杰力科技股份有限公司
Excelliance MOS Corporation

EM5845

5V, 3.5A, 1MHz, High Efficiency COT Mode Synchronous Buck Converter

General Description

The EM5845 is a high efficiency synchronous buck converter. It can support 3.5A continuous output current. The constant on-time control provides fast transient response and allows a small footprint when designed all ceramic output capacitors. Other features include internal soft-start, under-voltage protection, over-voltage protection, cycle-by-cycle current limit and thermal shutdown function. With aforementioned functions, these parts provide customers a compact, high efficiency, well-protected and cost-effective solutions. These parts are available in DFN3X3 package.

Ordering Information

Part Number	Package	Remark
EM5845VT	DFN3X3-10L	Diode Emulation Mode

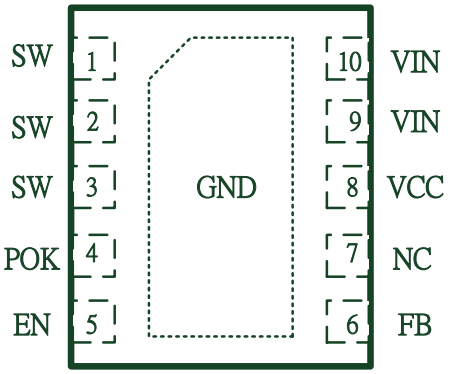
Features

- Constant On Time Control
- 2.7V to 5.5V Operating Input Range
- 0.6V, 1% Voltage Reference Accuracy
- Up to 3.5A Output Current
- Stable with Low ESR Output Ceramic Capacitors
- Default 1 MHz frequency operation
- Internal Soft Start / Soft Stop
- 80m and 40m Internal Power MOSFET Switches
- Cycle-by-Cycle Current Limit
- Output Under Voltage Protection
- Output Over Voltage Protection
- Power Good Indicator for Power Sequence Control
- Available in a DFN3X3 Package

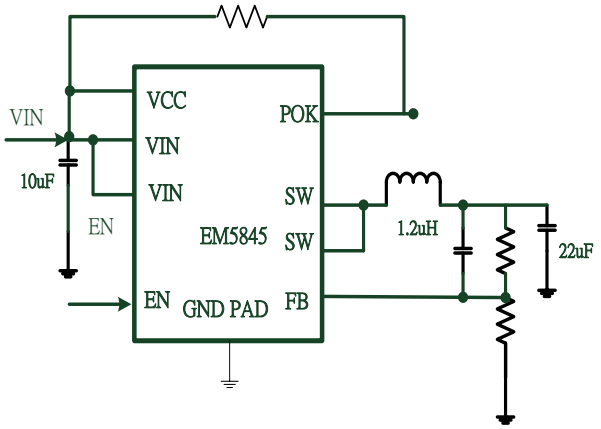
Applications

- Notebook & Tablet
- Graphic Cards & MB
- Low Voltage Logic Supplies
- Chipset Supplies
- Server System
- SMPS Post Regulators

Pin Configuration



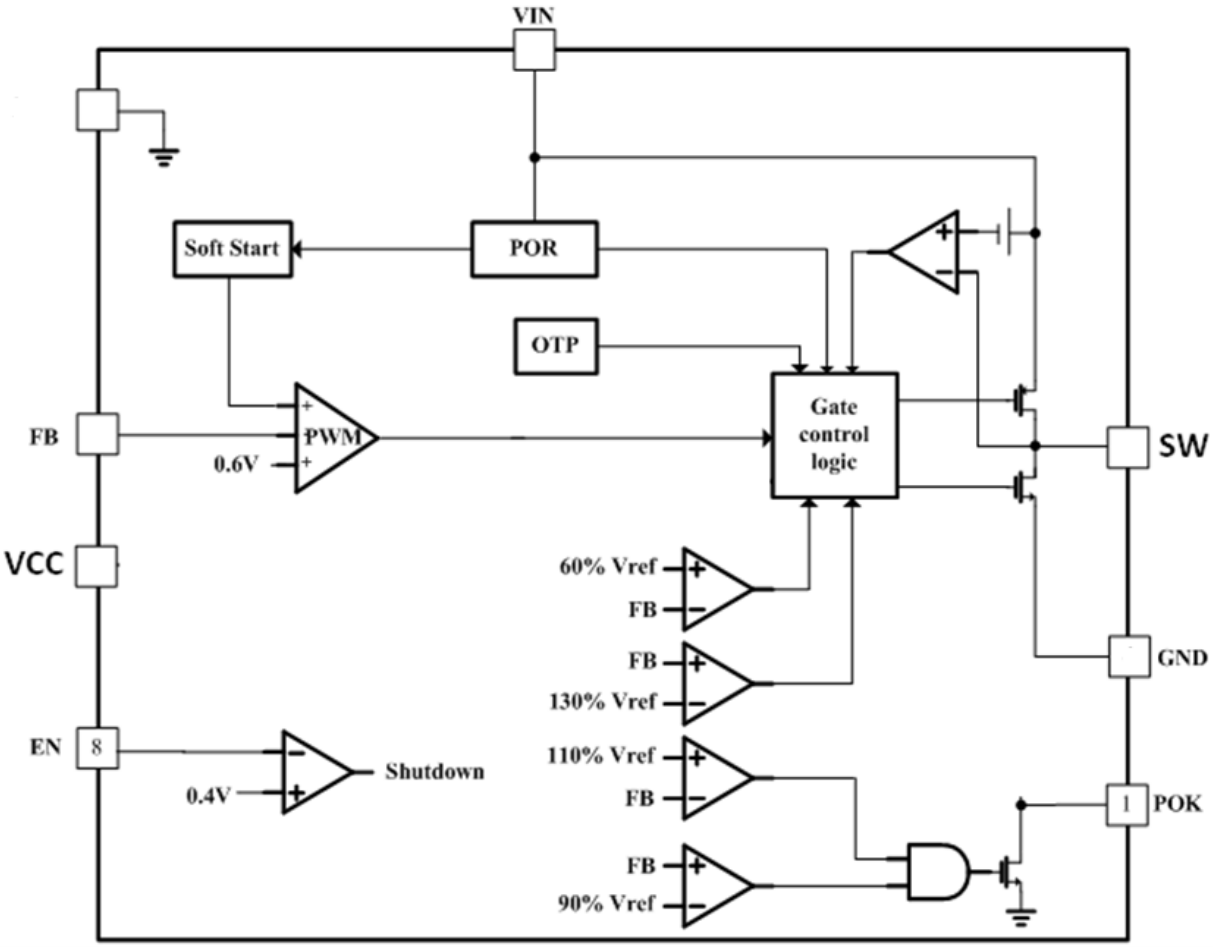
Typical Application Circuit



Pin Assignment

Pin Name	Pin No.	Pin Function
SW	1,2,3	**Switching node output.** Connect to external inductor.
PGOOD	4	Power Good Indicator. Requires external pull-up resistor.
EN	5	**Enable.** Pulling this pin lower than 0.4V disables the converter.
FB	6	**Feedback Voltage.** A resistor divider from the output to GND is used to set the regulation voltage.
NC	7	
VCC	8	**Supply Voltage.** This pin provides the bias supply for the EM5845. Ensure that a decoupling capacitor is placed near the IC.
VIN	9,10	**Main Power Conversion Input & Gate driver voltage supply.**
GND PAD	11	**Ground.** The GND pad must be soldered to a large PCB and connected to GND for maximum power dissipation and better noise immunity.

Function Block Diagram



Absolute Maximum Ratings (Note1)

- V_{IN} ---------- -0.3V to +6.0V
- V_{CC} ---------- -0.3V to +6.0V
- VSW ---------- -0.3V to +6.0V
  <20ns---------- -2.5V to +9V
- EN,VFB,PG---------- -0.3V to +6.0V
- Package Thermal Resistance,θ_{JA},DFN-10L 3X3 ---------- 70°C/W
- Power Dissipation, PD @ TA = 25°C, DFN-10L 3X3 ---------- 1.45W
- Junction Temperature---------- 150°C
- Lead Temperature (Soldering, 10 sec.)---------- 260°C
- Storage Temperature ---------- -65°C to 150°C
- ESD susceptibility (Note3)
  HBM (Human Body Mode)---------- 2KV
  MM (Machine Mode)---------- 200V

Recommended Operating Conditions (Note4)

- Control Voltage, V_{CC},V_{IN} ---------- +2.7V to +5.5V
- Junction Temperature ---------- -40°C to 125°C
- Ambient Temperature ---------- -40°C to 85°C

Electrical Characteristics

V_{IN}=5V, T_A=25°C, unless otherwise specified

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Input Section						
Vcc Shutdown Current	I_{SD}	V_{EN}=0V		0.1		uA
Supply Voltage	Vin		2.7		5.5	V
Power Voltage	Vcc		2.7		5.5	V
VCC Quiescent Current	Ic_Q			700		uA
VIN Quiescent Current	IIQ				100	uA
Power on Reset Threshold	UVLO	VIN&VCC wake up	2.2	2.4	2.6	V
Power on Reset Hysteresis	UVLO			0.3		V
Enable						
Enable High Voltage	V_{EN_H}		1.2			V
Enable Low Voltage	V_{EN_L}				0.4	V
Enable Input Current		V_{EN}=2V		2		uA
		V_{EN}=0V		0		uA
Switching Frequency						
Frequency	Fs	V_{IN}=5V, V_{OUT}=1.2V, I_{OUT}=1A	0.8	1	1.2	MHz
Min. Off Time	T_{OFF}		50	100	150	ns
Switch						
High Side MOS ON Resistance	R_{ON_HS}			80		mΩ
High Side MOS Current Limit	I_{CL}		4.8			A
Low Side MOS ON Resistance	R_{ON_LS}			40		mΩ
Reference Voltage						
Internal Reference	V_{REF}		0.594	0.6	0.606	V

POK						
POK Upper Trip Threshold	V_{POKU}			110		%
POK Lower Trip Threshold	V_{POKL}			90		%
POK Delay	T_{D_POK}			1		ms
POK Leakage Current	I_{L_POK}				1	uA
Protection section						
FB Under Voltage Protection	V_{FB_UVP}	FB falling	50	60	70	%
UVP delay time	T_{D_UVP}			7.5	10	us
FB Over Voltage Protection	V_{FB_OVP}	FB rising	120	130	140	%
OVP delay time	T_{D_OVP}			7.5	10	us
Soft-Start Interval	T_{SS}		0.6	1	2	ms
VOUT Discharge Resistance				100		Ω
Thermal Shutdown	T_{SD}			150		℃
Thermal Shutdown Hysteresis	T_{SD_HYS}			30		℃

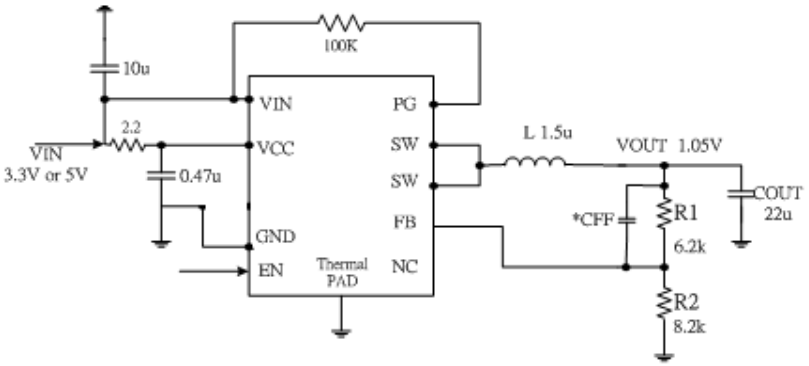
Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2. θ_{JA} is measured in the natural convection at T_A=25°C on a 4-layers high effective thermal conductivity test board with minimum copper area of JEDEC 51-7 thermal measurement standard.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

Reference Values of Feedback Networks and output LC filter combination



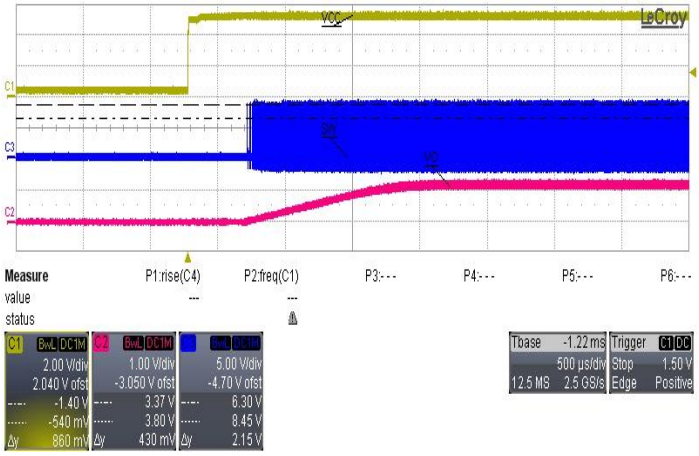
VOUT(V)	R1(kΩ)	R2(kΩ)	L (uH)	COUT (uF)	*CFF(pF)
3.3	**37**	**8.2**	**2.2**	**44**	**22p~470p**
1.8	**16.5**	**8.2**	**1.5**	**22**	
1.2	**8.2**	**8.2**	**1.5**	**22**	
1.05	**6.2**	**8.2**	**1.5**	**22**	
1	**5.6**	**8.2**	**1.5**	**22**	

* CFF is chosen for improving the transient load response

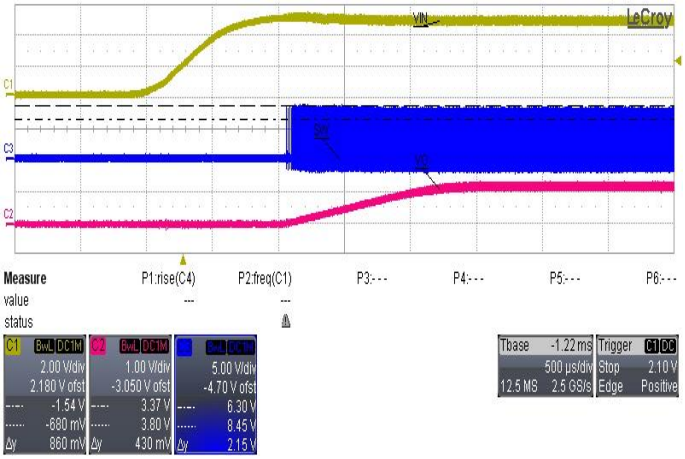
Typical Operating Characteristics

Ta=25℃, C_{IN}=10uF,C_{OUT}=22uF, L=1.5uH

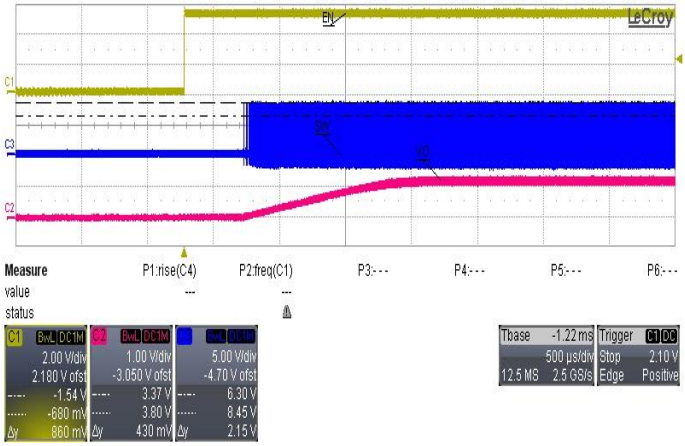
Power ON from VCC
CH1:VCC, CH2:SW, CH3:VO



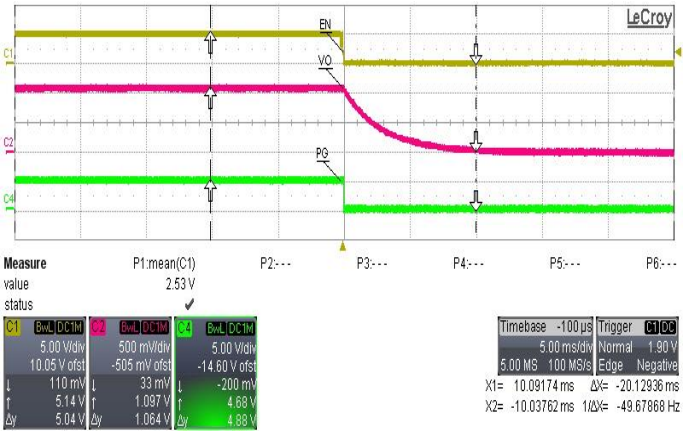
Power ON from VIN
CH1:VIN, CH2:SW, CH3:VO



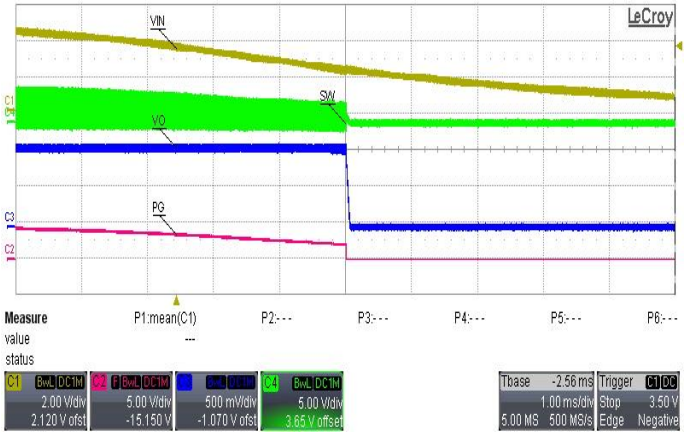
Power On from Enable
CH1:EN, CH2:SW, CH3:VO



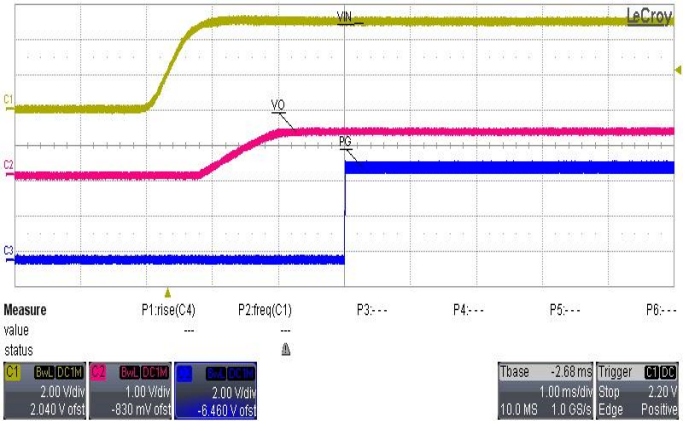
No Load Soft-Stop
CH1:EN, CH2:VO, CH3:PG



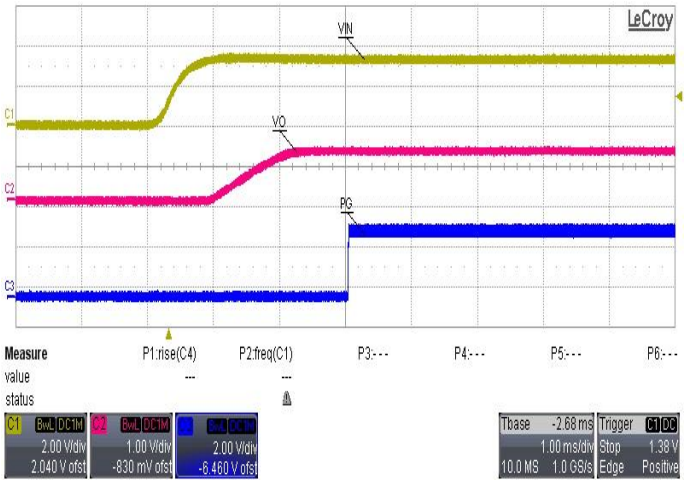
Power Off from VIN
CH1:VIN, CH2:PG, CH3:VO,CH4:VIN



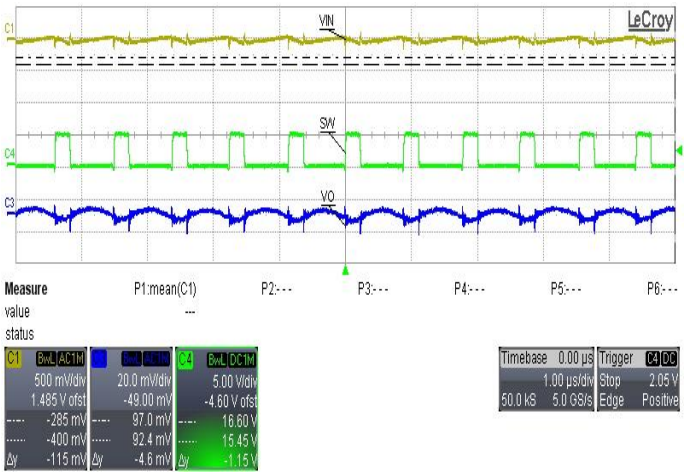
Power Good Signal when Power On
CH1:VIN, CH2:VO, CH3:PG



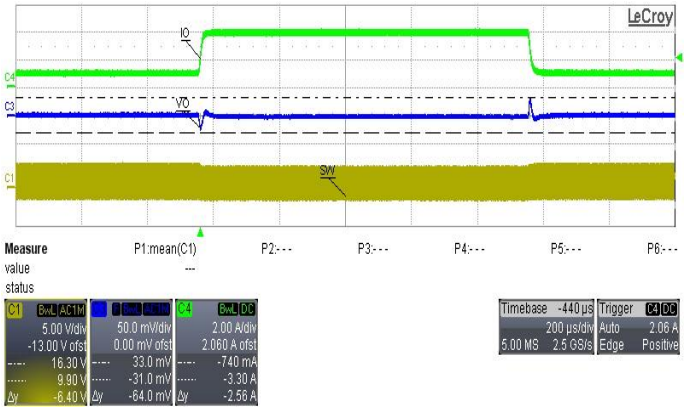
VIN=VCC 3.3V Power On
CH1:VIN, CH2:Vo, CH3:PG



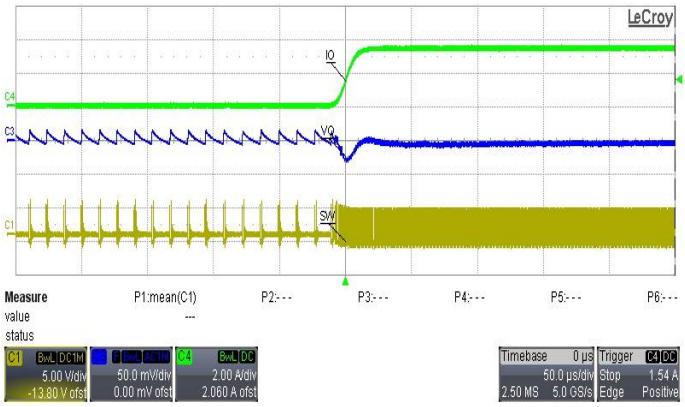
Output Voltage Ripple
CH1:VIN(ac), CH2:Vo(ac), CH3:SW



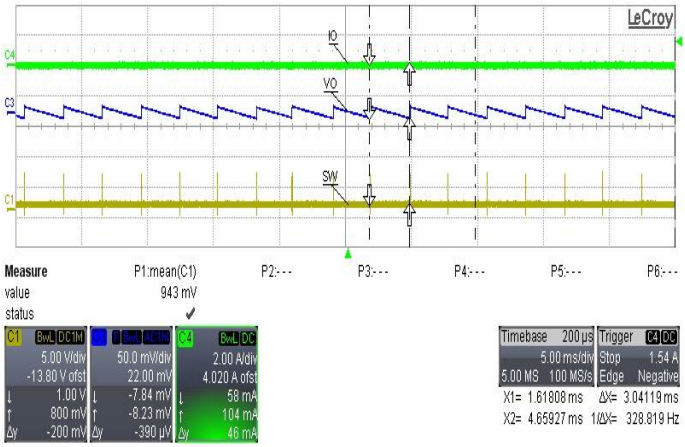
1A to 4A Transient Response
CH1:SW, CH2:Vo(ac), CH4:Io



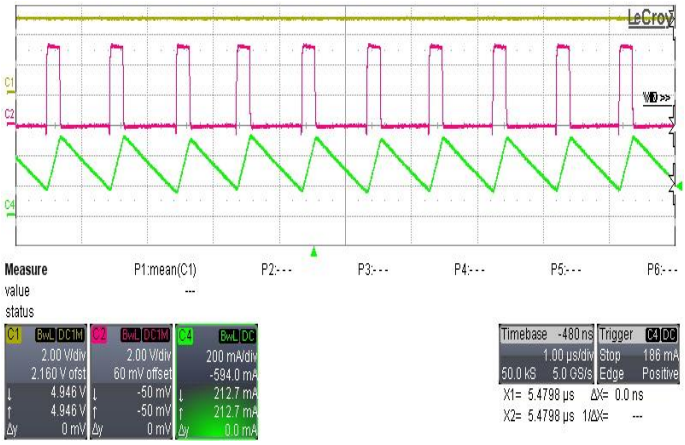
Light Load to Heavy Load Transition
CH1:SW, CH2:Vo(ac), CH4:Io



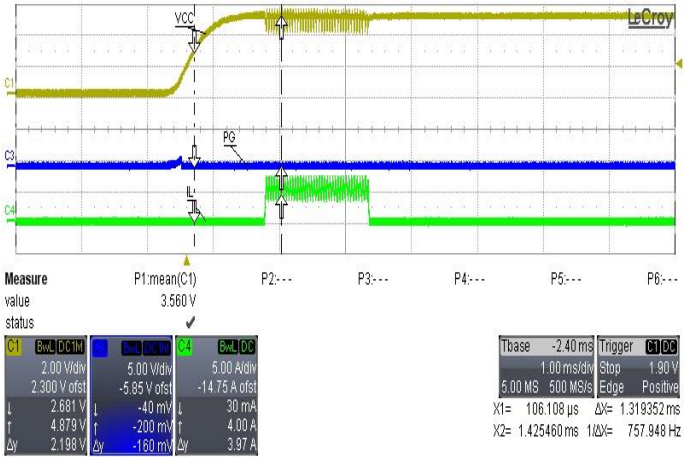
No Load Operation
CH1:SW, CH3:Vo(ac), CH4:Io



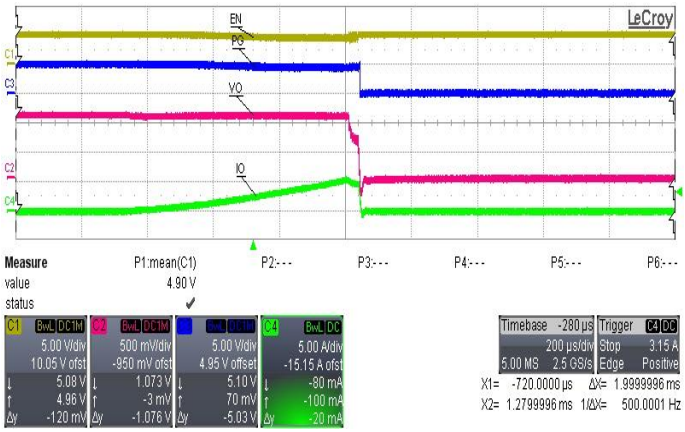
Normal Load Operation
CH1:VIN, CH2:SW, CH4:IL



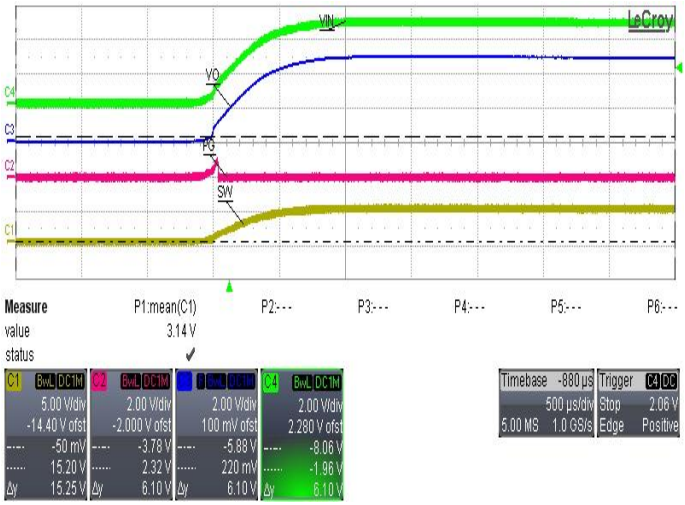
Vo Pre-Short Protection
CH1:VCC, CH3:PG, CH4:IL



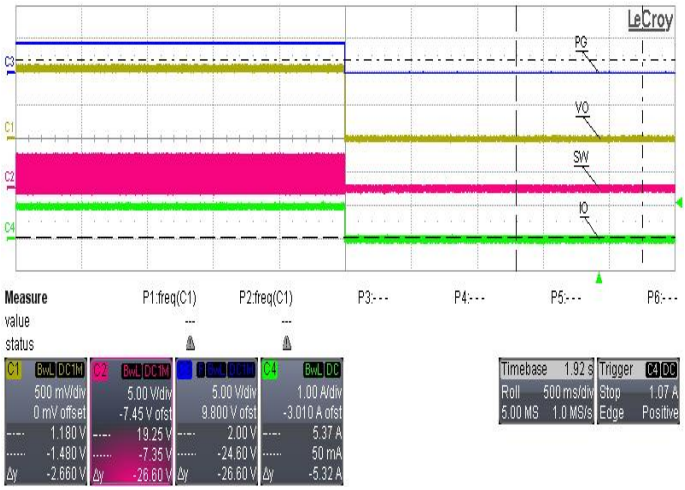
Vo Over Load Protection
CH1:EN, CH2:Vo,CH3:PG, CH4:Io



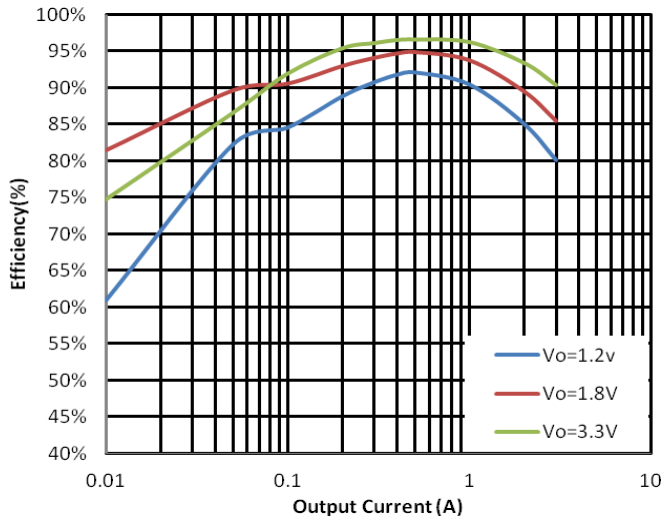
Vo Over Voltage Protection
CH1:SW, CH2:PG, CH3:Vo,CH4:VIN



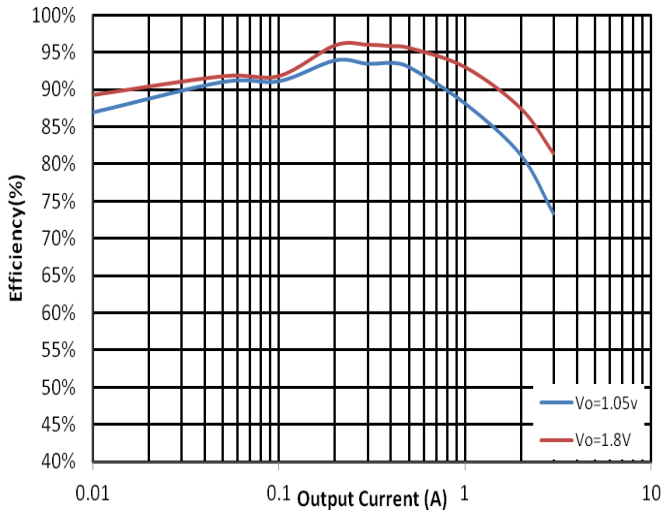
Over Temperature Protection
CH1:Vo, CH2:SW, CH3:PG, CH4:Io



VIN 5V Efficiency

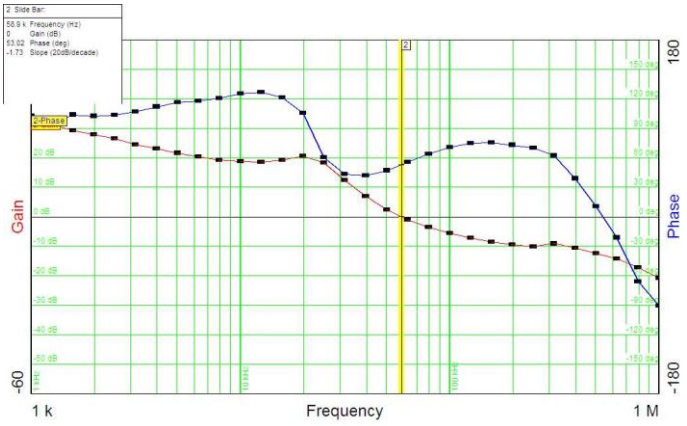


VIN 3.3V Efficiency



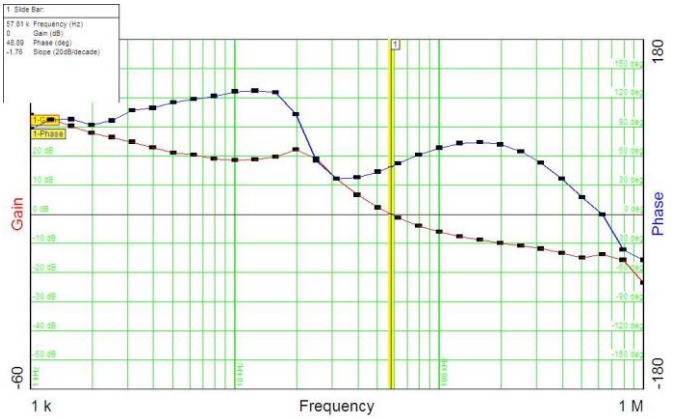
3.3**V to 1.8V, 3A, CFF=100p**

Cross frequency 59kHz, Phase Margin 53°



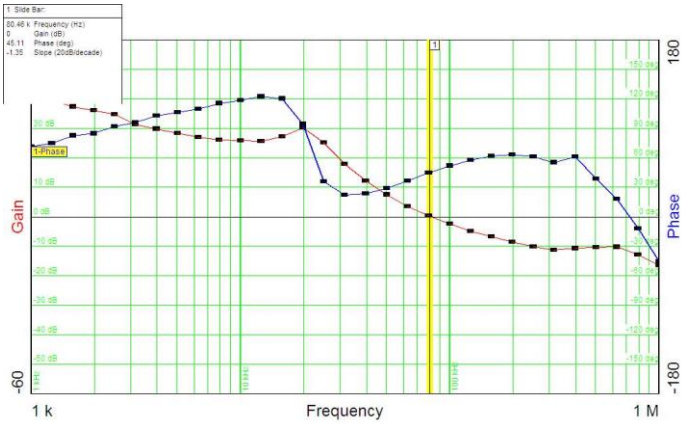
5V to 1.8V, 3A,CFF=100p

Cross frequency 58kHz, Phase Margin 49°



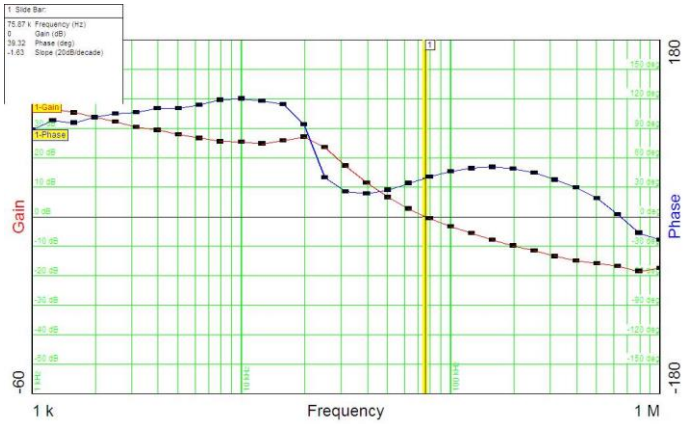
5V to 1.05V, 3A, CFF=100p

Cross frequency 80kHz, Phase Margin 45°

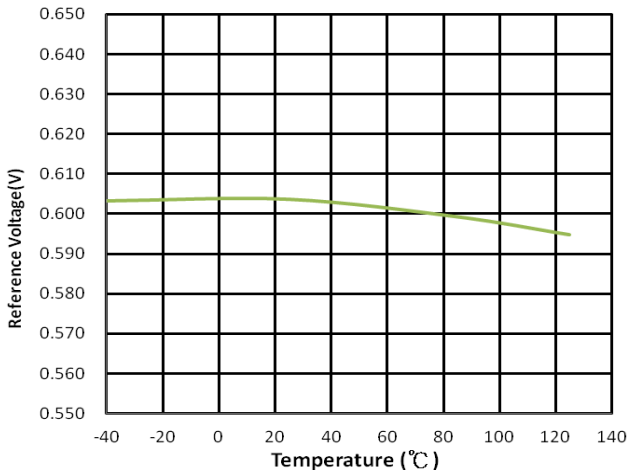


3.3**V to 1.05V, 3A,CFF=100p**

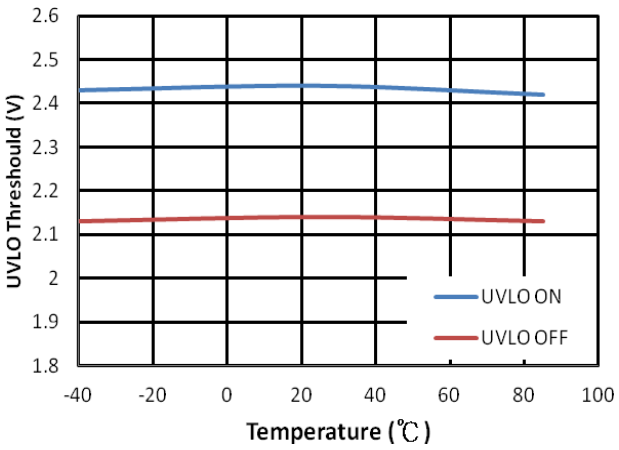
Cross frequency 76kHz, Phase Margin 40°



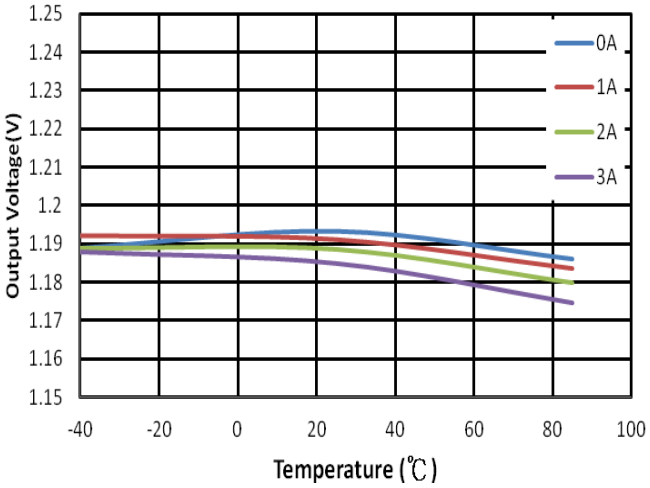
Reference Voltage VS. Temperature



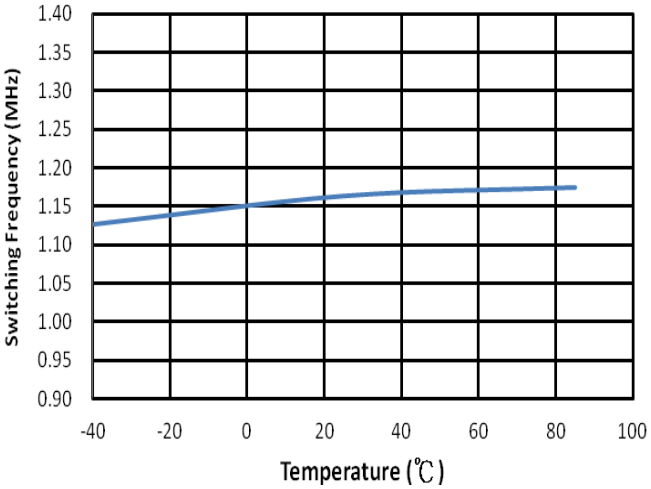
UVLO Threshold VS. Temperature



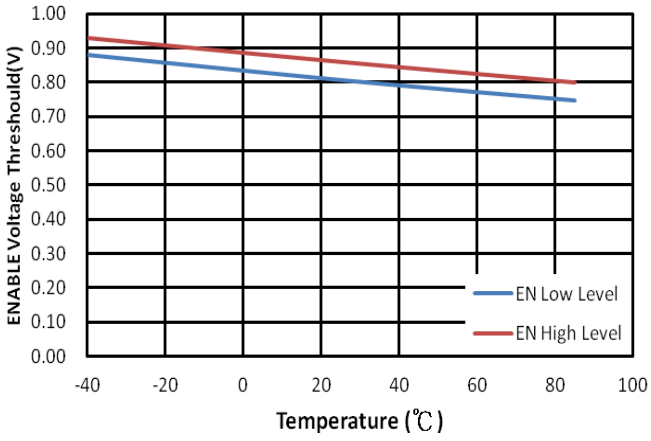
Output Voltage with Load VS. Temperature



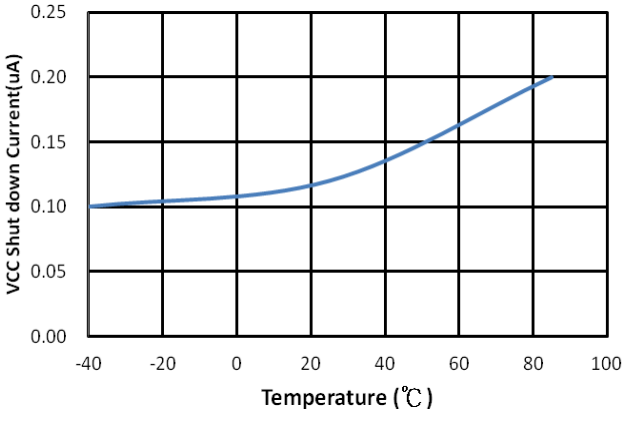
Switching Frequency VS. Temperature



Enable Threshold VS. Temperature



VCC Shutdown Current VS. Temperature



Functional Description

Theory of Operation

The EM5845 is a step-down dc-dc regulator that uses pseudo-fixed frequency constant-on-time control architecture with integrated high-side switch and low-side synchronous rectifier. The high switch frequency and tiny 3X3-10 pin DFN package enables the user to optimize the solution for minimum board space and efficiency.

The buck regulator employs pseudo-fixed frequency constant-on time control. This control method allows fast transient response than traditional current-mode control scheme thereby reducing the total component count due to lowering the size of the output capacitance.

Constant On-Time Control

The PWM control scheme used by constant on-time control, the high side switch on-time is determined by internal pulse generator. The pulse period is determined by V_O and V_{IN} information from V_{IN} and SW pin; the period is proportional to output voltage and inversely proportional to input voltage. The advantages of this control scheme are such as fast transient response, without external compensation and less output component count than other control method.

Light Load Power Saving Mode

The EM5845 offers an automatic pulse-skipping mode in order to provide excellent light load efficiency. The regulator senses the zero current point when the low-side gate is turned on and prevents the negative current flow by turning off the low-side gate signal. This saves power by eliminating re-circulation of the inductor current. When the low-side MOS is turned off, the regulator will enter discontinuous mode that reducing the switching loss due to switching frequency decreased. During this time, both power switches are shut off, and the output capacitor supplies all light load current. Because the output voltage dips and recovers occasionally, the output voltage ripple in this mode is larger than the ripple in the heavy load operation.

Soft-Start and Soft-Stop Function

The EM5845 has built-in soft-start function that ramps up the output voltage at constant slew rate to avoid output overshooting at start-up. The internal soft-start time is typically about 1ms.

The output soft-stop operation is active when the EN from high to low. An internal discharge resistor typically 100Ω is enabled in this condition to discharge the output capacitor through SW pin.

Chip Enable

When the input voltage exceeds the under voltage lockout (UVLO) threshold 2.4V typically, the EM5845 will be enabled by pulling the EN pin high. Leaving the EN pin floating or grounded will disable the chip. There is an internal 1MΩ resistor from the EN pin to ground.

Input UVLO Protection on VCC and VIN

The EM5845 has input under voltage lockout protection (UVLO), if the input voltage exceeds the UVLO on threshold 2.4V typically, and there is typically a 500us delay for internal circuit waking up then soft-start begins. The device will shut off if V_{CC} or V_{IN} falls below UVLO level.

Current limit Protection

The EM5845 has a minimum 4.8A current limit level for high side switch. If the internal high side sensing current is above this level, the FET will stop switching immediately and low-side FET will be turned on until the current level drops below the hysteresis window of current limit level.

Output Under-Voltage Protection

Output under-voltage protection works in conjunction with the current limit protection. If the FB voltage drops below 50% internal VREF, after a delay of 7.5us, the converter will be latched off. Under-voltage protection can be released by toggling the EN/VIN or VCC.

Output Over-Voltage Protection

If the FB voltage above 130% internal VREF, after a delay of 7.5us, the converter will be latched off. Over-voltage protection can be released by toggling the EN/VIN or VCC.

Functional Description

Power Good Indicator

The power good output is an open-drain output which requires a pull-up resistor. When the output voltage is 10% below the nominal voltage, PG is pulled low. It is held low until the output voltage returns to the nominal voltage. PG is held low during soft-start and activated about 1ms after output voltage reaches its regulation.

Over Temperature Protection

Over thermal protection limits the total power dissipation in the device, when the junction temperature exceeds 150℃, an internal thermal sensor shut down the device and allowing the IC to cooling down. The device will turn on again after the junction temperature cools by 25℃.

Switching Frequency Variation

The switching frequency varies with load current as a results of the power losses in the MOSFETs and the inductor. For a traditional PWM constant frequency converter, as the load increases the duty cycle also increases slightly to compensate for total losses in the integrated MOSFETs and DCR losses in the inductor. A constant on time control converter must also compensate this kind of losses. The on time is essentially fixed for a given Vo and VIN combination, to compensate the losses the off-time will tend to reduce slightly by constant on time loop controlled as load increases. For this reason, the switching frequency increases slightly with increasing load.

Application Information

Input Capacitor Selection

The first objective in selecting input capacitors is to reduce the ripple voltage amplitude seen at the input of the converter. Ceramic capacitors placed right at the input of the regulator reduce ripple voltage. These capacitors must be placed close to the converter input pins to be effective. High quality ceramic input capacitor, such as X5R or X7R and greater than 10uF are recommended for the input capacitor due to more stable temperature characteristic.

The input ripple voltage of converter is decided by the value of input capacitance. Input ripple voltage △Vin can be calculated by the following equation.

$$\Delta V_{IN} = \frac{Io(Max) \times V_O}{C_{IN} \times F_{SW} \times V_{IN}}$$

The RMS current rating of the input capacitor should be larger than the following equation.

$$\Delta I_{RMS} = I_O \times \sqrt{D \times (1-D)}$$

Inductor Selection

For a given input and output voltage, the inductor value and switching frequency determine the inductor ripple current. The ripple current increases with higher VIN and decreases with high inductance, the lower the ripple current reduces the core losses in the inductor, and output ripple voltage. A good starting point for selecting the ripple current is $\Delta I_L \le 0.3 \bullet I_{O(MAX)}$, so the inductor value should be chosen according to the following equation:

$$L = (\frac{V_O}{F_{SW} \times \Delta I_{L(MAX)}}) \bullet (1 - \frac{V_O}{V_{IN}})$$

When selecting an inductor, make sure that it is capable of supporting the peak output current without saturating. Inductor saturation will result in a sudden reduction in inductance that may cause the unstable operation.

Output Voltage Setting Resistor Selection

The device with an external adjustable output voltage, the output voltage is programmed by an external resistor divider connected from VO to VFB and then to AGND, as shown in the typical application schematic. The programmed output voltage is below,

$$V_O = V_{FB} \bullet (1 + \frac{R_1}{R_2})$$

Where VFB is equal to the internal reference voltage 0.6V, R1 is the resistance from Vo to FB, R2 is from VFB to AGND, and increases the quiescent current by R1 and R2, so larger resistance is desirable, select the R2 no larger than 200kΩ is preferable.

Output Capacitor Selection

An output capacitor is required to filter the inductor current. Output ripple and transient response are two critical factors when choosing the output capacitance. The COT mode allows for the usage of low ESR ceramic capacitors and thus smaller board layout, electrolytic capacitors may also be used. The following equations allow calculation of the required capacitance to meet a desired output ripple voltage.

For the ceramic capacitors (low ESR):

$$V_{OUTRIPPLE} = \frac{\Delta I_L}{8 * F_{SW} * C_O}$$

When using electrolytic capacitors (High ESR):

$$V_{OUTRIPPLE} = \Delta I_L * ESR$$

Regarding transient response considerable, a good starting point is to determine the allowable overshoot in Vo if the load is suddenly released. In this case, energy stored in the inductor will be transferred to Co causing its voltage to rising, so choosing the needs capacitance should be cover for both ripple and transient requirement. The most of applications will require a minimum of 22uF output capacitance. Like the input capacitor multilayer ceramic capacitors are X7R or X5R types. The maximum RMS current rating of the capacitors is:

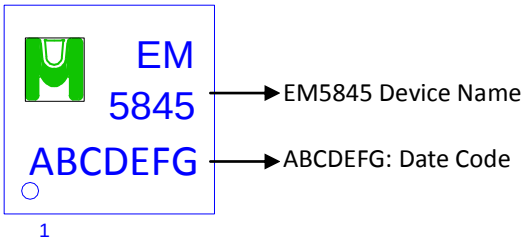
$$I_{CORMS} = \frac{1}{\sqrt{12}} \times \frac{V_O(V_{IN(MAX)} - V_O)}{L \times F_{SW} \times V_{IN(MAX)}} A_{RMS}$$

Layout Considerations

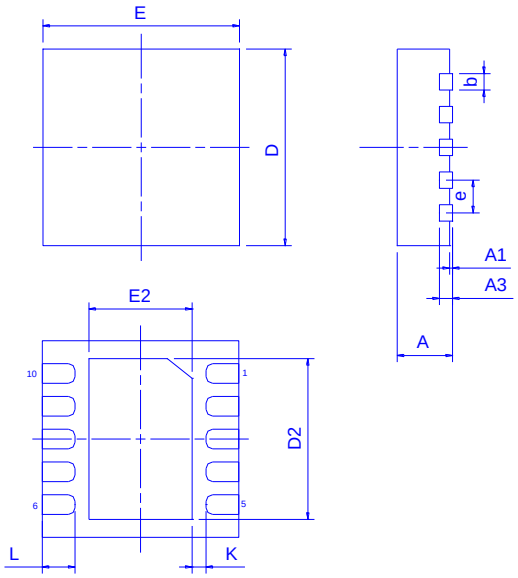
- The VIN, VCC decoupling capacitors should be as closed to the IC VIN and VCC pin.
- The FB voltage divider network should be as closed to the IC FB pin and away from switching node.
- Use widely trance for the High current path, From VIN, SW, Vo to GND path.
- Widely ground plan for good heat sinking and better noise immunity.

Marking Information

Device Name: EM5845VT for DFN3X3-10L



Outline Drawing



Dimension in mm

Dimension	A	A1	A3	b	D	E	D2	E2	e	L	K
Min.	0.7	0.00		0.18			2.20	1.40		0.30	0.20
Typ.	0.75	0.02	0.2	0.25	3.0	3.0			0.50	0.40	
Max.	0.80	0.05		0.30			2.70	1.75		0.50	

Recommended minimum pads