EM5235

23V 18mΩ Ideal Diode Protection Switch With Limited Power Source (LPS) protection

Gereral Description

The EM5235 ideal diode switch is intended for applications that require reverse current protection and “Power ORing” supply configuration. The input operating voltage range is between 3.3V and 23V, and both VIN and VOUT terminals are rated at 30V Absolute Maximum. The EM5235 provides under-voltage lockout, over-voltage, and over-temperature protection. The FLTB pin flags thermal shutdown, short circuit protection and over-voltage faults.

EM5235 is the ideal solution for multi-port Type-C PD current sinking application. The Ideal Diode TRCB feature prevents VIN to rise due to reverse current flow from VOUT under all conditions. There is also a Limited Power Source (LPS) protection feature to prevent excessive power flow through the device from other ports that are faulty or damaged. A short is detected if VIN voltage is higher than threshold voltage when the device is disabled (EN= Low). There is a 2.5s blanking time before the device pulls the LPSB output low to shut down other ports using their DISB pins.

An internal soft-start circuit controls inrush current due to highly capacitive loads and the slew rate can be adjusted using an external capacitor. The integrated back-to-back MOSFET offer industry’s lowest ON resistance and highest SOA to safely handle high current and a wide range of output capacitances on VOUT.

The EM5235 is available in a thermally enhanced 3.5 mm x 3 mm DFN-14 package which can operate over -40 °C to +125 °C junction temperature range.

Features

- 18mΩ typical ON resistance
- 3.3V to 23V operating input voltage
- VIN and VOUT rated at 30V abs max.
- Reverse voltage protection
- Fast recovery from reverse voltage protection
- Support Limited Power Source (LPS)
- Programmable Soft-Start
- VIN Under-Voltage Lockout (UVLO)
- VIN Over-Voltage Protection (OVP)
- Over Temperture Protection (OTP)
- Over Current Protection (OCP)
- VIN Discharge
- Thermally Enhanced DFN3.5x3-14L package
- RoHS & Halogen Free & TSA Compliant

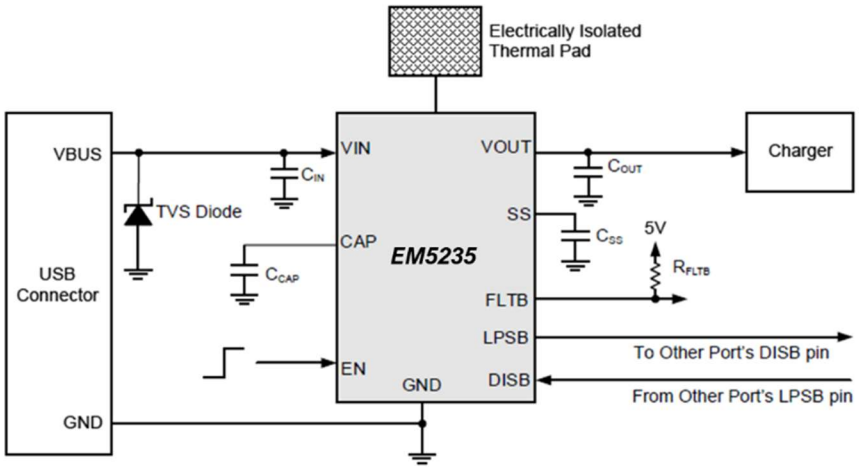
Applications

- USB PD power source switch
- Smart phone and tablet
- Notebook, Ultrabook and desktops

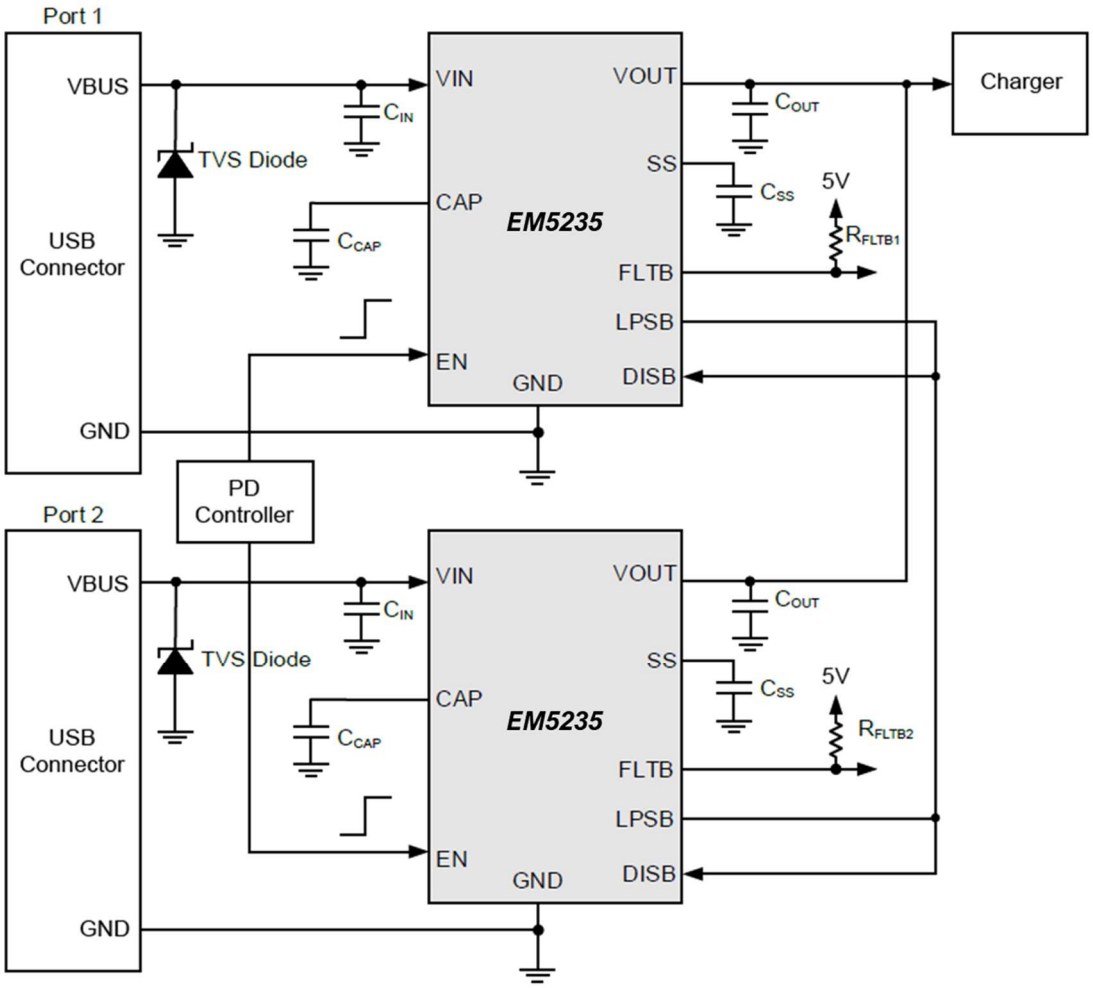
Ordering Information

Part Number	Fault Recovery	Package
EM5235AVME	Auto-Restart	DFN3.5x3-14L
EM5235BVME	Latch-Off	DFN3.5x3-14L

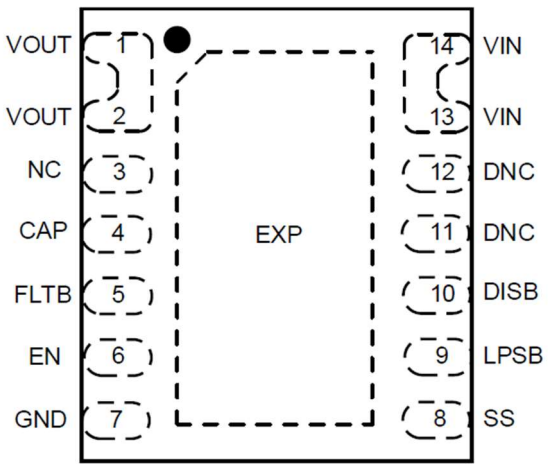
Typical Application Circuit



Typical Multiple Ports Application Circuit



Pin Configuration



DFN3.5x3-14L
(Top Transparent View)

Pin Description

Pin Number	Pin Name	Pin Function
1, 2	VOUT	Output pins. Connect to internal load.
3	NC	No connect.
4	CAP	Connect a 1nF Capacitor to GND. No external load is allowed on this pin.
5	FLTB	Fault Indicator, Active low, open-drain output.
6	EN	Enable, Active.
7	GND	Ground.
8	SS	Soft-start pin. Connect a capacitor CSS from SS to GND to set the soft-start time.
9	LPSB	LPS Fault Output Indicator. LPSB will pull low if VIN exceeds LPBS detection voltage threshold when the part is disabled (EN= Low).
10	DISB	Disable Bar input pin. DISB has an internal 10 μA pull-up current source. For 3-port or less systems tie all DISB pins together. Once DISB pulls low the power MOSFET will turn off but IC will remain active. Only cycling VIN can re-enable the devices.
11	DNC	Do not connect. No external connections allowed.
12	DNC	Do not connect. Internally connected to common drain node of power switch.
13, 14	VIN	Connect to adapter or power input. Place a 10μF capacitor from VIN to GND. When EN goes low, VIN will internally discharge to GND.
EXP	EXP	Exposed Thermal Pad. It is the common drain node for the power switches and it must be electrically isolated. Solder to a metal surface directly underneath the EXP and connect to floating copper thermal pads on multiple PCB layers through many VIAs. For best thermal performance, make the floating copper pads as large as possible.

Absolute Maximum Ratings

Exceeding the Absolute Maximum Ratings may damage the device.

Parameter	Rating
VIN, VOUT to GND	-0.3V to +28V
EN, SS, FLTB, DISB, LPSB to GND	-0.3V to +6V
CAP to VIN	-0.3V to +6V
Junction Temperature (T_J)	+150°C
Storage Temperature (T_S)	-65 °C to +150°C
ESD Rating HBM All Pins	±2kV
IEC 61000-4-2:VINAndVOUT Pins	±8kV

Recommended Operating Conditions

The device is not guaranteed to operate beyond the Maximum Recommended Operating Conditions.

Parameter	Rating
VIN, VOUT to GND	3.3V to 23V
EN, FLTB, DISB, LPSB to GND	0V to 5.5V
SS	0V to 3V
CAP to VIN	0V to 5.5V
Switch Current (I_{SW})	0A to 8A
Peak Switch Current (I_{SW}) for 10ms @ 2% Duty cycle	20A
Junction Temperature (T_J)	-40°C to +125°C

Electrical Characteristics

T_A= 25°C, VIN= 20V, EN= 5V, C_{CAP}= 1nF, C_{IN}= 10µF, C_{OUT}= 10µF, C_{SS}= 5.6nF, unless otherwise specified.

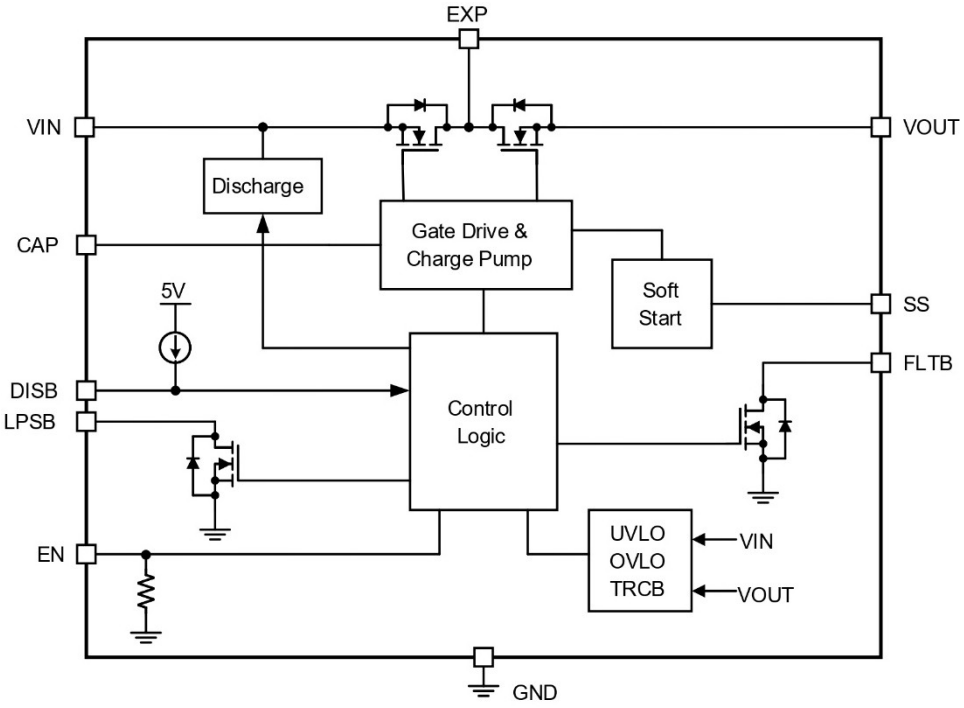
Symbol	Parameter	Conditions	Min	Typ	Max	Units
General						
V_{VIN}	Input Supply Voltage		3.3		23	V
V_{UVLO}	Under-voltage Lockout Threshold	VIN rising	2.85		3.25	V
V_{UVLO_HYS}	Under-voltage Lockout Hysteresis			150		mV
I_{VIN_ON}	Input Quiescent Current	IOUT= 0A		650	910	µA
I_{VIN_OFF}	Input Shutdown Current	IOUT= 0A, EN= 0V		75	150	µA
I_{VOUT_OFF}	Output Leakage Current	VOUT= 20V, VIN= 0V, EN= 0V		48	150	µA
R_{ON_20V}	Switch ON-Resistance (1)	IOUT > 2.25A		18		mΩ
R_{ON_5V}		VIN= 5V, IOUT > 2.25A		19		mΩ
V_{EN_H}	EN Input High Threshold	EN rising			1.4	V
V_{EN_L}	EN Input Low Threshold	EN falling	0.4			V
I_{EN_BIAS}	EN Pin Input Pull-low Resistance			1		MΩ
V_{FLTB_LO}	FLTB Pull-down Voltage	FLTB sinking 3mA			0.3	V
Input Over-Voltage Protection (OVP)						
V_{OVP}	Over-voltage Protection Threshold	VIN rising	23.1	24	25	V
V_{OVP_HYS}	Over-voltage Protection Hysteresis	EM5235A only		300		mV
t_{OVP_DEB}	Over-voltage Protection Debounce Time			512		µs

Electrical Characteristics

T_A= 25°C, VIN= 20V, EN= 5V, C_{CAP}= 1nF, C_{IN}= 10µF, C_{OUT}= 10µF, C_{SS}= 5.6nF, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Ideal Diode Regulation Voltage						
V_{ID_REG}	Ideal diode voltage regulation	VIN - VOUT		35		mV
Dynamic Timing Characteristics						
t_{D_ON}	Turn-On Delay Time	From EN rising edge to VOUT reaching 10% of VIN.		10		ms
t_{ON}	Turn-On Rise Time	VOUT from 10% to 90%		2		ms
t_{OFF}	Turn-Off Fall Time	From EN falling Edge to IOUT= 0A		32		µs
t_{REC}	Auto Restart Interval after OVP or TSD Fault Conditions	EM5235A only		64		ms
$t_{SCP\_REC\_01}$	Auto Restart Interval upon Startup Short Circuit Condition	EM5235A only		64		ms
$t_{SCP\_REC\_02}$	Auto Restart Interval at Each Retry upon Startup Short Circuit Condition	EM5235B only. Latch-off after 4 times retry		2		ms
Thermal Shutdown (TSD)						
T_{SD}	Thermal Shutdown Threshold	Temperature rising		140		°C
T_{SD_HYS}	Thermal Shutdown Hysteresis	Temperature falling EM5235A only		30		°C
VIN Discharge						
$V_{DISC\_DET\_FALL}$	VIN falling edge threshold for VIN discharge turn on			4.25	4.4	V
$V_{DISC\_DET\_RISE}$	VIN rising edge threshold for VIN				4.5	V
V_{DISC_MIN}	discharge turn off				0	V
$t_{DISC\_TIMEOUT}$	VIN Discharge off voltage	VOUT = 5 V		1		s
I_{VIN_DISC}	VIN Discharge Current Time Out	From EN falling edge to VIN		4		mA
Limited Power Source Function (LPS)						
$V_{LPSB\_VIN\_DET}$	LPSB Detection Voltage Threshold	VIN rising, EN = 0 V	6.0	6.3		V
$V_{LPSB\_VIN\_HYS}$	LPSB Detection Voltage Hysteresis	VIN falling		150		mV
t_{LPSB}	LPSB Debounce Time	From VIN > VLPSB_VIN_DET to LPSB < 0.3V, EN = 0 V		2.5		s
V_{LPSB_LO}	LPSB Pull-Down Voltage	LPSB sinking 3 mA			0.3	V
I_{DISB_BIAS}	DISB pull up current			10		µA
V_{DISB_H}	DISB Input High Threshold	DISB rising			1.4	V
V_{DISB_L}	DISB Input Low Threshold	DISB falling	0.4			V
t_{DISB_RESP}	DISB Detection Response Time to			160		µs

Function Block Diagram



Timing Diagrams

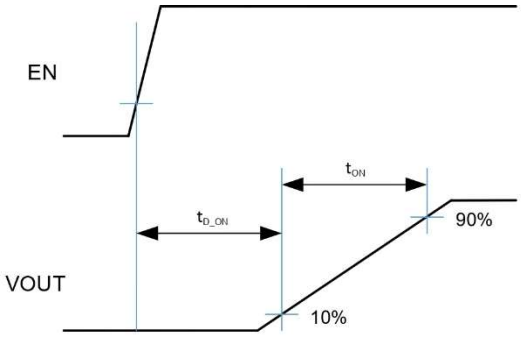


Fig. 1. Turn-on Delay and Turn-on Time

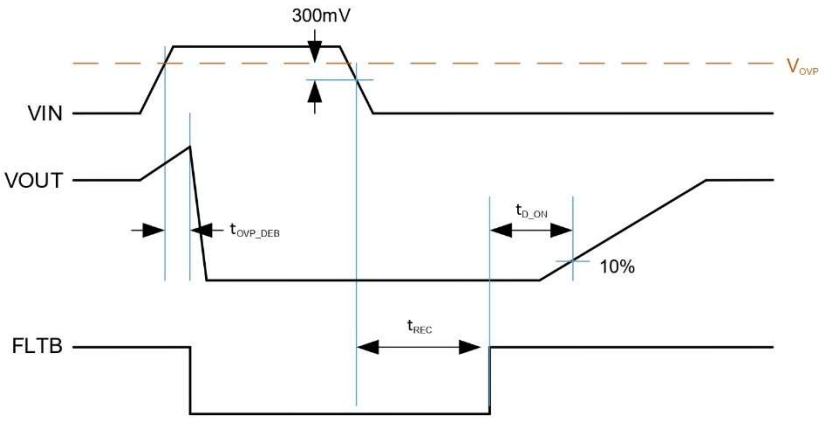


Fig. 2. Over-Voltage Protection (EM5235A)

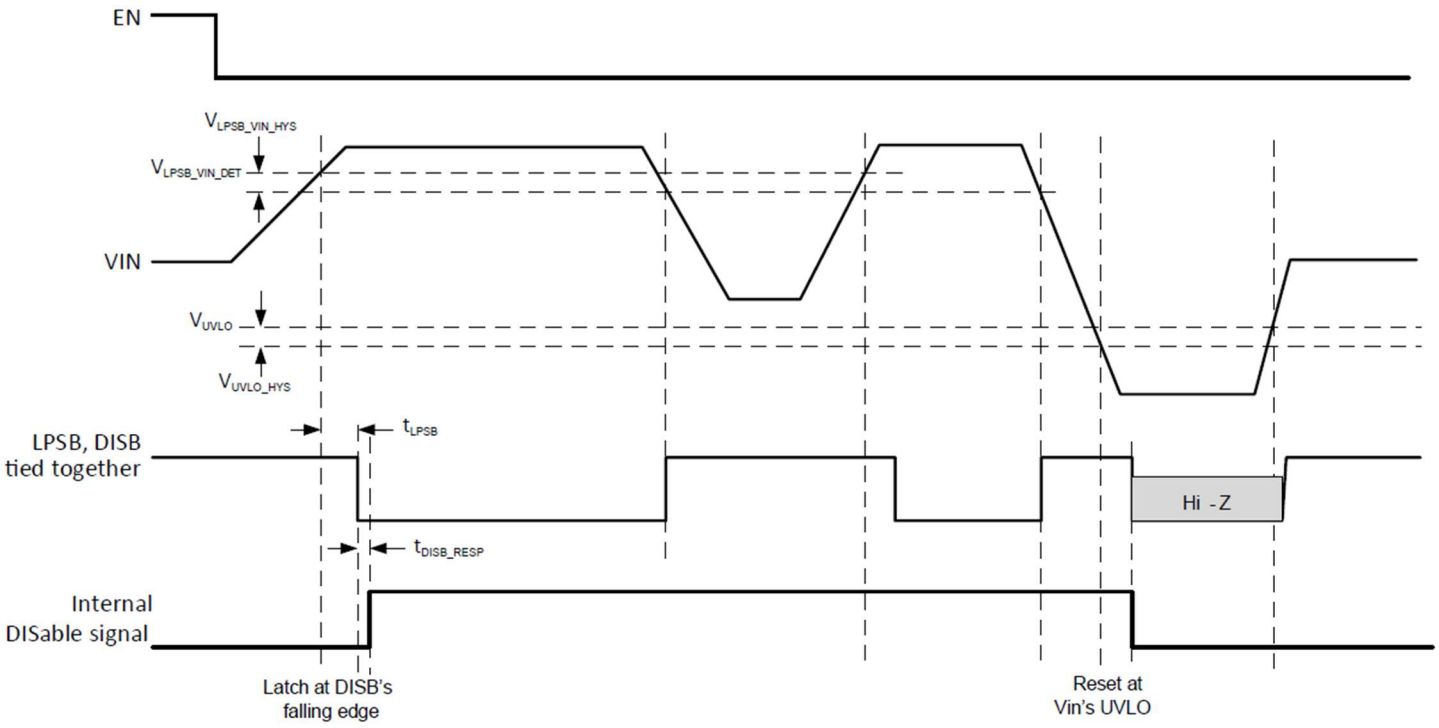
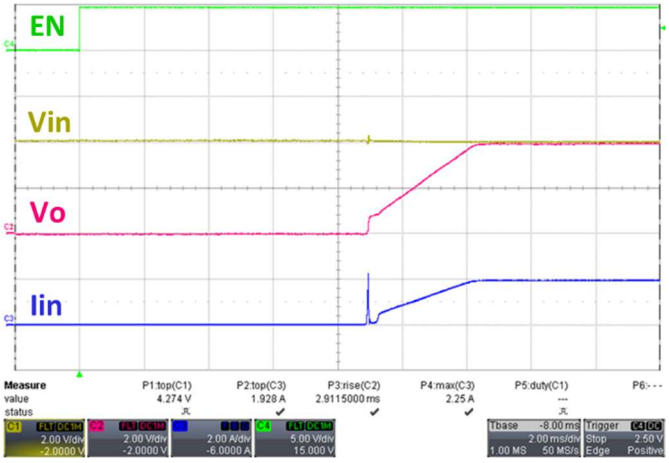


Fig. 3. Limited Power Supply Protection

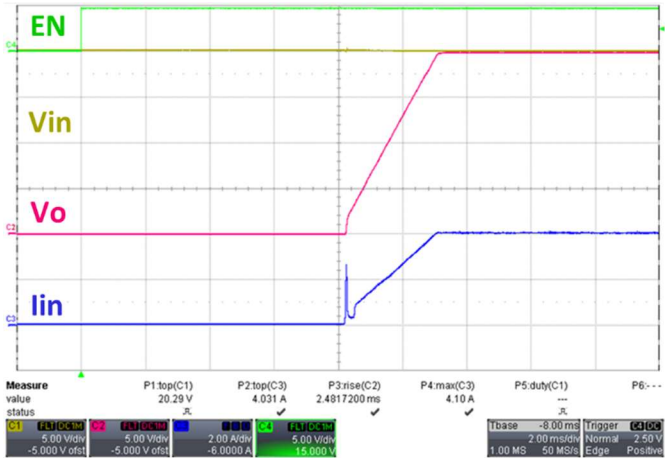
Typical Characteristics

T_A= 25°C, VIN= 20V, EN= 5V, C_{CAP}= 1nF, C_{IN}= 10µF, C_{OUT}= 10µF, C_{SS}= 5.6nF, unless otherwise specified.

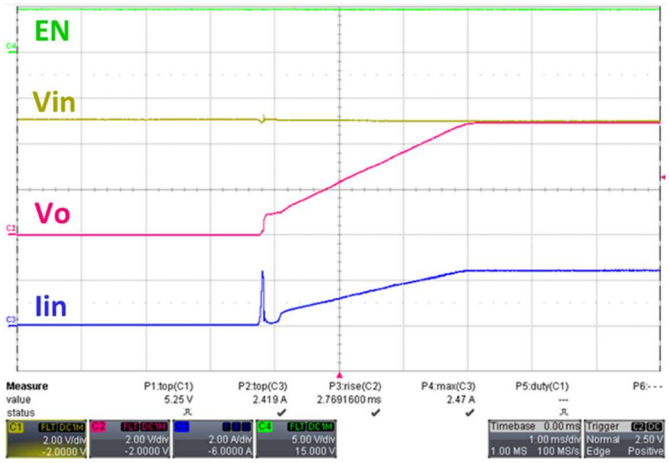
Soft Start Delay Time
(VIN= 4V, R_{OUT} = 2Ω)



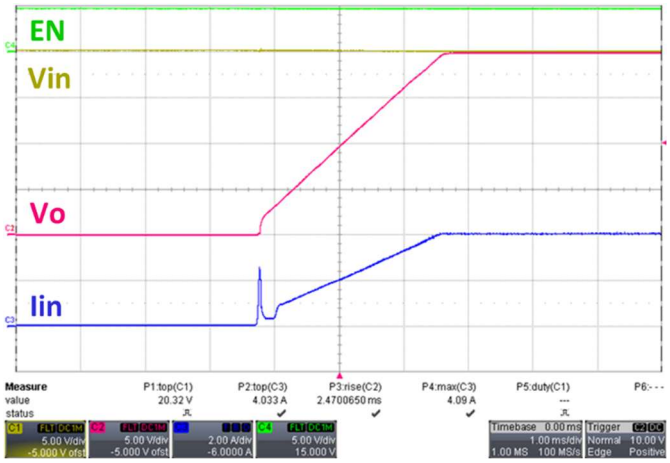
Soft Start Delay Time
(VIN= 20, R_{OUT} = 5Ω)



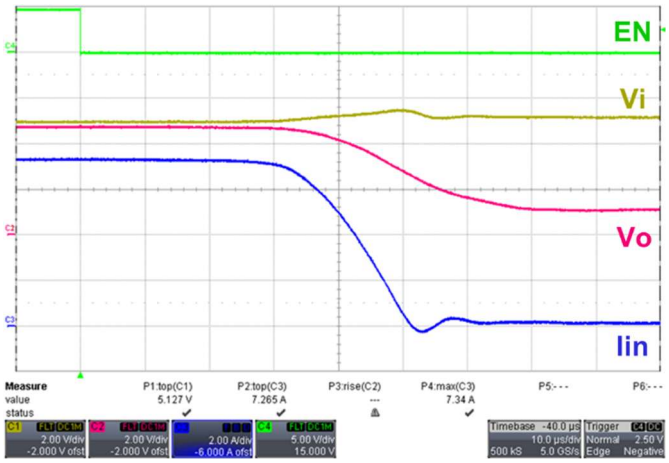
Soft Start Ramp Time
(VIN= 5V, R_{OUT} = 2Ω)



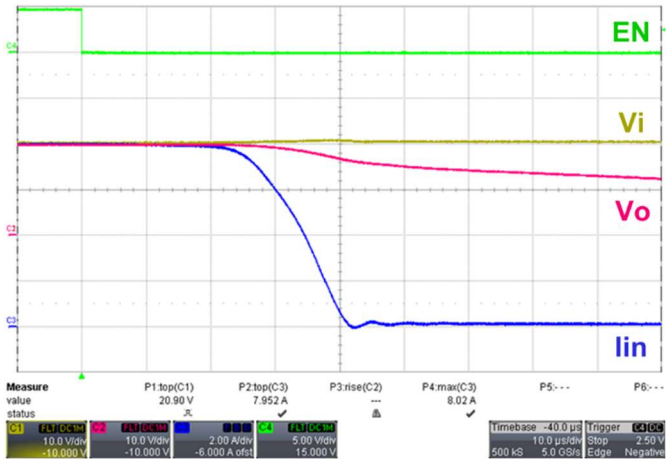
Soft Start Ramp Time
(VIN= 20V, R_{OUT} = 5Ω)



Shut Down
(VIN= 5V, R_{OUT} = 0.625Ω)



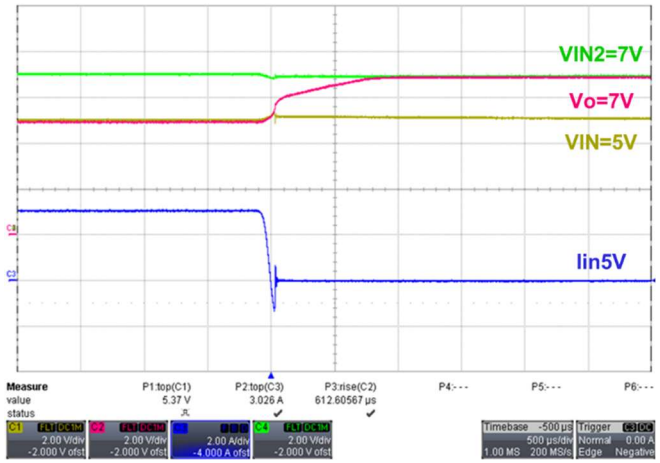
Shut Down
(VIN= 20V, R_{OUT} = 2.5Ω)



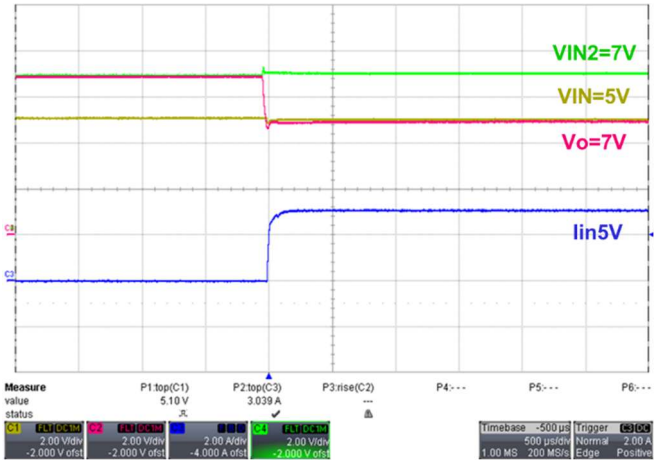
Typical Characteristics

T_A= 25°C, VIN= 20V, EN= 5V, C_{CAP}= 1nF, C_{IN}= 10µF, C_{OUT}= 10µF, C_{SS}= 5.6nF, unless otherwise specified.

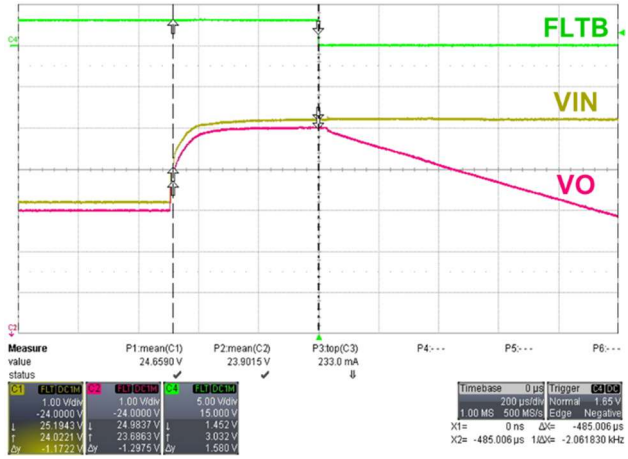
Reverse Voltage Blocking - Entry
(Load= 3A)



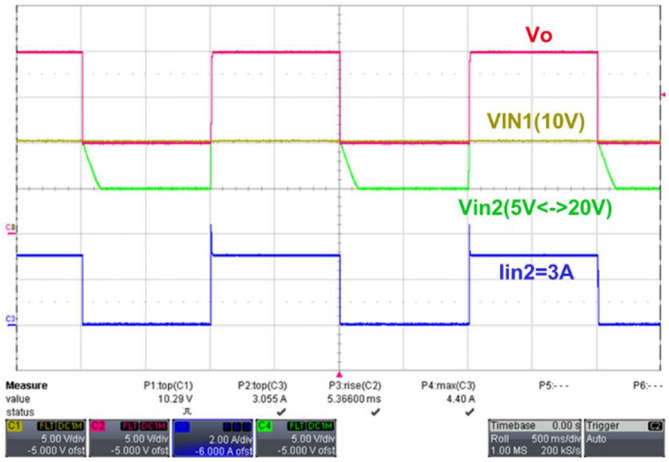
Reverse Voltage Blocking - Exit
(Load= 3A)



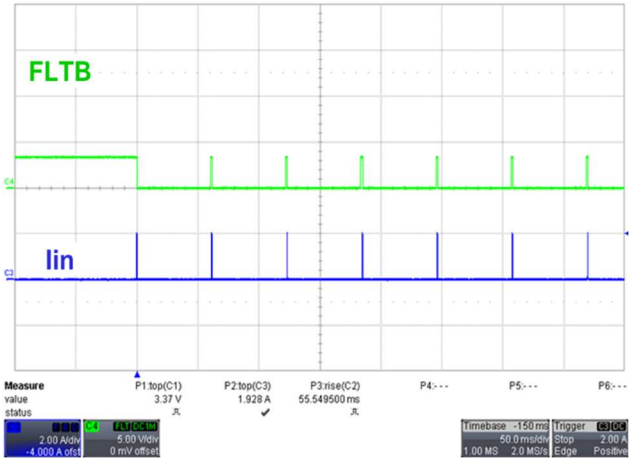
Over Voltage Protection
(VIN= 20V, R_{OUT} = 100Ω)



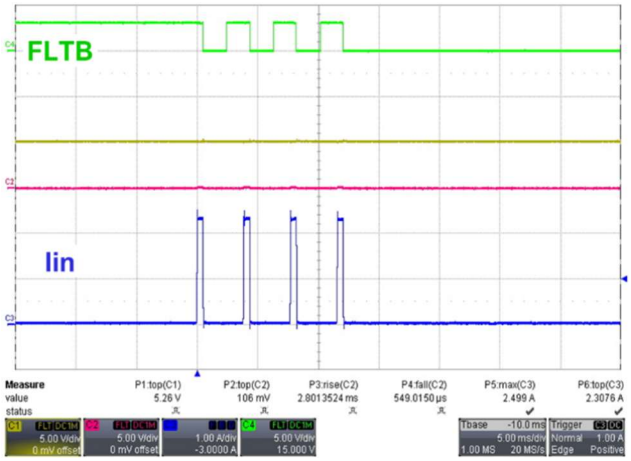
Oring Operation
(EN1=EN2= high, VIN1= 12V, VIN2= 5V→20V→5V, VOUT1 and VOUT2 are tied together)



Short Ciruit Protection During Startup
(EM5235A)



Short Ciruit Protection During Startup
(EM5235B)

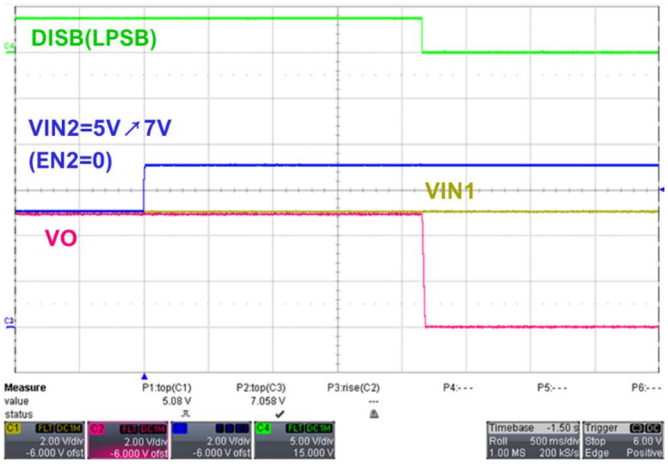


Typical Characteristics

T_A= 25°C, VIN= 20V, EN= 5V, C_{CAP}= 1nF, C_{IN}= 10µF, C_{OUT}= 10µF, C_{SS}= 5.6nF, unless otherwise specified.

Limited Power Source Operation

(EN= 0V, VIN= 5V->7V)



Typical Characteristics

T_A= 25°C unless otherwise specified.

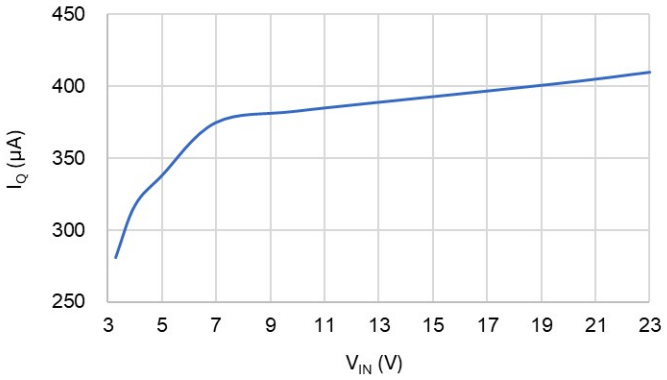


Fig. 4. Quiescent Current vs VIN

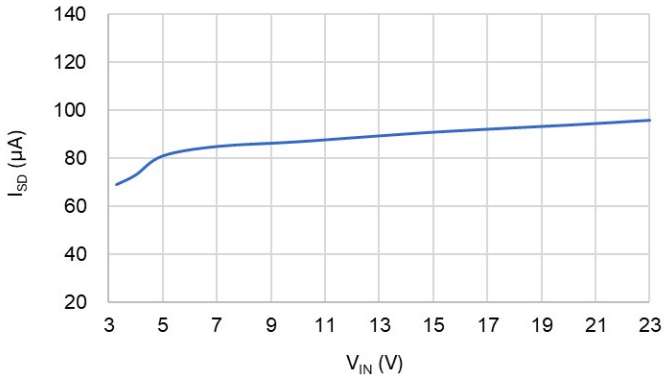


Fig.5. Shutdown Current vs VIN

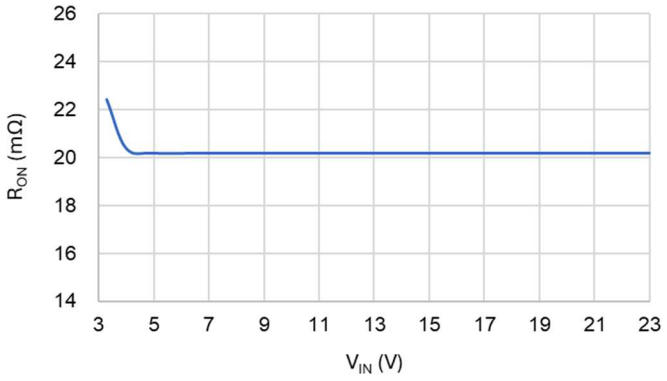


Fig. 6. On Resistance vs VIN

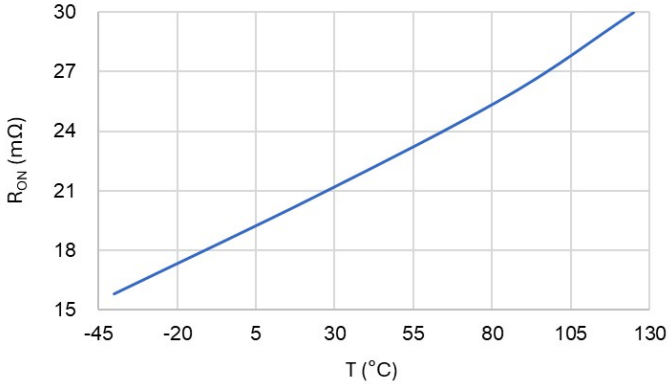


Fig. 7. On Resistance vs Temperature
(VIN= 20V)

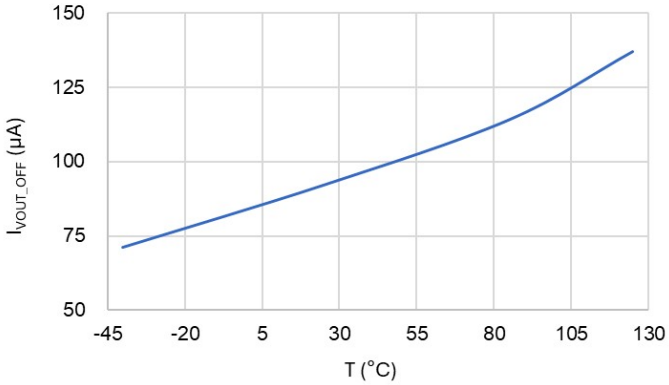


Fig. 8. VOUT Leakage Current vs Temperature
(VOUT= 20V, VIN= 0V, EN= 0V)

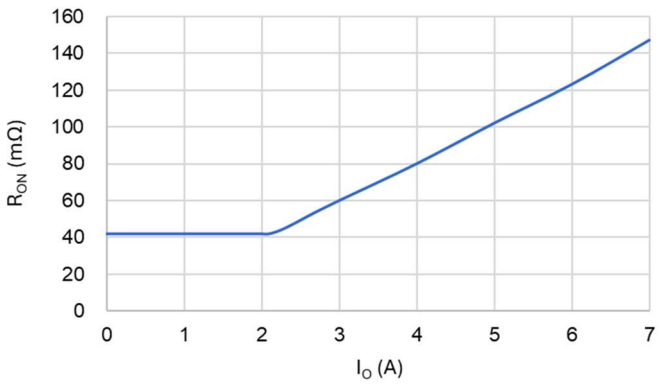


Fig. 9. VIN-VOUT vs Output Current

Functional Description

The EM5235 is a high-side protection switch with adjustable soft-start, over-voltage and over-temperature protections. It is capable of operating from 3.3V to 23V and rated up to 8A.

The internal power switch consists of 2 back-to-back connected N-channel MOSFETs. When the switch is enabled, the overall resistance between VIN and VOUT is only 18mΩ when IOUT > 3.5A, minimizing power loss and heat generation. The back-to-back configuration of MOSFETs completely isolates VIN and VOUT when the switch is turned off, preventing leakage between the two pins.

Enable

The active high EN pin is the ON/OFF control for the power switch. The device is enabled when the EN pin is high and VIN > V_{UVLO}. The EN pin must be driven to a logic high (V_{EN_H}) or logic low (V_{EN_L}) state to guarantee operation.

Input Under-Voltage Lockout (UVLO)

The internal control circuit is powered from VIN. The Under- Voltage Lock Out (UVLO) circuit monitors the voltage at the input pin (VIN) and only allows the power switches to turn on when it is higher than UVLO threshold (V_{UVLO}).

Over-Voltage Protection (OVP)

The voltages at VIN pin are constantly monitored once the device is enabled. In case the voltage exceeds the OVP threshold, over-voltage protection is activated:

1. If the power switch is on, it will be turned off after OVP debounce time (t_{OVP_DEB}) to isolate VOUT from VIN.

2. OVP will prevent power switch to be turned on if it is in off state.

In either case FLTB pin is pulled low to report the fault condition. The device can only be re-enabled by either toggling EN pin or cycling the input power supply.

Reverse Voltage Blocking

When the device is on with no load or under light load conditions, EM5235 regulates VOUT 35mV below VIN. As the load current is increased or decreased the device adjusts the gate drive to maintain the 35mV drop from VIN to VOUT. As the load current increases the device increases the gate drive until the gate is fully on and VOUT to VIN drop is determined by IR drop through the MOSFET. If for any reason VOUT increases such that VIN to VOUT drop is less than 35mV, the gate driver forces the switch to turn off.

Thermal Shut Down Protection (TSD)

Thermal shutdown protects device from excessive temperature. The power switch is turned off when the die temperature reaches thermal shutdown threshold of 140°C. There is a 30°C hysteresis for the EM5235A: The power switch is allowed to turn on again if die temperature drops below approximately 110°C.

EM5235A (Auto-Restart version): Once the TSD is removed, the power switch with be turn on again to restart after 64ms (t_{REC}) blanking time.

EM5235B (Latch-Off version): The device will latch off and only be turned on after either toggling the EN input logic to reset the device or cycling the input voltage.

Soft Start Slew Rate Control

When EN pin is asserted logic high, the slew rate control circuitry applies a voltage on the gate of the power switch in a manner such that the output voltage is ramped up linearly until it reaches the input voltage level. The output ramp up time is programmed by an external soft-start capacitor (C_{SS}). The following formula provides the estimated 10% to 90% ramp up time.

$$t_{ON} = \frac{C_{SS}}{0.0023} - 100$$

where C_{SS} is in nF and t_{ON} is in μs.

System Startup

The device is enabled when EN ≥ 1.4 V and VIN is higher than UVLO threshold (V_{UVLO}). The device will check if any fault condition exists. If no fault exists, the power switch is turned on and VOUT is then ramped up after enable delay (t_{D_ON}), controlled by the soft-start time (t_{ON}) until VOUT reaches VIN voltage level. Soft start time can be programmed externally through SS input with a capacitor C_{SS} to control in-rush current.

In-rush Current Limit and SCP at Start Up

EM5235 has the current limit and short circuit protection functions at start up. With this current limit control, the inrush current can be effectively clamped to reduce the initial current spikes. At initial startup, the internal power switch carries large voltage close to VIN and has large power loss. To ensure the internal MOSFET working in Safe Operation Area (SOA), a fixed timer is set to shut down the power switch if the inrush current is clamped by current limit for about 512μs continuously. This timer will be reset once the inrush current drops below the current limit. For short circuit event, the part will shut down after this 512μs timer is finished. In case of large output capacitors, the soft start time needs to increase to avoid the large inrush current hit the current limit for 512μs. SCP is not active after the soft start is completed.

EM5235A (Auto-Restart version): The power switch is turned off under SCP condition at startup. The device will try to restart indefinitely for every 64ms ($t_{SCP\_REC\_01}$) until it is disabled.

EM5235B (Latch-Off version): The power switch is turned off under SCP condition at startup. The device will try to restart 4 times with 2ms ($t_{SCP\_REC\_02}$) blanking time. If SCP condition still exist after this 4 retries, the device will be latched off. After latch-off, either toggling the EN input logic to reset the device or cycling the input voltage can turn on the power switch.

Fault Protection

The EM5235 offers protection against the following fault conditions: VIN over voltage (OVP), VOUT greater than VIN (RVP), and over temperature (OTP). When the device is first enabled, the power switch is off and fault conditions are checked. If VIN is higher than the OVP threshold, or SCP during start up or the die temperature is higher than thermal shutdown threshold, the FLTB pin will be pulled low to flag the fault. After the power switch turns on, the device continuously monitors all fault conditions. The switch is immediately turned off when over voltage, VOUT greater than VIN or over temperature is detected. FLTB pin will be subsequently pulled low at OVP or TSD condition.

Table 1. EM5235A Fault flag response to all protection functions

Protection	Fault Response	FLTB Status
IDTRCB	Auto-restart without soft-start at fault removal	High Impedance
Startup SCP	Auto-restart after 64ms	Low
TSD	Auto-restart with soft-start at 64ms after fault removal	Low
OVP	Auto-restart with soft-start at 64ms after fault removal	Low

Table 2. EM5235B Fault flag response to all protection functions

Protection	Fault Response	FLTB Status
IDTRCB	Auto-restart without soft-start at fault removal	High Impedance
Startup SCP	4 times retry then latch off	Low
TSD	Latch-off	Low
OVP	Latch-off	Low

Slow Turn Off

Slow turn off reduces the voltage spikes that can arise if the switch is turned off too quickly. The device current is ramped down to 0A in 32μs after the EN is de-asserted to reduce these voltage spikes.

Limited Power Source (LPS) Protection

When the device is disable (EN= 0V), it continuously monitors the VIN voltage. If VIN exceeds LPSB detection threshold ($V_{LPSB\_VIN\_DET}$) for more than 2.5s, the LPSB pin is pulled low to indicate a possible short across the power switch as shown in Fig. 13 LPSB is an open drain output and an external pull up is required under no fault condition.

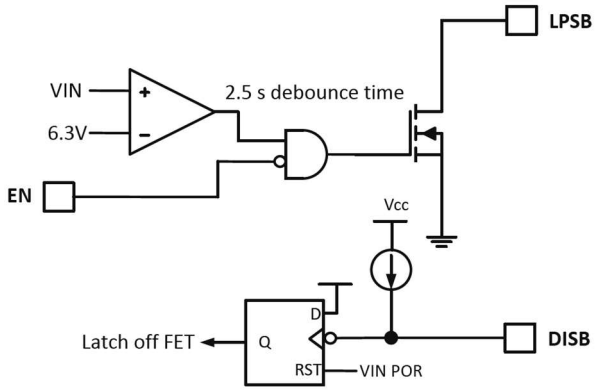


Fig. 13. LPSB pulls low when VIN > 6.3V and part is disabled.

For multi-port ORing or parallel power applications, the LPSB pin of a EM5235 device can be connected to DISB pin of one or more EM5235 devices at other ports as shown in Figure 14. This configuration will turn off all connected devices regardless of the status of their EN pins. When all devices are off, the shared power bus at VOUT will not be energized. Thus, no excessive power will flow from VOUT bus to the port of the shorted power switch.

The LPSB is cleared when VIN drops below LPSB detection lower threshold voltage ($V_{LPSB\_VIN\_DET}$ - $V_{LPSB\_VIN\_HYS}$) or the device is enabled. However, DISB going high does not enable the connected EM5235. The device can only be turned on by cycling VIN power. Please refer the Fig. 3 for timing details.

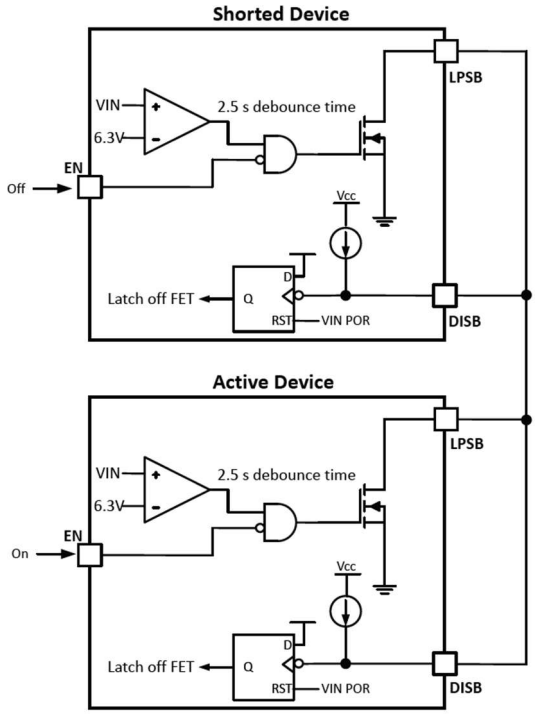


Fig. 14. Connected LPSB and DISB of all devices to protect excessive power through shorted device.

Input Capacitor Selection

The input capacitor prevents large voltage transients from appearing at the input, and provides the instantaneous current needed each time the switch turns on to charge output capacitors and to limit input voltage drop. It is also to prevent high-frequency noise on the power line from passing through to the output. The input capacitor should be located as close to the pin as possible. A 10μF ceramic capacitor is recommended. For Type-C port application, the USB specification limits the capacitance on VBUS (VIN) to a maximum of 10μF. Use this maximum value for noise immunity due to the system and cable plug/unplug transients.

VIN Discharge

The VIN discharge current is 4mA. The discharge current is active when enable is low and the VIN falls below $V_{DISC\_DET\_FALL}$ If there is voltage ($V_{DISC\_DET\_FALL}$) on VOUT, the discharge circuit will discharge the VIN to 0V. If the voltage on VOUT is less than V_{UVLO}, the discharge circuit will be turned off when VIN falls below V_{UVLO}. There is also a watchdog timer that will turn off the discharge if the discharge circuit cannot discharge the VIN down to 0V within $t_{DISC\_TIMEOUT}$.

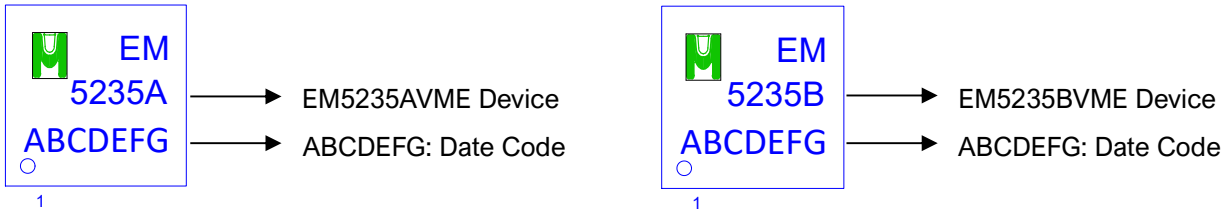
Layout Guidelines

The exposed thermal pad transfers heat from the EM5235 to the PCB. It is the common drain node of the power switch and no electrical connection is allowed. In order to transfer heat from the device as quick as possible, put a thermal copper pad directly beneath the exposed pad. Make the pad as large as the exposed pad. Extend out the top of the device for better heat sinking capability. For more effective heat sinking, attach the exposed pad to as many layers as possible (inner layers and the back side of the PCB). Each inner layer must be an island with no electrical connection to any other signals or power. Place the maximum number of VIAs as allowed within the exposed pad area.

The output and input capacitors (COUT and CIN) should be placed as close as possible to their respective pins (VOUT and VIN). This reduces transient under/overshoots due to load or line transients to a minimum.

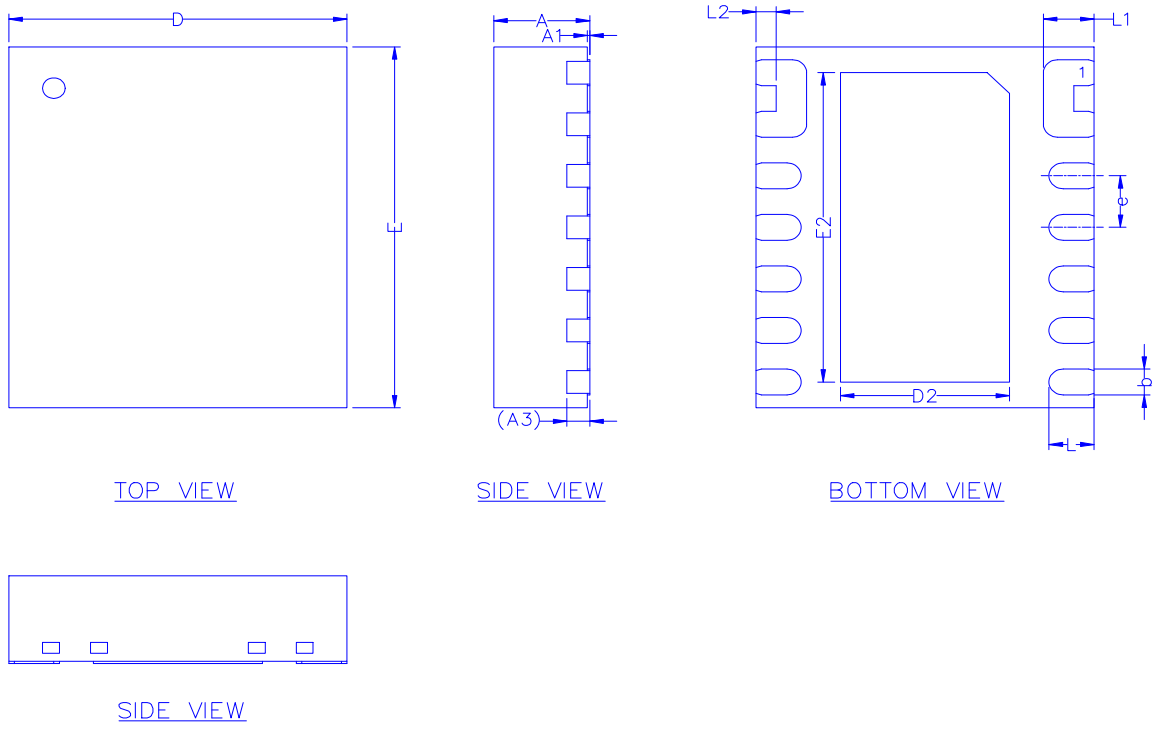
Ordering & Marking Information

Device Name: EM5235AVME & EM5232BVME for DFN3.5X3-14L



Outline Drawing

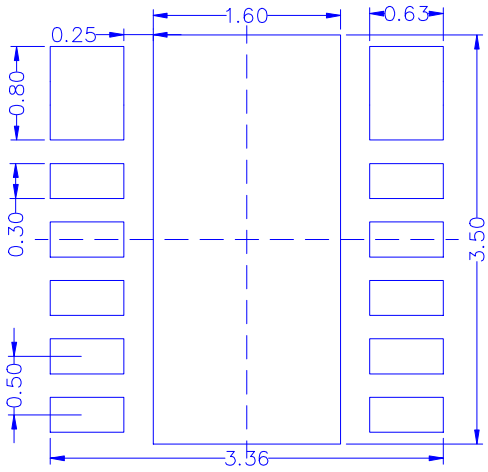
DFN3.5X3-14L



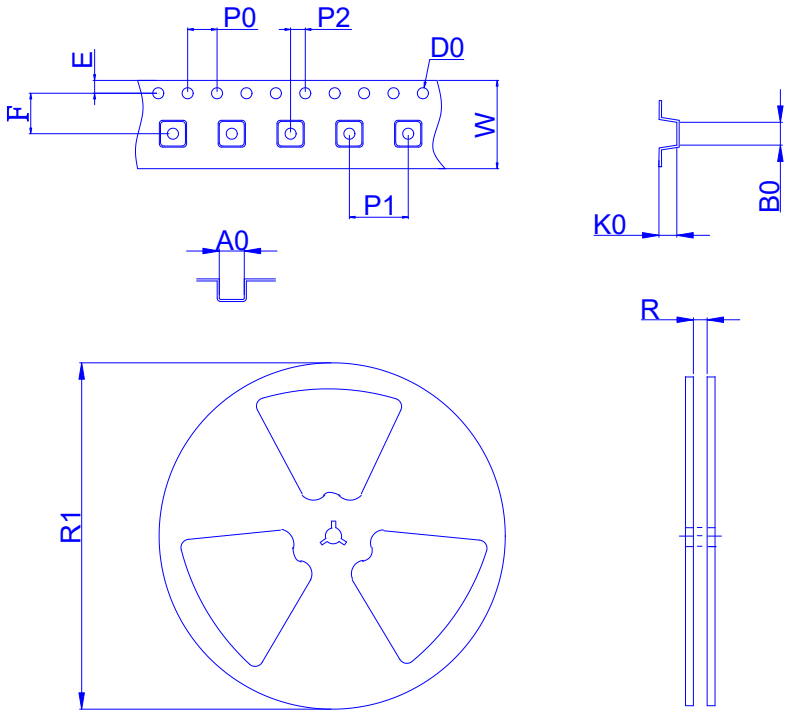
Dimension in mm

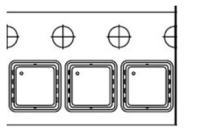
Dimension	A	A1	A3	b	D	E	D2	E2	e	L	L1	L2
Min.	0.80	0.00	-	0.18	2.90	3.40	1.40	2.90	0.40	0.30	0.35	0.08
Typ.	0.85	0.02	0.203	0.25	3.00	3.50	1.50	3.00	0.50	0.40	0.45	0.18
Max.	0.90	0.05	-	0.30	3.10	3.60	1.60	3.10	0.60	0.50	0.55	0.28

Footprint



◆ Tape&Reel Information: 5000pcs/Reel



Package	DFN3.5X3-14L
Reel	13”
Device Orientation	FEED DIRECTION 

Dimension in mm

Dimension	Carrier tape									Reel	
	A0	B0	D0	E	K0	P0	P1	P2	W	R	R1
Typ.	3.25	3.75	1.55	1.75	1.10	4.00	8.00	2.00	12.00	12.40	330.00
±	0.10	0.10	+0.10 -0.00	0.10	0.10	0.10	0.10	0.05	+0.30 -0.10	REF	REF