ELM615DA

36V 5A synchronous Step-down converter with dual-channel current limit

https://www.elm-tech.com

■General description

ELM615DA is a high-efficiency, high-voltage, synchronous step-down DC-DC converter with integrated high-side and low-side power MOSFETs. ELM615DA uses proprietary constant on-time (COT) control to provide excellent line and load transient response. ELM615DA features slew rate control and spread spectrum frequency modulation to minimize EMI/EMC emissions. With wide input range from 4V to 36V, the converter can deliver output voltage ranging from 0.8V to VIN with up to 5A continuous output current. The converter can be configured as single output or dual outputs with independent constant current (CC) regulation for each output. In the event of output overload or short circuit, the converter will be into hiccup mode. Other protection features include cycle-by-cycle current limit, input under and over voltage protection and thermal shutdown. ELM615DA also provides programmable cable voltage drop compensation by selecting an appropriate external resistor of the divider net work divider. Switching frequency is internally set to 180kHz. ELM615DA is available in SOP-8_EP package.

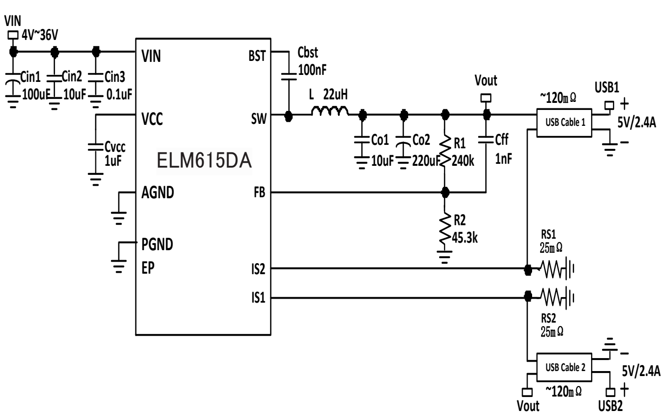
■Features

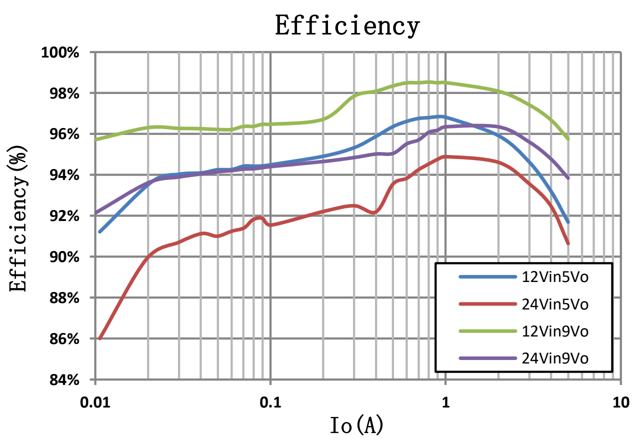
- Input voltage range : 4V to 36V
- Output current : 5A
- Overcurrent protection : Switch cycle
- Built-in wiring resistance voltage drop compensation circuit
- Short circuit protection : Hiccup mode
- Overheat protection : 155°C
- Spread spectrum switching : 180kHz 6% FM spread
- Integrated switch on resistor : 40mΩ high side/40mΩ low side
- Minimum on time : 70nsec
- Soft start : 3msec
- Package : SOP-8 (Exposed pad on back side)

■Application

- Dual-port car charger
- Automotive and Industrial Supplies
- Point of Load

■Standard circuit





■Selection guide

ELM615DA-N

Symbol		
a	Part No.	ELM615
b	Package	D: SOP-8 (With exposed back pad)
c	Product version	A
d	Taping direction	N: Please refer to page 13

＊ Taping direction is one way.

ELM615 D A - N
↑ ↑ ↑ ↑
a b c d

■Maximum absolute ratings (1)

Parameter	Symbol	Limit	Unit
Supply voltage Vin to GND	V_{IN}	+39	V
PGND-GND Supply voltag	V_{PGND}	-0.3 to +0.3	V
SW-GND Supply voltag	V_{SW}	-0.3 to V_{IN}+0.3	V
SW-GND Surge voltage (30ns)	V_{SW_S}	-3 to V_{IN}+3	V
BST-SW Supply voltage	V_{BST}	-0.3 to +6.0	V
All Other Pins to GND	V_{ALL}	-0.3 to +6.0	V
Lead temperature	T_L	+260	°C
Junction temperature	T_J	+150	°C
Storage temperature range	T_{STG}	-65 to +150	°C
Thermal resistance (3), (4)	θ_{JA}	51	°C/W
Thermal resistance (3), (4)	θ_{JC}	13	
Power dissipation (3), (4)	P_D	2.1	W

■Recommend operating conditions (2)

Parameter	Symbol	Limit	Unit
Input voltage	V_{IN}	+4 to +36	V
Output voltage	V_{OUT}	0.8 to V_{IN}	V
Operating temperature range	T_{OP}	-40 to +125	°C

Note:

(1) Stress exceeding those listed “Maximum absolute ratings” may damage the device.

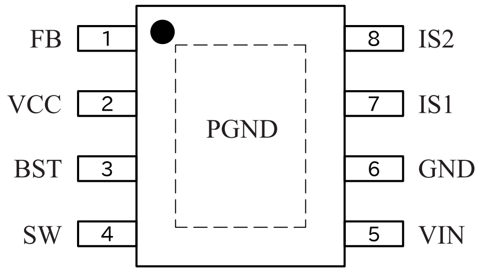
(2) The device is not guaranteed to function outside of the recommended operating conditions.

(3) Measured on JESD51-7, 4-Layer PCB.

(4) The maximum allowable power dissipation is a function of the maximum junction temperature T_{J_MAX}, the junction to ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D\_MAX}= (T_{J\_MAX}-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

■Pin configuration

SOP-8(TOP VIEW)



Exposed pad on backside

Pin No	Symbol	Pin description
1	FB	Feedback input. Connect FB to the center of the external resistor divider from the output to the AGND to set the output voltage.
2	VCC	Internal 5V LDO output. The driver and control circuits are powered from this voltage. Decouple with a minimum 1μF ceramic capacitor to PGND as close to the pin as possible.
3	BST	High-Side driver bootstrap supply. Connect a 0.1μF capacitor between SW and BST for proper operation.
4	SW	Output pin of internal power switches. Connect this pin to the inductor and bootstrap capacitor.
5	VIN	Supply voltage. The VIN pin supplies power for internal MOSFET and regulator. ELM615DA operates from a +4V to +36V input rail. Bypass VIN to PGND with a 10μF or greater low ESR ceramic capacitor.
6	GND	System analog ground.
7	IS1	IS1: The Channel 1 output current sense input pin. Connect a sense resistor from this pin to AGND. When the voltage on this pin increases to 60mV, ELM615DA reduces output voltage and regulates IS1 at 60mV.
8	IS2	IS2: The Channel 2 output current sense input pin. Connect a sense resistor from this pin to AGND. When the voltage on this pin increases to 60mV, ELM615DA reduces output voltage and regulates IS2 at 60mV.
EP	PGND	Exposed Pad is connected to the low side MOSFET Power Ground. Connect EP to a large-area

■Block diagram

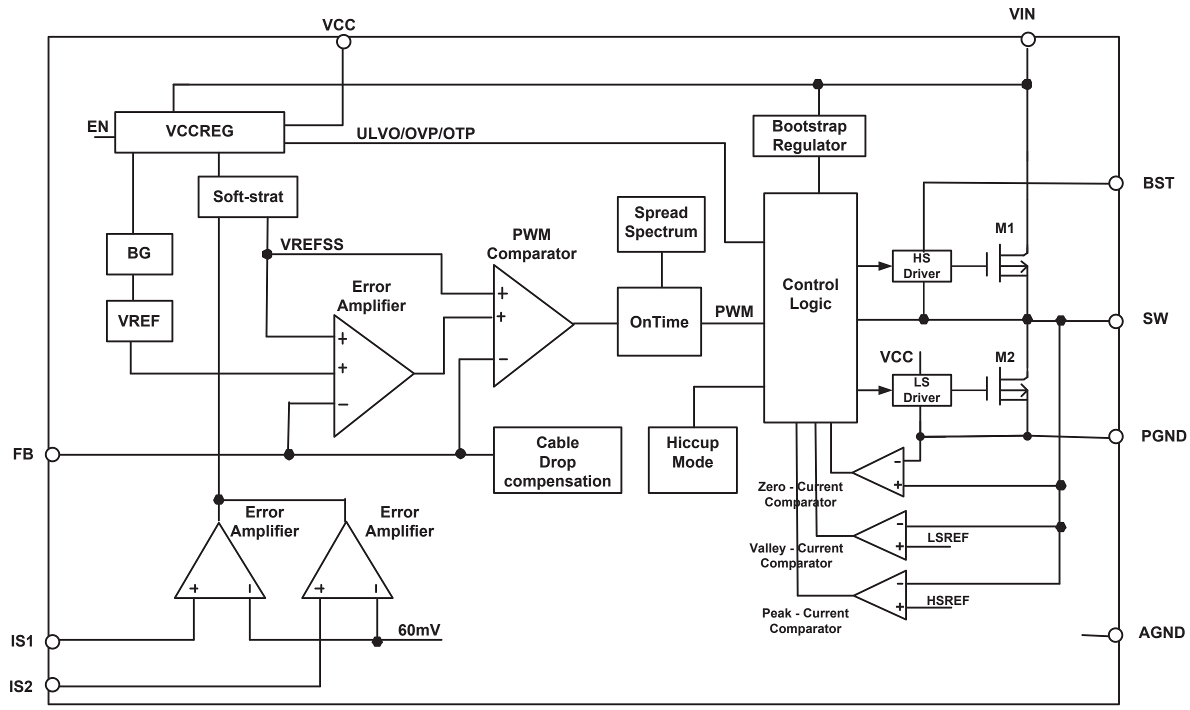


Fig-1. ELM615DA car charger functional block diagram (IS1/IS2)

■Electrical characteristics

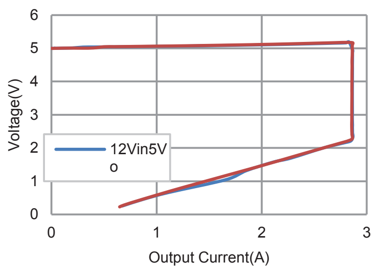
V_{IN} = 12V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Test conditions	Min.	Typ.	Max.	Unit
Operating input voltage	V_{IN}		4	-	36	V
Input under voltage lockout threshold rising	V_{UVLO}		-	3.80	4.05	V
Input under voltage lockout threshold hysteresis	V_{UVHYS}		-	430	-	mV
Input over voltage lockout threshold rising	V_{OVLO}		-	38.3	-	V
Input over voltage lockout threshold hysteresis	V_{OVHYS}		-	1.8	-	V
VCC regulator	V_{CC}	V_{FB}=0.84V, I_{VCC}=0 to 30mA	4.8	5.1	5.4	V
Supply current (quiescent)	I_{CC}	V_{FB}=0.84V	-	100	-	μA
High-side switch on resistance	R_{ON_HS}		-	40	-	mΩ
Low-side switch on resistance	R_{ON_LS}		-	40	-	mΩ
Switch leakage	I_{SW_LEAK}	V_{FB}=0.84V, V_{IN}=36V Vsw=0V or 36V	-20	-	+20	μA
Feedback regulation voltage	V_{FBREG}		784	800	816	mV
Feedback pin Input current	I_{FB}	V_{FB}=0.8V	-100	-	+100	nA
Minimum on time	T_{ON_MIN}		-	70	-	ns
Minimum off time	T_{OFF_MIN}		-	100	-	ns
Maximum duty cycle	D_{MAX}	V_{IN}=12V, V_{FB}=0.7V	-	100	-	%
High-side switch peak current limit	I_{PK}		-	7.5	-	A
Low-side switch valley current limit	I_{VALLEY}		-	6.5	-	A
Low-side switch zero current detection	I_{ZX}		-	90	-	mA
Thermal shutdown	T_{SD1}		-	155	-	°C
Thermal shutdown hysteresis	T_{SD2}		-	25	-	°C
Switching frequency	F_{SW}		-	180	-	kHz
Spread-spectrum modulation frequency			-	3	-	kHz
Output voltage cable compensation		V_{IN}=12V, R_1=240kΩ I_{OUT}=I_{OUT1}+I_{OUT2}=5A	-	+0.6	-	V
IS1 / IS2 reference voltage	V_{IS}		-	60	-	mV

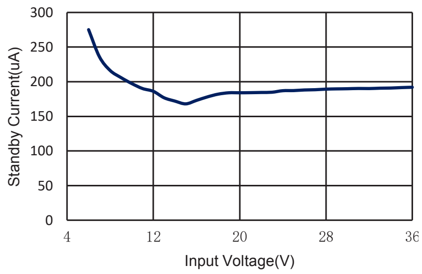
■Typical characteristics

- Circuit of Fig-1, C_{IN}=100µF, C_{OUT}=10µF+220µF, L=22µH, R_{IS1}=R_{IS2}=20mΩ, T_A=+25°C

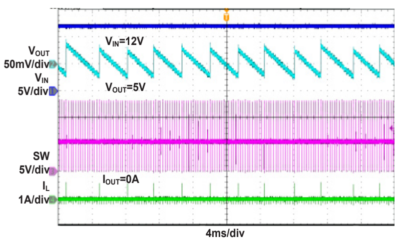
CV/CC Curve



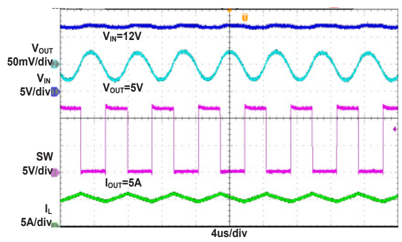
Standby Current vs Input Voltage



Steady State Test



Steady State Test



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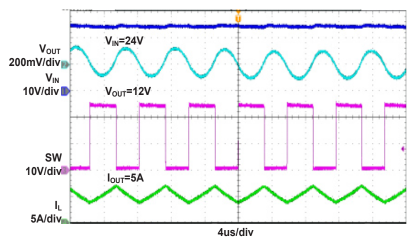

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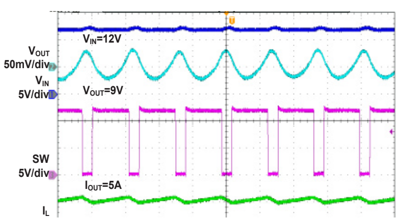
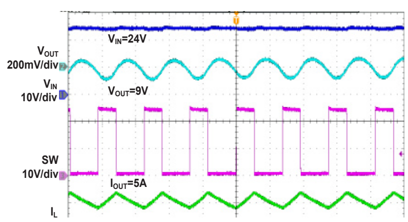
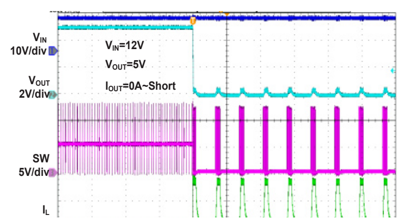


Steady State Test

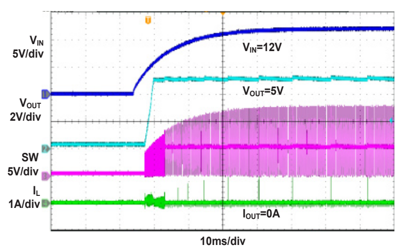


Short Protection

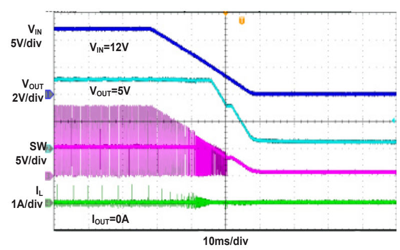


• Circuit of Fig-1, C_{IN}=100µF, C_{OUT}=10µF+220µF, L=22µH, R_{IS1}=R_{IS2}=20mΩ, T_A=+25°C

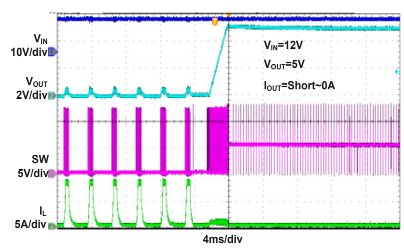
Vin Power on



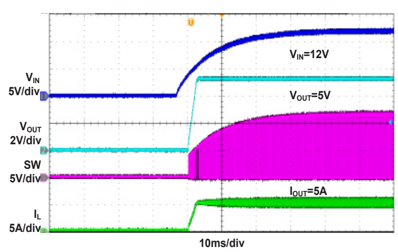
Vin Power off



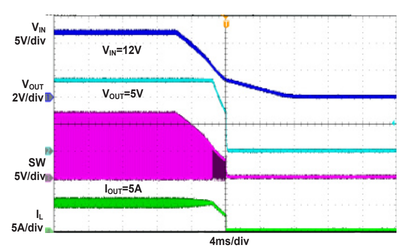
Short Protection



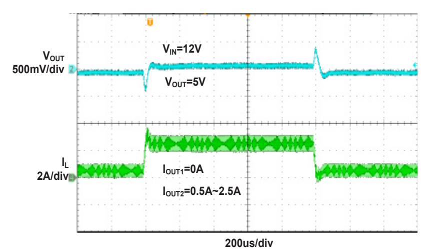
Vin Power on



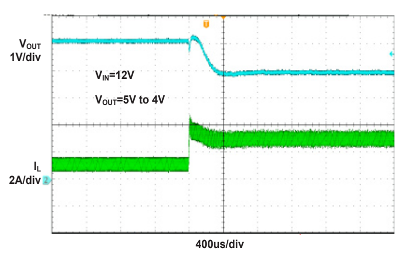
Vin Power off



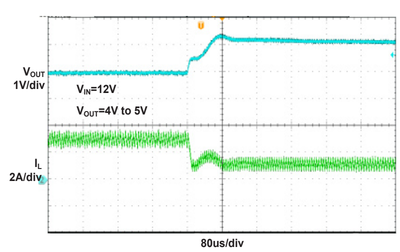
Load Transient



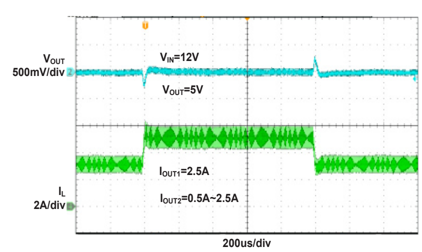
CV mode to CC mode



CC mode to CV mode



Load Transient



■Detailed description

ELM615DA is a constant on-time controlled synchronous step-down converter with 4V to 36V input voltage range. The device can provide up to 5A continuous output current. Output voltage is set by an external resistor divider with feedback point connected to FB pin.

1. CC/CV mode control

ELM615DA operates in either Constant Voltage (CV) mode or Constant Current (CC) mode depends on load condition. When channel 1 and channle2 output current is below constant current threshold, ELM615DA regulates output voltage in CV mode. As Channel 1 or Channel 2 output current increases and reaches the Constant Current threshold, ELM615DA enters CC mode and by reducing output voltage and maintaining relative channel output current constant. Once FB pin voltage falls below 0.4V, the regulated channel current level will linearly fold back as FB voltage continues to drop.

2. Spread-spectrum option

ELM615DA has an internal spread-spectrum option to optimize EMI performance. The modulation signal is a triangular wave with a period of 340us at 180kHz. Therefore, switching frequency will linearly vary between 180kHz -6% to 180kHz every 330us.

3. Internal soft-start

ELM615DA has built-in 3ms soft-start. During the soft start period, output voltage is ramped up linearly to the regulation voltage, independent of the load current level and output capacitor value.

4. Output over current protection

ELM615DA has cycle-by-cycle HS current limit protection to prevent inductor current from running away. Once HS current limit is triggered, ELM615DA will turn on LS and wait for the inductor to drop down to a predetermined level before the HS can be turned on again. If this current limit condition is repeated for a sustained long period of time, ELM615DA will consider it as over-load or short circuit. Either way, ELM615DA will enter hiccup mode, where it stop switching for a pre-determined period of time before automatically re-try to start up again. It always starts up with soft-start to limit inrush current and avoid output overshoot.

■Application information

1. Setting output voltage

The output voltage is set using the FB pin and a resistor divider connected to the output as shown in AP Circuit below. The output voltage (V_{OUT}) can be calculated according to the voltage of the FB pin (V_{FB}=0.8V Typical), Thus the output voltage is:

$$V_{OUT} = V_{FB} \times \left(\frac{R_1}{R_2} + 1\right)$$

2. Programmable cable compensation

ELM615DA provides programmable cable compensation by selecting appropriate external feedback resistor divider to compensate resistive voltage drop over the chargers' output cable. The cable compensation voltage can be expressed as

$$I_{FB} \times R_1 = I_{OUT} \times R_{CABLE}$$

$$\Delta V_{OUT} = 2.5\mu A \times \frac{I_{OUT}}{5A} \times R1$$

I_{OUT} is equal to sum of channel 1 and channel 2 output current.

3. Setting the channel 1 and 2 CC current

ELM615DA channel 1 constant current value is set by the resistor R_{IS1} connected between the IS1 and GND pins. Channel 2 constant current value is set by the resistor R_{IS2} between the IS2 and GND pins. The CC current is determined by the equation as follows

$$I_{CS1} = 60mV/R_{IS1}$$

$$I_{CS2} = 60mV/R_{IS2}$$

4. Input capacitor selection

The input capacitor must sustain the ripple current produced during the period of "ON" state of the high side MOSFET, so a low ESR ceramic capacitor is required to minimize the loss. The input ripple current RMS value can be calculated by the following equation:

$$I_{INRMS} = I_{OUT} \sqrt{D \times (1- D)}$$

Where D is the duty cycle, I_{INRMS} is the input RMS current, and I_{OUT} is the load current. The equation reaches its maximum value with D = 0.5. The loss of the input capacitor can be calculated by the following equation:

$$P_{CIN} = ESR_{CIN} \times I_{INRMS}^2$$

Where P_{CIN} is the power loss of the input capacitor and ESR_{CIN} is the effective series resistance of the input capacitance. Due to large di/dt through the input capacitor, low ESR ceramic capacitors should be used.

Depending on the application, additional capacitors may be required to improve input ripple current, transient response characteristics, and EMI characteristics. The value of C_{IN} is determined in relation to the power supply impedance. If the power supply impedance is high, a large input capacitor is required. The input capacitor must withstand a voltage equal to or greater than the maximum input voltage.

5. Inductor selection

The inductor is chosen to meet the requirements of the output voltage ripple and the load transient response. The higher inductance can reduce the inductor's ripple current and lower output ripple voltage. Use an inductor with a DC current rating of at least 25% percent higher than the maximum load current for most applications. For highest efficiency, select an inductor with a DC resistance less than 15mΩ. The inductor ripple current and output voltage ripple is approximated by the following equations:

$$\Delta I = \frac{V_{IN} - V_{OUT}}{F_S \times L} \cdot \frac{V_{OUT}}{V_{IN}}, \quad L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times F_S \times \Delta I}$$

$$I_{L\_MAX} = I_{LOAD} + \frac{\Delta I}{2}, \quad \Delta V_{OUT} = \Delta I \times ESR$$

Although the increase of the inductance reduces the ripple current and voltage, it contributes to the decrease of the response time for the regulator to load transient. The way to set a proper inductor value is to have the ripple current (ΔI) be approximately 20%~50% of the maximum output current. Once the value has been determined, select an inductor capable of carrying the required peak current without going into saturation. It is also important to have the inductance tolerance specified to keep the control accuracy of the system. 20% tolerance (at room temperature) is reasonable for the most inductor manufacturers. For some types of inductors, especially those with ferrite core, the ripple current will increase abruptly when it saturates, which will result in larger output ripple voltage. Use a larger inductance for improved light-load efficiency.

6. Output capacitor selection

An output capacitor is required to filter the output and supply the load transient current. The high capacitor value and low ESR will reduce the output ripple and the load transient drop. In typical switching regulator design, the ESR of the output capacitor bank dominates the transient response. The number of output capacitors can be determined by the following equations:

$$ESR_{MAX} = \frac{\Delta V_{ESR}}{\Delta I_{OUT}}$$

$$\text{Number of capacitors} = \frac{ESR_{CAP}}{ESR_{MAX}}$$

ΔV_{ESR} = change in output voltage due to ESR
ΔI_{OUT} = load transient
ESR_{CAP} = maximum ESR per capacitor (specified in manufacturer's data sheet)
ESR_{MAX} = maximum allowable ESR

High frequency decoupling capacitors should be placed as closely to the power pins of the load as physically possible. For the decoupling requirements, please consult the capacitor manufacturers for confirmation.

7. Layout consideration

To ensure stable, high efficiency and low noise operation of the power converter system, the PCB layout is a critical step. Due to high current and voltage slew rate, several signal paths need to be carefully designed to minimize stray inductance and parasitic capacitance that could generate noise and degrade performance. Followings are the layout guidelines:

(1) The loop (V_{IN}-SW-L-C_{OUT}-GND) carries high current. The traces within this loop should be kept as wide

and short as possible to reduce parasitic inductance and high-frequency loop area. It is also good for efficiency improvement.

(2) Place Input capacitor as close as possible to the IC Pins (V_{IN} and GND) and the input loop area should be as small as possible to reduce parasitic inductance, input voltage spike and noise emission.

(3) Feedback components (R_1, R_2, R_T and C_{FF}) should be routed as far away from the inductor and the BST and SW pins to minimize noise coupling.

(4) A Ground plane using one PCB layer is recommended for stable operation with low ground impedance.

■ELM615DA car charger application schematic

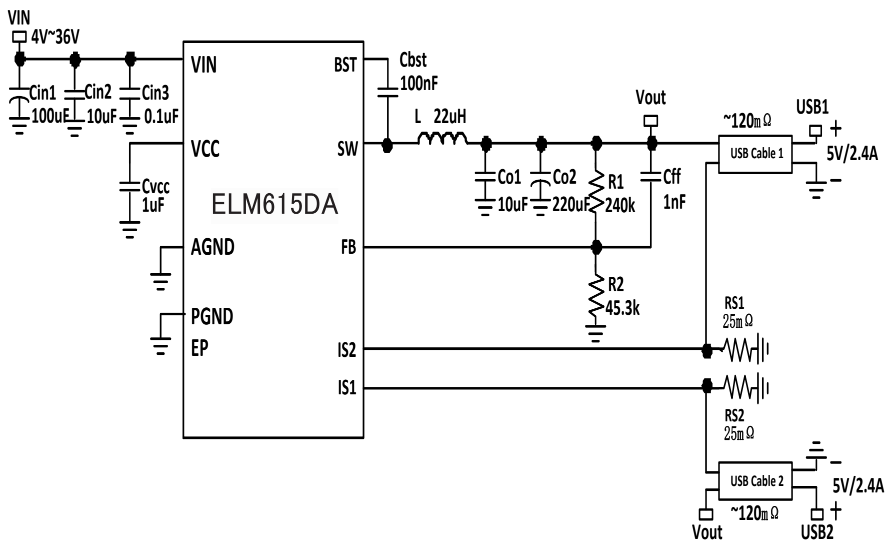
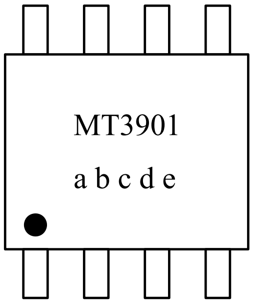


Fig-2. Typical application circuit for 5V/4.8A dual-output car charger

EVB BOM list

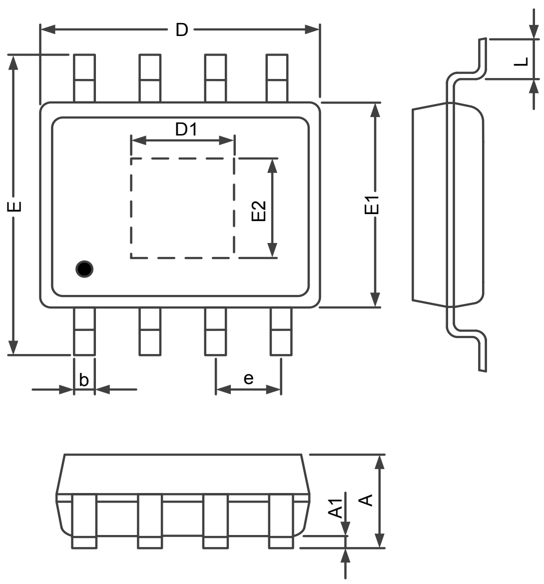
Qty	Ref	Value	Description	Package
1	C_{IN1}	100µF	Electrolytic capacitor, 50V	EC 8×12mm
1	C_{IN2}	10µF	Ceramic capacitor, 50V, X5R	0603
1	C_{IN3}	0.1µF	Ceramic capacitor, 50V, X5R	0603
1	C_{OUT1}	10µF	Ceramic capacitor, 50V, X5R	0805
1	C_{OUT2}	220µF	Solid-state capacitor	8×12mm
1	C_{BST}	100nF	Ceramic capacitor, 16V, X5R	0603
1	C_{VCC}	1µF	Ceramic capacitor, 10V, X5R	0603
1	L	22µH	Inductor	SMD
2	RS1, RS2	25mΩ	Ceramic capacitor, 10V, X5R	1206
1	R_1	240KΩ	Resistor, ±1%	0603
1	R_2	45.3KΩ	Resistor, ±1%	0603
1	R_{CABLE}	120mΩ	Resistor, ±1%	0805
1	C_{FF}	1nF	Ceramic Capacitor, 10V, X5R	0603
1	Power IC	ELM615DA	Step-down DC/DC converter	SOP-8

■Marking



Mark	Content
MT3901	Product ID : ELM615DA
a to e	Assembly lot number

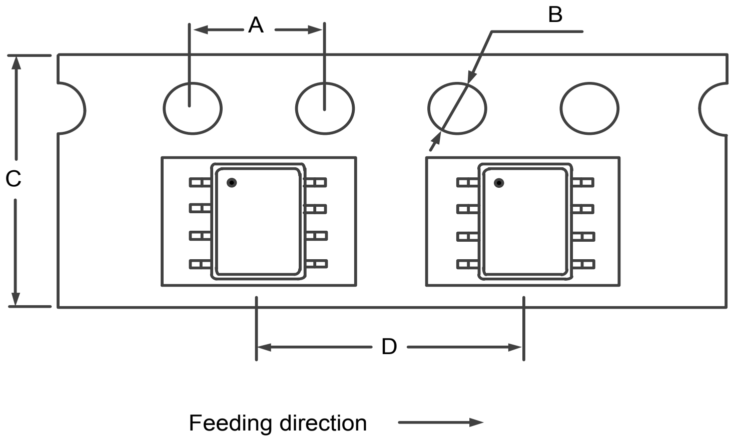
■SOP-8 Package information



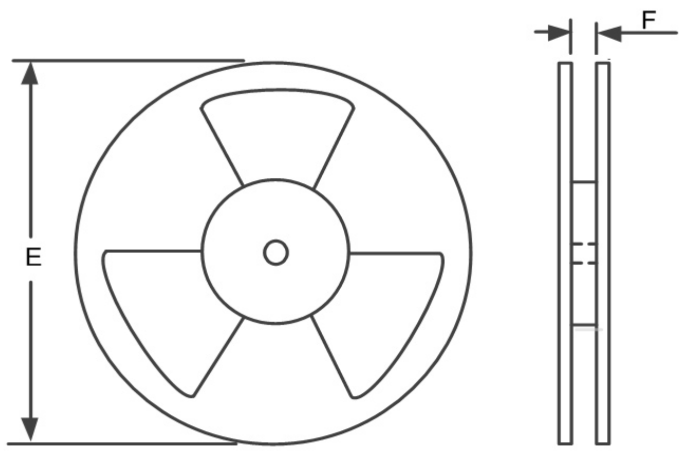
Symbols	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	1.35	1.75	0.053	0.069
A1	0.00	0.15	0.000	0.006
D	4.70	5.10	0.185	0.200
E1	3.70	4.10	0.145	0.161
D1	2.90	3.50	0.114	0.138
E2	2.00	2.50	0.080	0.098
E	5.80	6.20	0.228	0.244
L	0.40	1.27	0.016	0.050
b	0.31	0.51	0.012	0.020
e	1.16	1.37	0.046	0.054

■SOP-8 Carrier tape & reel dimensions

• Orientation/carrier tape information



• Reel information



• Dimension details

PKG type	A	B	C	D	E	F	Q'ty/Reel
SOP-8	4.0 mm	1.5 mm	12.0 mm	8.0 mm	13 inches	13.0 mm	2,500