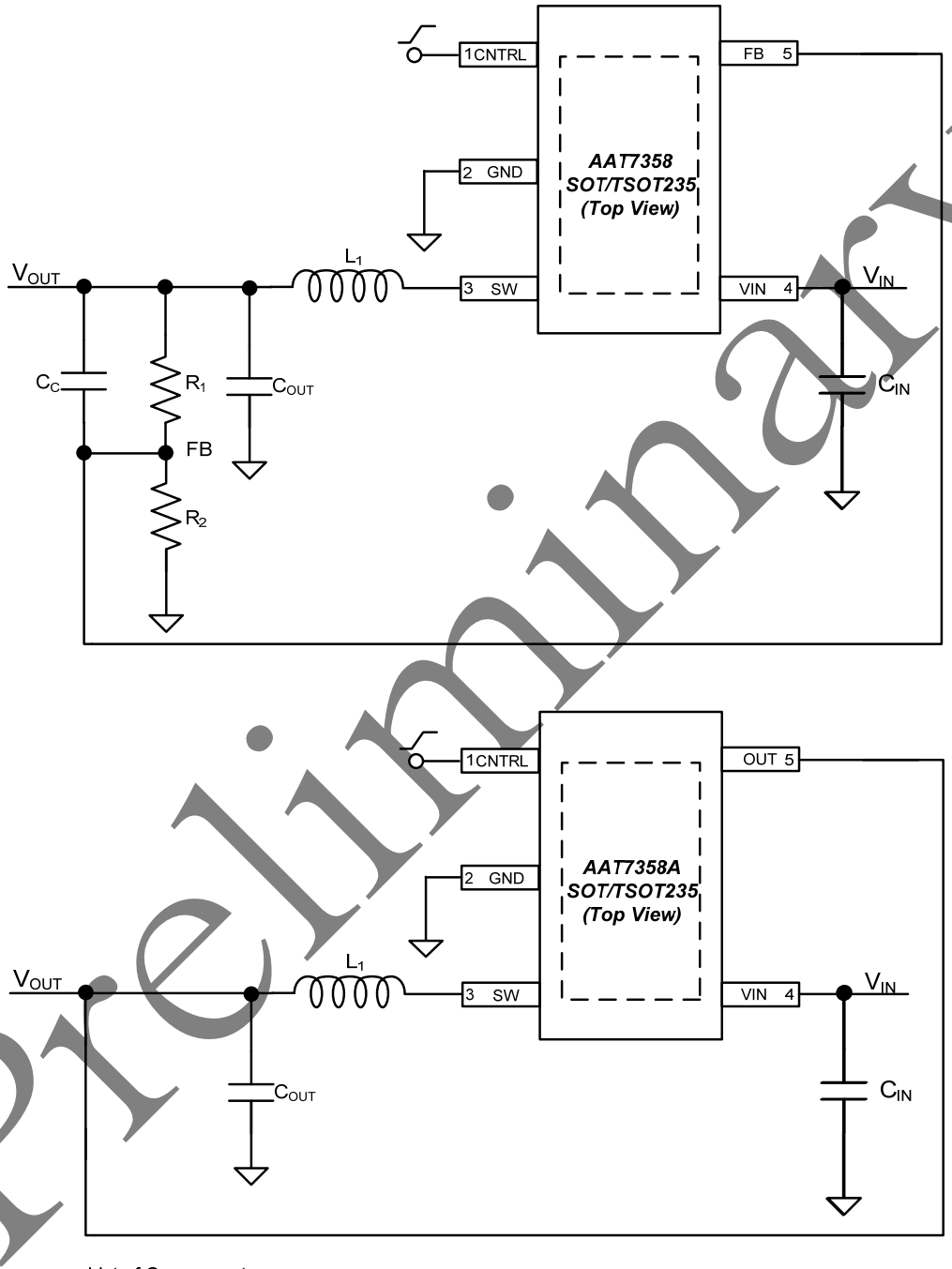
ORDERING INFORMATION

DEVICE TYPE	PART NUMBER	PACKAGE	PACKING	TEMP. RANGE	MARKING	MARKING DESCRIPTION
AAT7358	AAT7358-S5-T	S5: SOT235	T: Tape and Reel	–40°C to +85°C	C07 YYY	C07 = AAT7358, YYY = tracing code, AAA, AAB, AAC…
AAT7358	AAT7358-S18-T	S18: TSOT235	T: Tape and Reel	–40°C to +85°C	C07 YYY	
AAT7358B	AAT7358B-S5-T	S5: SOT235	T: Tape and Reel	–40°C to +85°C	C22 YYY	C22 = AAT7358B, YYY = tracing code, AAA, AAB, AAC…
AAT7358B	AAT7358B-S18-T	S18: TSOT235	T: Tape and Reel	–40°C to +85°C	C22 YYY	
AAT7358A	AAT7358XXA-S5-T	S5: SOT235	T: Tape and Reel	–40°C to +85°C	C5X YYY	C5X = AAT7358A , 1. Lot No. : YYY = tracing code, AAA , AAB, AAC… 2. X= Voltage Code:
AAT7358A	AAT7358XXA-S18-T	S18: TSOT235	T: Tape and Reel	–40°C to +85°C	C5X YYY	
AAT7358C	AAT7358XXC-S5-T	S5: SOT235	T: Tape and Reel	–40°C to +85°C	C6X YYY	C6X = AAT7358C , 1. Lot No. : YYY = tracing code, AAA , AAB, AAC… 2. X= Voltage Code:
AAT7358C	AAT7358XXC-S18-T	S18: TSOT235	T: Tape and Reel	–40°C to +85°C	C6X YYY	

Voltage Code	Input Voltage (V)
K	1.0
M	1.2
T	1.8
U	2.5
X	3.3

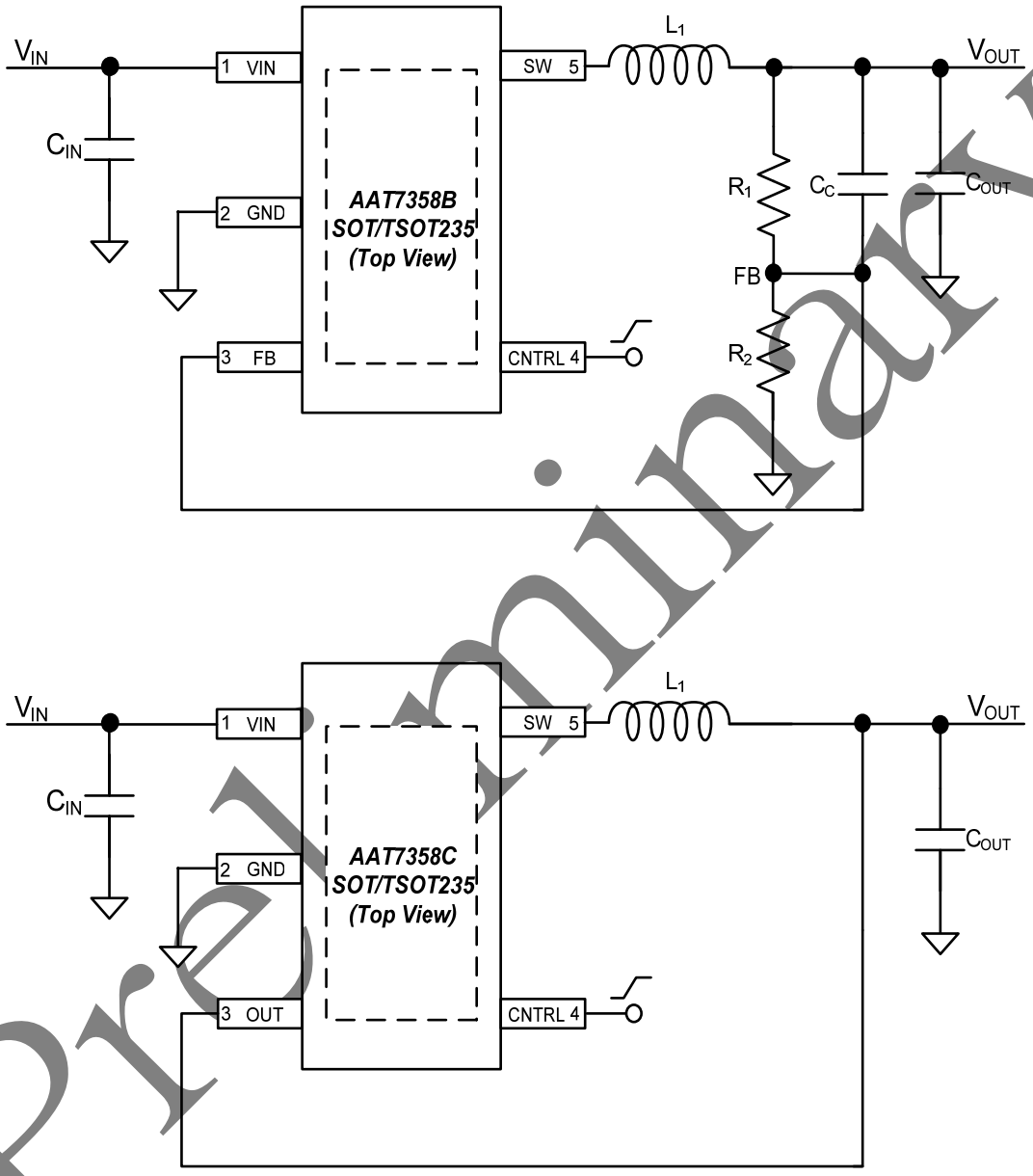
Note 1: Note: All AAT products are lead free and halogen free.
(XX stands for Input voltage.)

TYPICAL APPLICATION



List of Components:
- L_1 = 2.2µH
- C_{IN} = C_{OUT} = 10µF
- R_1 = R_2 = 100kΩ (For V_{OUT}=1.2V)
- C_C=20pF

TYPICAL APPLICATION



List of Components:

- L_1 = 2.2µH
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- R_1 = R_2 = 100kΩ (For V_{OUT}=1.2V)
- C_C=20pF

ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	VALUE	UNIT
Power Supply Voltage (VIN)	V_{IN}	–0.3 to +7.0	V
Switch Point Voltage (SW)	V_{SW}	–0.3 to +7.0	V
Output Voltage (VOUT)	V_{OUT}	–0.3 to (V_{IN} +0.3)	V
Logic Input Voltage (EN)	V_{CTL}	–0.3 to (V_{IN} +0.3)	V
Feedback Voltage (FB)	V_{FB}	–0.3 to (V_{IN} +0.3)	V
Ground (GND)	V_{PGND}	–0.3 to +0.3	V
Junction Temperature	T_J	150	°C
Operating Temperature Range	T_C	–40 to +85	°C
Storage Temperature Range	$T_{STORAGE}$	–65 to +150	°C
Power Dissipation, P_d @ T_C = 25°C , SOT23-5 Package	P_d	0.364	W
Power Dissipation, P_d @ T_C = 25°C , TSOT23-5 Package	P_d	0.364	W
Thermal Resistance Junction to Ambient, SOT23-5 Package	Θ_{JA}	275	°C /W
Thermal Resistance Junction to Ambient, TSOT23-5 Package	Θ_{JA}	275	°C /W
Lead Temperature (Soldering 10 sec)	T_{SOLDER}	260	°C

Note 1: Stresses above those listed under ABSOLUTE MAXIMUM RATINGS may cause permanent damage to the devices.
Note 2: Exposure to ABSOLUTE MAXIMUM RATINGS conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN	MAX	UNIT
Operating Ambient Temperature	T_C	–40	+85	°C
Power Supply Voltage	V_{IN}	2.5	5.5	V

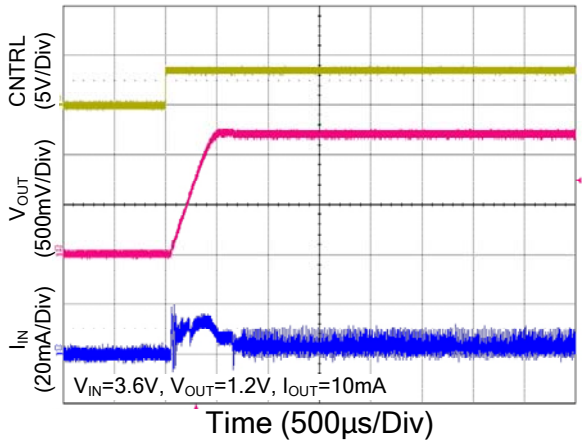
ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, V_{OUT} = 1.2V, T_C = –40°C to +85°C .Unless Otherwise Specified. Typical values are tested at 25°C ambient temperature.)

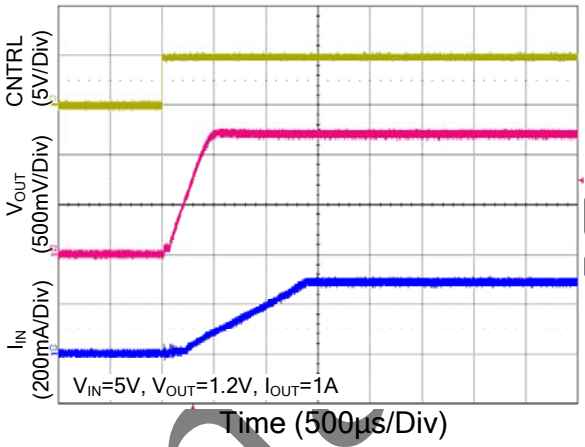
PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Supply Voltage	V_{IN}		2.5	-	5.5	V
Feedback Voltage	V_{FB}	Load = 300mA, T_C = 25°C (AAT7358, AAT7358B)	0.588	0.600	0.612	V
Output Voltage Accuracy	V_{OUT}	Load = 300mA, T_C = 25°C (AAT7358A, AAT7358C)	–2	-	+2	%
Supply Quiescent Current	I_{PWM}	V_{FB} = 0.5V, Mode = High, I_{LOAD} = 0A	-	-	300	µA
	I_{PFM}	V_{FB} = 0.7V, Mode = Low, I_{LOAD} = 0A	-	-	30	µA
	I_{SD}	V_{EN} = 0V, V_{IN} = 5.5V	-	0.01	1.00	µA
Peak Inductor Current	I_{PK}		-	1.5	-	A
Output Temperature Variation		T_C = –40°C to+85°C Load = 300mA	–2	-	+2	%
Reference Voltage Line Regulation	ΔV_{FB}	V_{IN} = 2.5V to 5.5V	-	-	0.4	%/V
Output Voltage Load Regulation	$V_{LOADREG}$		-	0.5	-	%
P Channel Power FET ON Resistance	R_{PDSON}	I_{SW} = 100mA	-	0.25	-	Ω
N Channel Power FET ON Resistance	R_{NDSON}	Guaranteed by Design	-	0.25	-	Ω
Switching Frequency	f_{OSC}		1.45	1.80	2.20	MHz
Enable Input Rising Voltage Threshold	V_{EN}		0.3	1.0	1.5	V
Enable Input Current	I_{EN}		-	±0.01	±1.00	µA
ISW Leakage Current	I_{LSW}	V_{EN} = 0V, V_{SW} = 0V or 5.5V, V_{IN} = 5.5V	-	±0.01	±1.00	µA
Soft Start Period	$t_{SOFTSTART}$		-	500	-	µs
Thermal Shutdown	T_{SD}		140	160	180	°C
Thermal Shutdown Hysteresis	T_{HYS}		10	20	35	°C

TYPICAL OPERATING CHARACTERISTICS

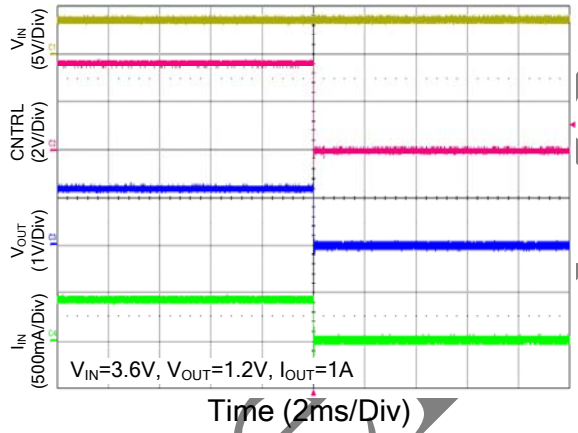
Power on with CNTRL



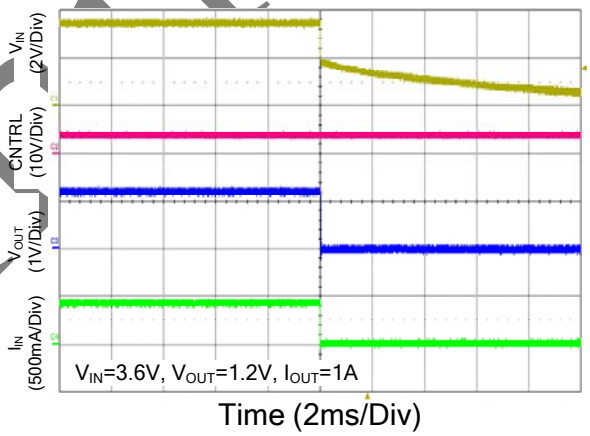
Power on with CNTRL



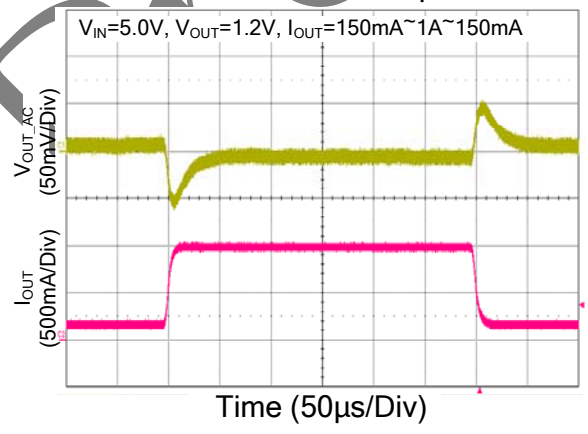
Power off with CNTRL



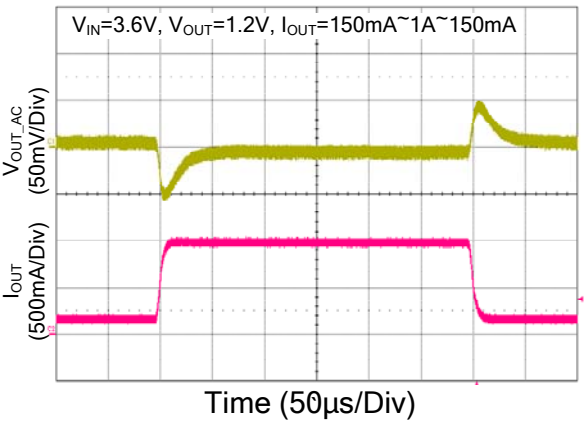
Power off with V_{IN}



Load Transient Response

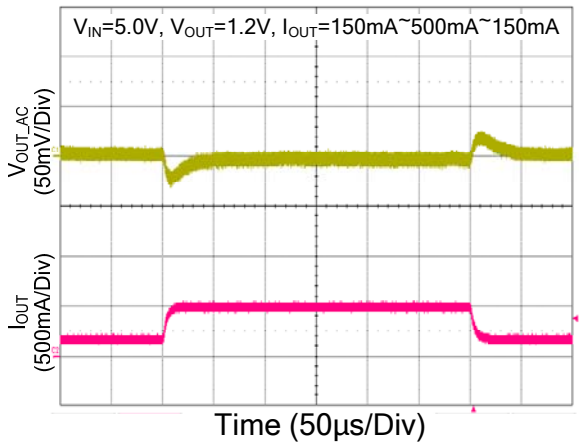


Load Transient Response

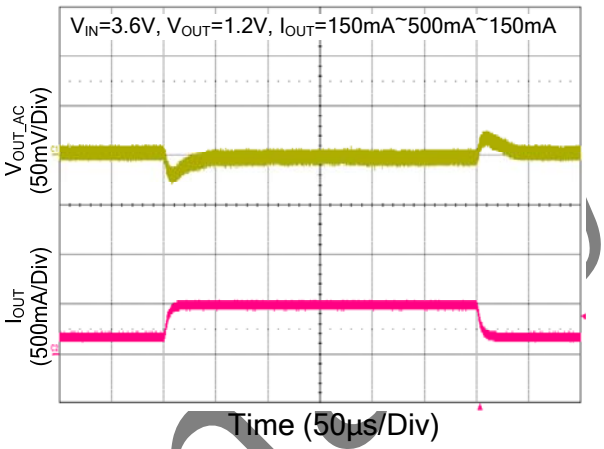


TYPICAL OPERATING CHARACTERISTICS

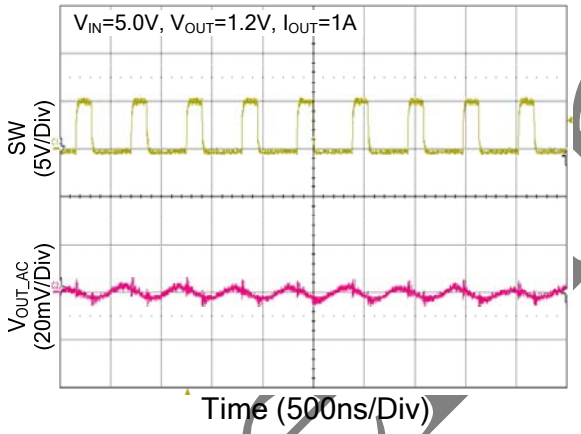
Load Transient Response



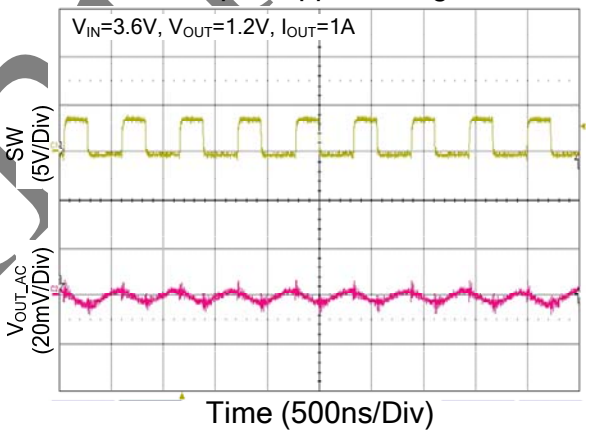
Load Transient Response



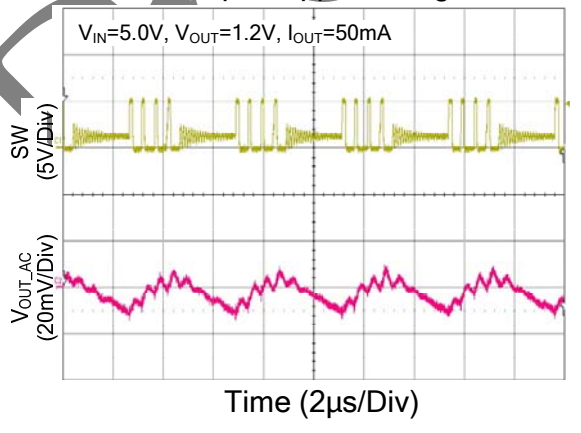
Output Ripple Voltage



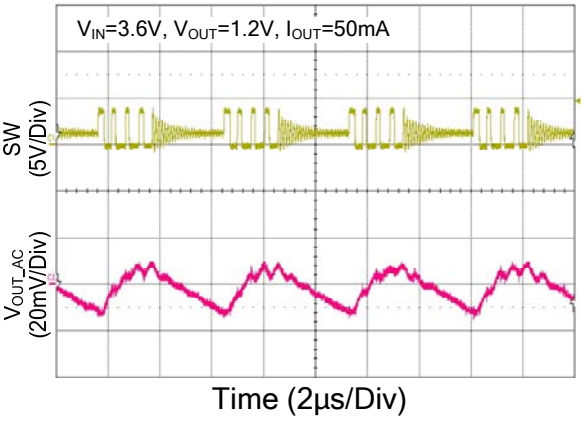
Output Ripple Voltage



Output Ripple Voltage



Output Ripple Voltage



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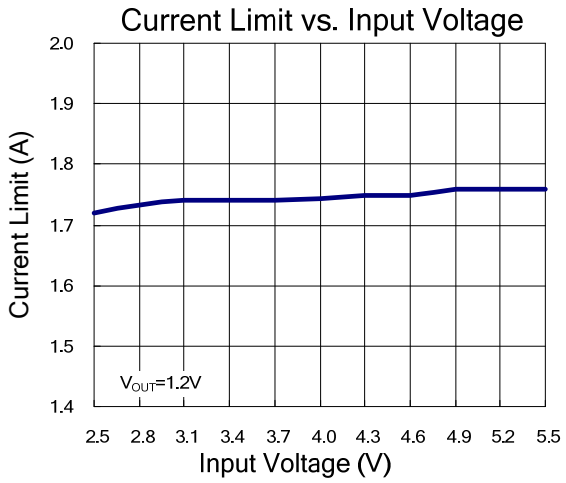
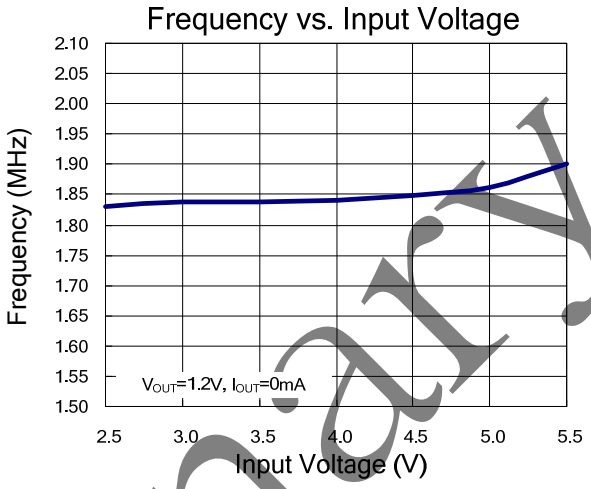
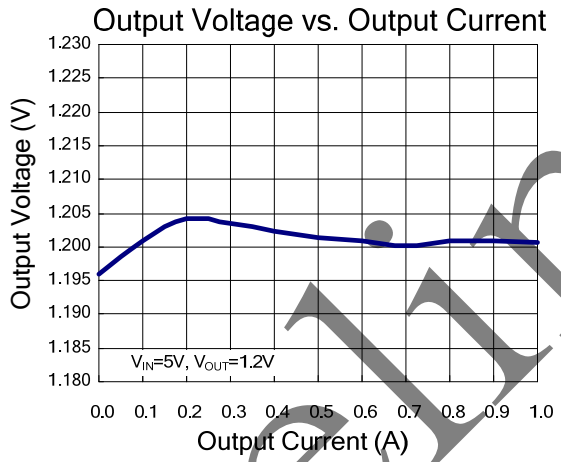
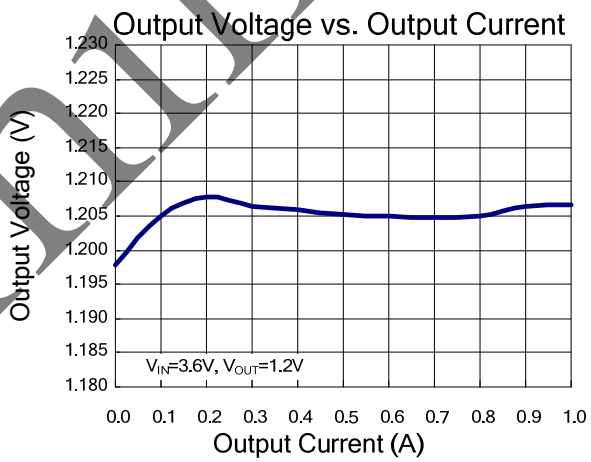
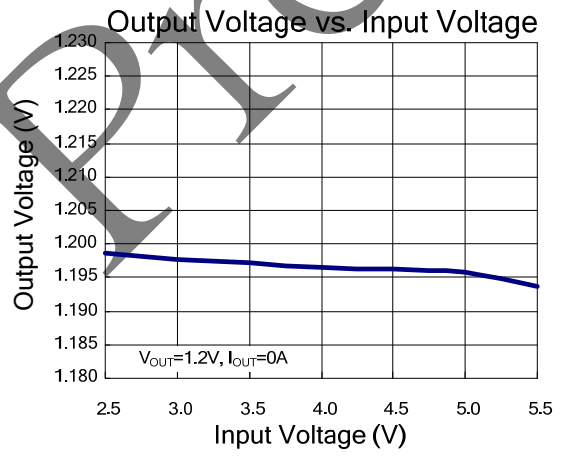
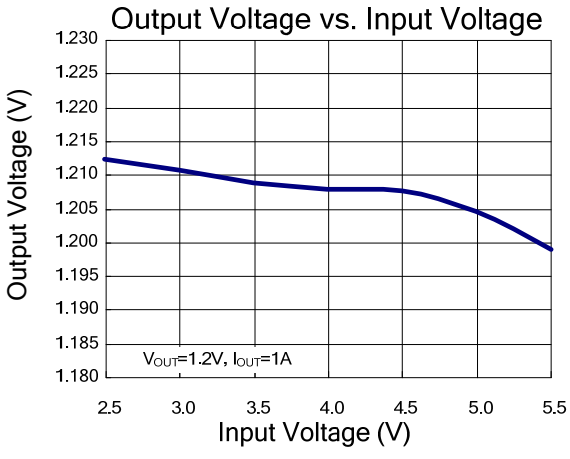




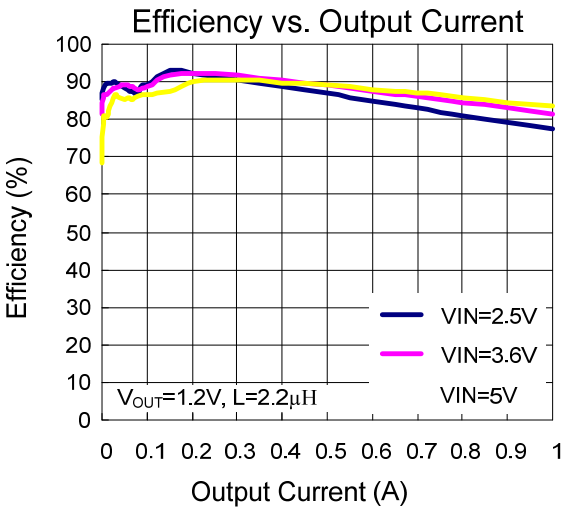


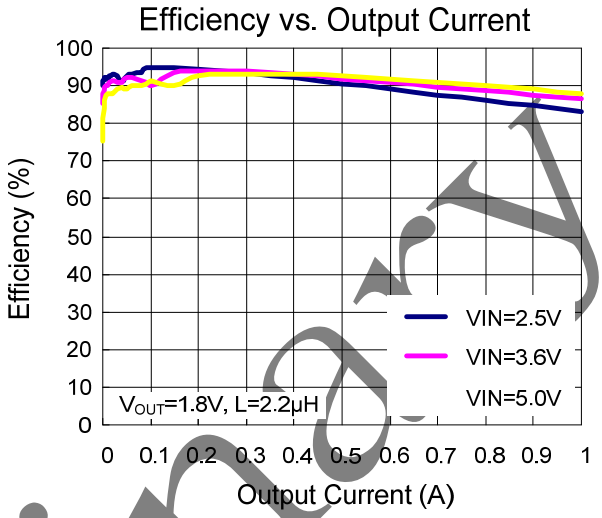


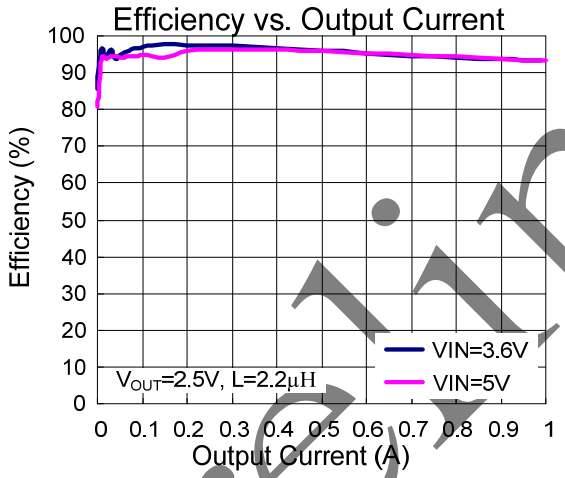




TYPICAL OPERATING CHARACTERISTICS





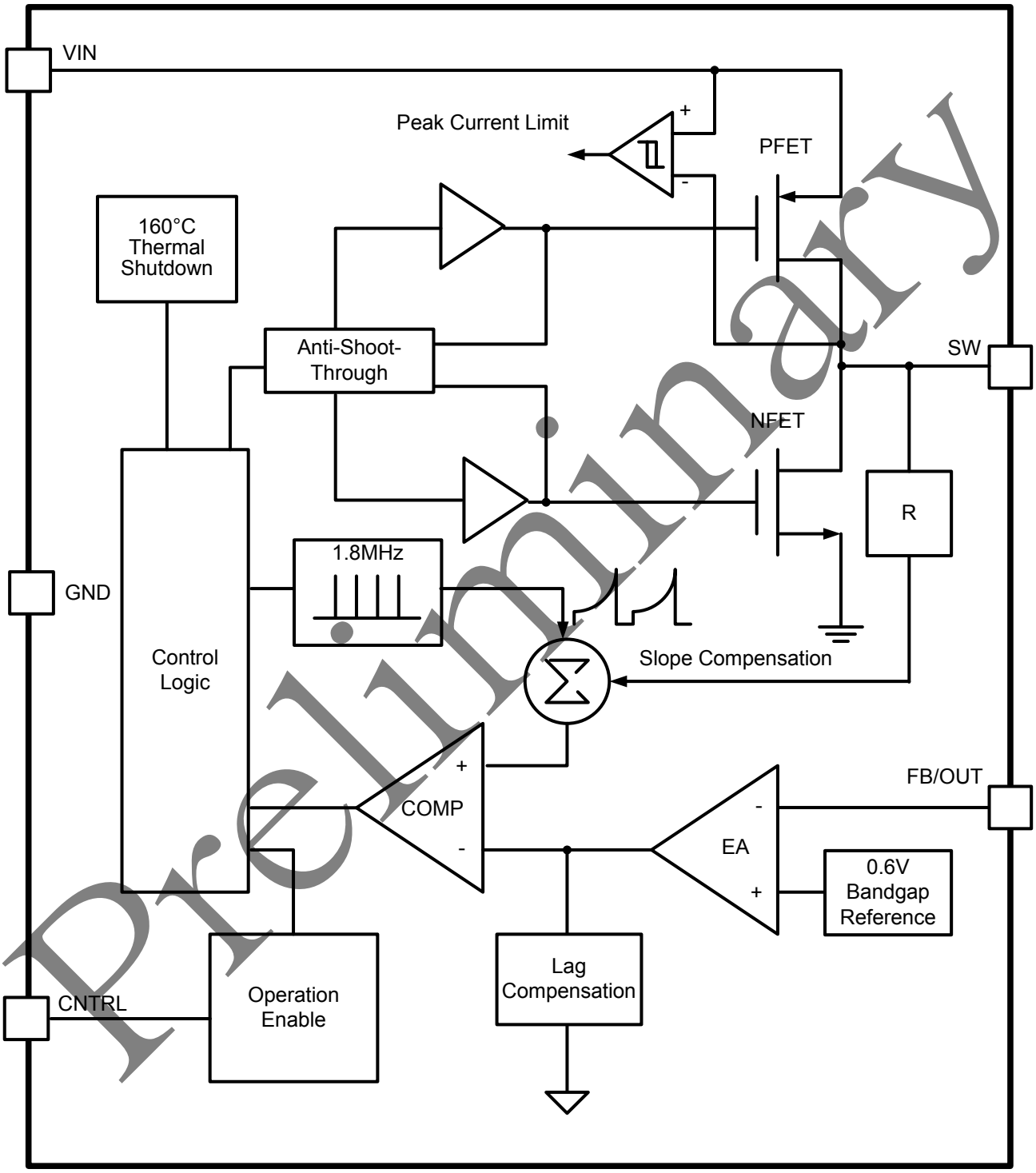


PIN DESCRIPTION

Pin No.	Name AAT7358/ AAT7358A	I/O	Description
1	CNTRL	I	Enable logic Input Pin. Pull the voltage at this pin above V_{CTLH} to enable the device.
2	GND	-	System/PWR Ground Pin. Connect this pin to a clean ground.
3	SW	O	Regulator Switching Output Pin. SW is connected to the drain terminals of the internal power MOSFETs. Connect this pin to the regulated output through a 2.2µH inductor.
4	VIN	I	Power Supply Input Pin. Connect this pin to a Li^+–Ion battery or an equivalent power source. Connecting VIN to ground through a 10µF bypass capacitor is recommended.
5	FB/ OUT	I/O	Feedback Pin (Output pin).The regulator output voltage can be programmed with an external resistor feedback loop connected between this pin and the regulated output (AAT7358).

Pin No.	Name AAT7358B/ AAT7358C	I/O	Description
1	VIN	I	Power Supply Input Pin. Connect this pin to a Li^+–Ion battery or an equivalent power source. Connecting VIN to ground through a 10µF bypass capacitor is recommended.
2	GND	-	System/PWR Ground Pin. Connect this pin to a clean ground.
3	FB /OUT	I/O	Feedback Pin (Output pin). The regulator output voltage can be programmed with an external resistor feedback loop connected between this pin and the regulated output (AAT7358B).
4	CNTRL	I	Enable logic Input Pin. Pull the voltage at this pin above V_{CTLH} to enable the device.
5	SW	O	Regulator Switching Output Pin. SW is connected to the drain terminals of the internal power MOSFETs. Connect this pin to the regulated output through a 2.2µH inductor.

FUNCTION BLOCK DIAGRAM



DETAILED DESCRIPTION

The AAT7358/ AAT7358A/ AAT7358B/ AAT7358C is a buck converter with current-mode operation. The AAT7358/ AAT7358A/ AAT7358B/ AAT7358C includes a high-side PFET and a low-side NFET which eliminate the need for an external Schottky diode and have low on-resistance to maximize efficiency. Moreover, the AAT7358/ AAT7358A/ AAT7358B/ AAT7358C is compensated internally so that no external compensation network is required.

PWM Mode Operation

AAT7358/ AAT7358A/ AAT7358B/ AAT7358C uses the peak current mode pulse width modulation (PWM) control scheme for fast transient response and cycle-by-cycle current limiting (Figure 1.). The PWM maintains a constant frequency and varies the duty ratio according to the output voltage and load current. This modulation scheme provides high efficiency at medium to heavy load conditions, and reduces the output ripple at light load conditions. In this operating mode, the PFET turns on each cycle for a minimum on-time of 25ns (typ.), and turns off when an internal sawtooth signal exceeds the error amplifier output (EO). The sawtooth signal is composed of the sensed inductor current and an artificial slope compensation ramp to prevent oscillation at duty ratios higher than 50%. After the high-side PFET is turned off, the low-side NFET is turned on until the next cycle begins. (Figure 2.) demonstrates the PWM mode control scheme.

PWM CCM Typical Waveform

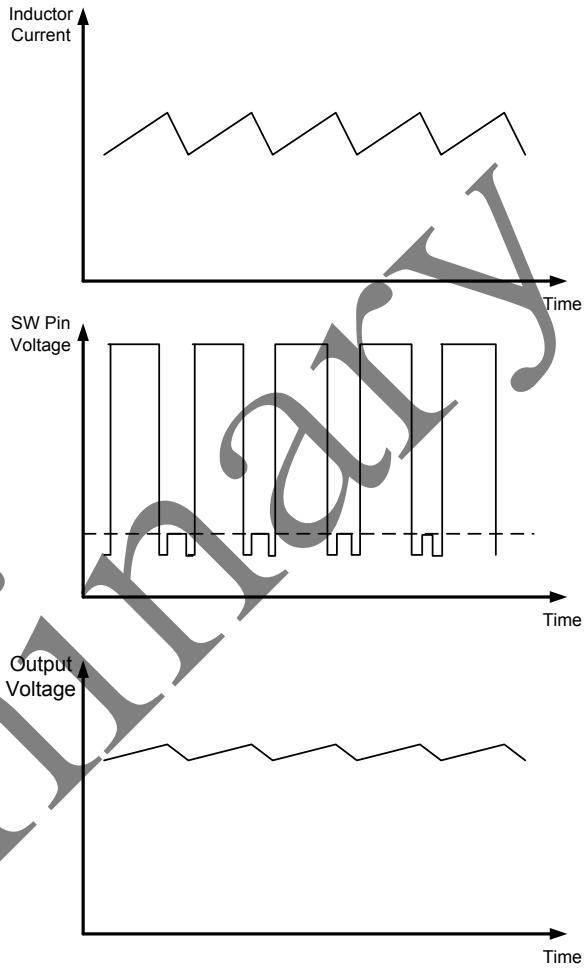


Figure 1. PWM Mode Operation Signal Waveforms

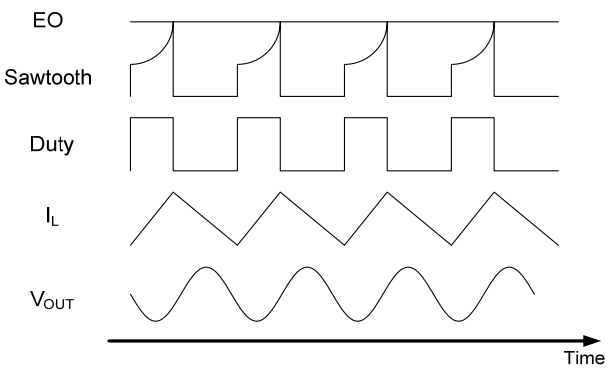


Figure 2. PWM Mode Control Signal Waveforms

Enable

The Control (CNTRL) pin allows user to enable and disable the converter for purposes such as power-up sequencing. When CNTRL is pulled above 1.5V, the converter is enabled, the internal reference circuit wakes up, and the system initiates the soft-start operation. When CNTRL is pulled below 0.3V, the converter is disabled, both the PFET and the NFET are turned off, and the output capacitor is discharged.

Soft-Start

The AAT7358/ AAT7358A/ AAT7358B/ AAT7358C has built-in soft-start mechanism to minimize the inrush current during start-up. Once the voltage at the CNTRL pin rises above 1.5V, the device begins to charge the output capacitor with pulses of increasing duty cycle. The soft-start duration typically lasts 500µs and varies depending on V_{IN}, V_{OUT}, and the load. A typical output voltage waveform during soft-start is shown in Figure 3.

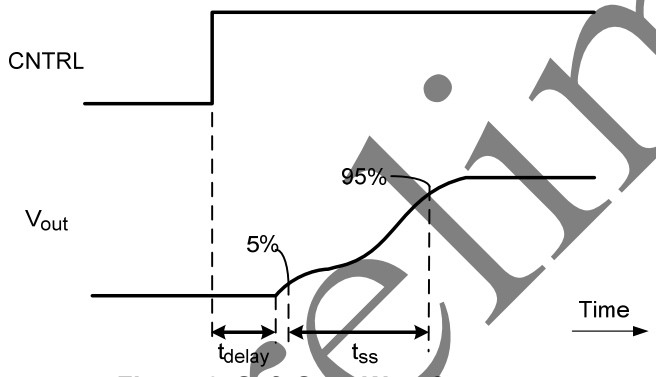


Figure 3: Soft-Start Waveform

Thermal Shut Down

The AAT7358/ AAT7358A/ AAT7358B/ AAT7358C provides a built-in thermal protection function. The thermal shutdown threshold temperature is 160°C (typ.) with a 15°C (typ.) hysteresis.

OCP and SCP

When the load current exceeds the typical operation threshold, the peak inductor current is clamped at 1.5A for over-current protection (OCP). If the OCP signal remains high and the voltage at the FB pin falls below 0.2V (typ.), The short circuit protection (SCP) is triggered and the AAT7358/ AAT7358A/ AAT7358B/ AAT7358C is disabled to protect the device itself and its peripheral circuitry.

Once the SCP function is triggered, the device can be re-started by first pulling the CNTRL pin low then high again.

Light Load Mode Operation

The AAT7358/ AAT7358A/ AAT7358B/ AAT7358C is implemented with an highly efficient light load operation mode, which is activated during light load condition, typically at load current below 100mA (varies with V_{IN} and V_{OUT}). In a light load condition, the system is only awake temporarily to charge the output and maintain its level around the nominal value, while most circuits are usually turned-off to conserve energy. The precision comparator sets the system sleep/wake-up thresholds, and controls the output ripple to typically below 3% of the nominal value.

DESIGN PROCEDURE

Output Voltage Programming

The output voltage is set by the external voltage divider (refer to Typical Application Circuit):

$$V_{OUT} = \frac{R1 + R2}{R2} \times V_{REF}$$

Where V_{REF} is the internal reference voltage of 0.6V.

Compensation Information

The parasitic capacitance at the FB pin forms a pole with the external voltage divider resistors. A feedfoward capacitor (Cc) is recommended to cancel out this pole. The value of Cc can be determined by the following equation:

$$Cc = \frac{C_{PARASITIC} \times (R1 // R2)}{R1 - (R1 // R2)}$$

Where $C_{PARASITIC}$ = 20pF (typ.).

Inductor Selection

The typical value of inductor is 2.2µH. The selection of inductor affects system performance under different operating conditions. The inductor is rated by its equivalent series resistance (ESR) and saturation current. A lower ESR of the inductor results in higher efficiency for the buck converter. A lower inductance inductor results in larger inductor current ripple and output voltage ripple. The inductor current ripple and maximum output current under steady-state can be calculated by the following:

$$\Delta I_L = \frac{V_{IN} - V_{OUT}}{L} \times \frac{V_{OUT}}{V_{IN}} \times \frac{1}{f_s}$$

$$I_{L\_MAX} = I_{O\_MAX} + \frac{\Delta I_L}{2}$$

Where ΔI_L is the peak-to-peak inductor current ripple, I_{L_MAX} is the maximum inductor current, L is the inductor value, f_S is the switching frequency (1.8MHz typ.), and I_{O_MAX} is the maximum output current. During heavy load transients, the maximum inductor current will rise above that calculated value, thus it is recommended to choose an inductor with rated saturation current larger than the calculated value.

Input and Output Capacitor Selection

In PWM mode, the supply current into high-side PFET is a square wave of duty cycle V_{OUT}/V_{IN}. A low ESR input capacitor with proper RMS current rating is required to prevent large voltage transients. The maximum RMS capacitor current is calculated as follows:

$$I_{RMS\_IN} \cong I_{O\_MAX} \times \frac{\sqrt{V_{OUT}(V_{IN} - V_{OUT})}}{V_{IN}}$$

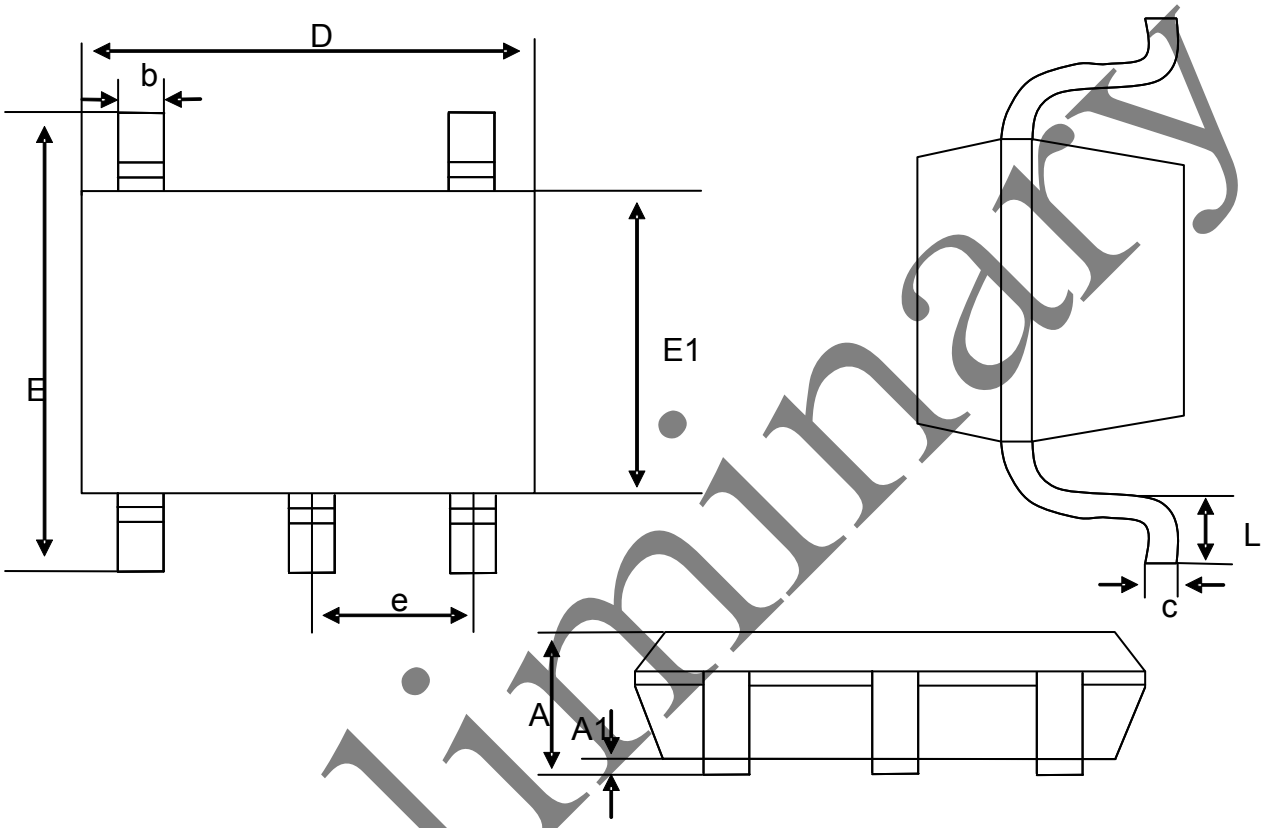
The typical value of the output capacitor is 10µF. A lower ESR and larger capacitance of the output capacitor results in a smaller output voltage ripple. The output voltage ripple consists of voltage spikes caused by the output capacitor ESR and voltage ripples from inductor current ripple that charges and discharges the output capacitor:

$$\Delta V_{OUT} \cong \Delta I_L \left(ESR + \frac{1}{8 \times fs \times C_{OUT}} \right)$$

Ceramic capacitors are recommended due to their high ripple current rating, high voltage rating and low ESR. Typically the RMS current rating will meet the application requirement.

PACKAGE DIMENSION

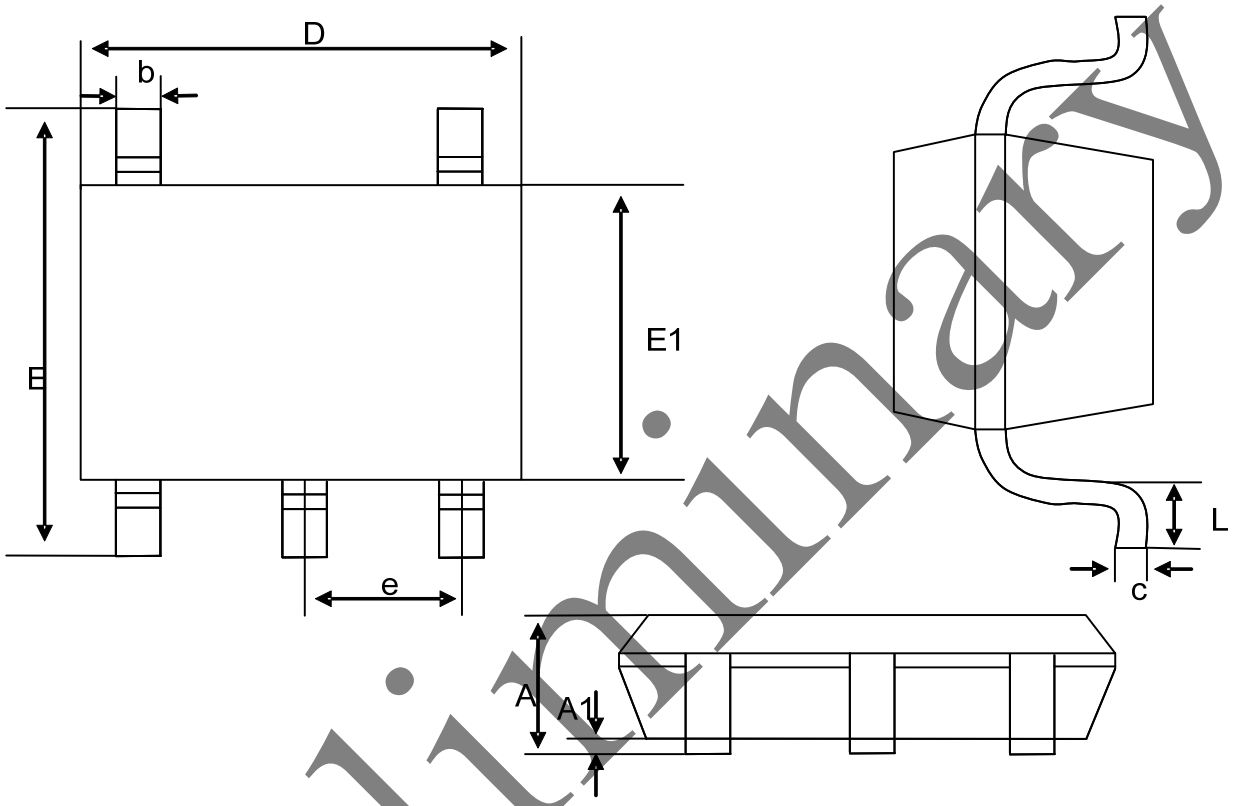
SOT23-5 (SOT25)



Symbol	Dimensions In Millimeters		
	MIN	TYP	MAX
A	0.90	-----	1.30
A1	0.05	-----	0.15
b	0.30	-----	0.50
c	0.08	-----	0.20
D	2.70	2.90	3.10
E	2.60	2.80	3.00
E1	1.40	1.60	1.80
e	0.85	0.95	1.05
L	0.35	0.45	0.55

PACKAGE DIMENSION

TSOT23-5 (TSOT25)



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