

4.2V to 20V Input, 2A Synchronous Step-Down Voltage Regulator

UM5485S SOT23-6
UM5485FSB SOT23-6

1 Description

The UM5485 is simple, easy-to-use, 2A synchronous step-down converters in SOT-23 package. The device is optimized to operate with minimum external component counts and also optimized to achieve low standby current.

These switch mode power supply (SMPS) devices employ COT mode control providing a fast transient response and supporting both low-equivalent series resistance (ESR) output capacitors such as specialty polymer and ultra-low ESR ceramic capacitors with no external compensation components.

The UM5485 operates in pulse skip mode, which maintains high efficiency during light load operation. The UM5485 is available in a 6-pin SOT package, and specified from a -40°C to 125°C Junction temperature.

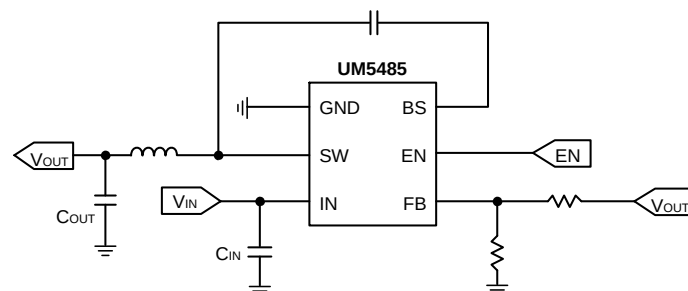
2 Applications

- Digital TV Power Supply
- High Definition Blu-ray Disc Players
- Networking Home Terminal
- Digital Set Top Box (STB)
- Surveillance

3 Features

- UM5485 2A Converter Integrated 97-m Ω and 55-m Ω FETs
- COT Mode Control with fast transient response
- Input Voltage Range: 4.2 V to 20 V
- Output Voltage Range: 0.77 V to 5 V
- Pulse-skip mode
- 650 kHz Switching Frequency (Typ)
- Low Shutdown Current Less than 5 μA
- 2.5% Feedback Voltage Accuracy (25 $^{\circ}\text{C}$)
- Startup from Pre-Biased Output Voltage
- Hiccup-mode Overcurrent Protection
- Cycle-by-Cycle Overcurrent Limit
- Non-Latch UVP and TSD Protections
- Fixed Soft Start: 1 ms

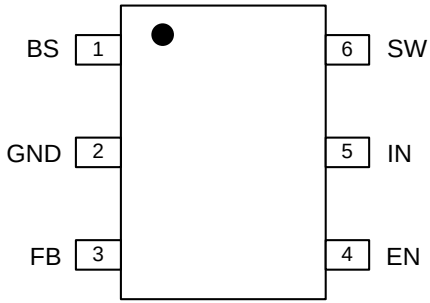
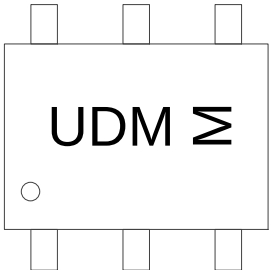
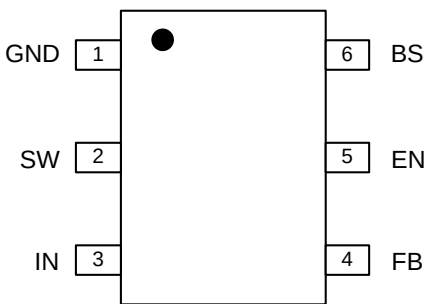
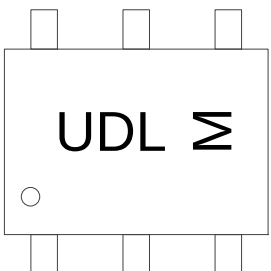
4 Typical Application Circuit



5 Ordering Information

Part Number	Mark Code	Package Type	Shipping Qty
UM5485S	UDM	SOT23-6	3000pcs/7 Inch Tape & Reel
UM5485FSB	UDL	SOT23-6	3000pcs/7 Inch Tape & Reel

6 Pin Configuration and Function

	 M: Month Code UM5485S SOT23-6
	 M: Month Code UM5485FSB SOT23-6

6 Pin Configuration and Function (continued)

Table 6-1. Pin Functions

Pin No.		Pin Name	Function
UM5485S	UM5485FSB		
2	1	GND	Ground. Source terminal of low-side power NFET as well as the ground terminal for controller circuit. Connect sensitive FB to this GND at a single point.
6	2	SW	Switch node connection between high-side NFET and low-side NFET.
5	3	IN	Input voltage supply pin. The drain terminal of high-side power NFET.
3	4	FB	Converter feedback input. Connect to output voltage with feedback resistor divider.
4	5	EN	Enable input control. Active high and must be pulled up to enable the device.
1	6	BS	Supply input for the high-side NFET gate drive circuit. Connect 0.1 μ F capacitor between BS and SW pins.

7 Specifications

7.1 Absolute Maximum Ratings (Note 1)

over operating free-air temperature range (unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IN}			-0.3		22	V
V_{EN}	Voltage on EN pin		-0.3		22	V
V_{BS}	Voltage on BS pin		-0.3		26	V
V_{BS}	Voltage on BS pin (10 ns transient)		-0.3		27	V
V_{BS}	Voltage on BS pin (vs SW)		-0.3		6	V
V_{FB}	Voltage on FB pin		-0.3		6	V
V_{SW}	Voltage on SW pin		-1.8		22	V
V_{SW}	Voltage on SW pin (10 ns transient)		-3.2		23	V
V_{ESD}	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001	All pins		± 3		kV
	Charged-device model (CDM), per ANSI/ESDA/JEDEC JS-002			± 2		kV
T_J	Junction Temperature Range		-40		125	$^{\circ}$ C
T_{STG}	Storage Temperature Range		-55		150	$^{\circ}$ C

Note 1: Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

7.2 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V _{IN}	Supply Voltage on IN pin		4.0		20	V
V _{BS}	Voltage on BS pin		-0.1		24	V
V _{BS}	Voltage on BS pin (10 ns transient)		-0.1		25	V
V _{BS}	Voltage on BS pin (vs SW)		-0.1		5	V
V _{EN}	Voltage on EN pin		-0.1		20	V
V _{FB}	Voltage on FB pin		-0.1		5	V
V _{SW}	Voltage on SW pin		-1.5		20	V
V _{SW}	Voltage on SW pin (10 ns transient)		-3		21	V

7.3 Thermal Information

Symbol	Parameter	SOT23-6	Unit
		6 Pins	
R _{θJA}	Junction-to-ambient thermal resistance	92.6	°C/W
R _{θJC(TOP)}	Junction-to-case (top) thermal resistance	48.5	°C/W
R _{θJB}	Junction-to-board thermal resistance	15.5	°C/W
ψ _{JT}	Junction-to-top characterization parameter	2.5	°C/W
ψ _{JB}	Junction-to-board characterization parameter	15.5	°C/W

7.4 Electrical Characteristics

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

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V _{IN}	Input Voltage Range		4.2		20	V
Supply Current						
I _{VIN}	Switching supply current	VIN current, L=2.2μH, VOUT=3.3V, floating		330	470	μA
	Shutdown supply current	VIN current, EN = 0 V		0.5	3	
Logic Threshold						
V _{IH}	Input high Voltage	EN	1.5			V
V _{IL}	Input low Voltage	EN			0.7	V
I _{EN}	EN pulldown current	V _{EN} = 1.5 V		1.25		μA
R _{EN}	EN pin resistance to GND	V _{EN} = 1.5 V		1200		kΩ

7.4 Electrical Characteristics (continued)
 $V_{IN} = 12\text{ V}$, $V_{EN} = V_{IN}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
FB Voltage and Discharge Resistance						
V_{FBTH}	FB threshold	$V_{OUT} = 3.3\text{ V}$, $I_O = 10\text{ mA}$, Pulse skip mode (Note 1)		774		mV
	FB threshold	$V_{OUT} = 3.3\text{ V}$, continuous mode operation	744	763	782	mV
I_{FB}	FB input current	$V_{FB} = 0.8\text{ V}$		0	± 1	μA
MOSFET						
$R_{DS(ON)H}$	High-side switch resistance	$T_A = 25^\circ\text{C}$, $V_{BS} - V_{SW} = 5\text{ V}$		97		$\text{m}\Omega$
$R_{DS(ON)L}$	Low-side switch resistance	$T_A = 25^\circ\text{C}$		55		$\text{m}\Omega$
Current Limit						
I_{OCL}	Current limit	DC current, $V_{OUT} = 3.3\text{ V}$, $L = 2.2\text{ }\mu\text{H}$	2.8	4.8	5.2	A
On-time Timer Control						
$t_{OFF(MIN)}$	Minimum off time	$V_{FB} = 0.2\text{ V}$		180	310	ns
Soft Start						
t_{SS}	Soft-start time	Internal soft-start time		1.1		ms
Frequency						
f_{SW}	Switching frequency	$V_{IN} = 12\text{ V}$, $V_{OUT} = 3.3\text{ V}$, $I_{OUT} = 1\text{ A}$		650		kHz
Output Undervoltage And Overvoltage Protection						
V_{UVP}	Output UVP threshold	Hiccup detect ($H > L$)		68		%
$t_{HICCUP(WAIT)}$	Hiccup on time			1		ms
$t_{HICCUP(RE)}$	Hiccup time before restart			14		ms

7.4 Electrical Characteristics (continued)

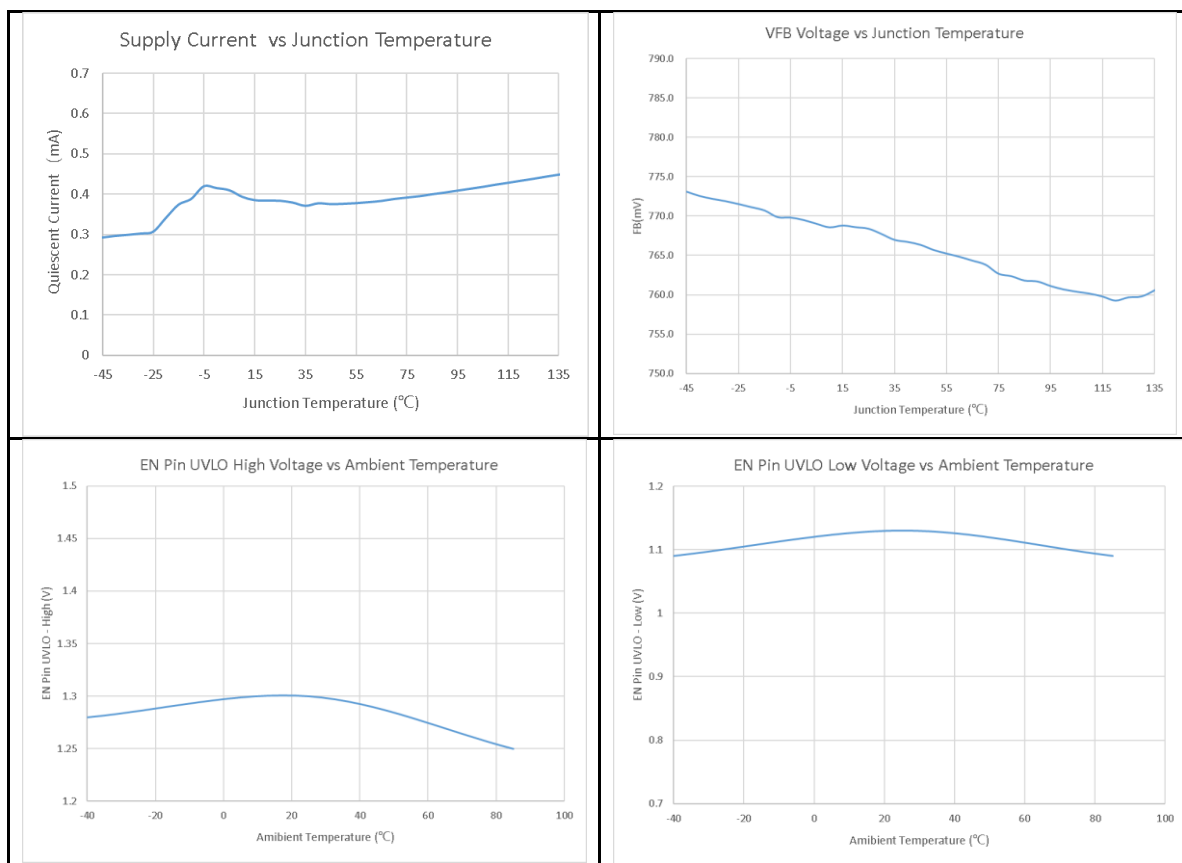
$V_{IN} = 12\text{ V}$, $V_{EN} = V_{IN}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Undervoltage Lockout (UVLO)						
V _{UVLO}	Wake up V _{IN} voltage			3.5	3.8	V
	Shutdown V _{IN} voltage		3	3.1		
	Hysteresis V _{IN} voltage			0.4		
Thermal Protection						
T _{SD}	Thermal shutdown threshold (Note 1)	Temperature rising		165		℃
T _{HYS}	Thermal shutdown hysteresis (Note 1)			45		℃

Note 1: Not production tested, guaranteed by design.

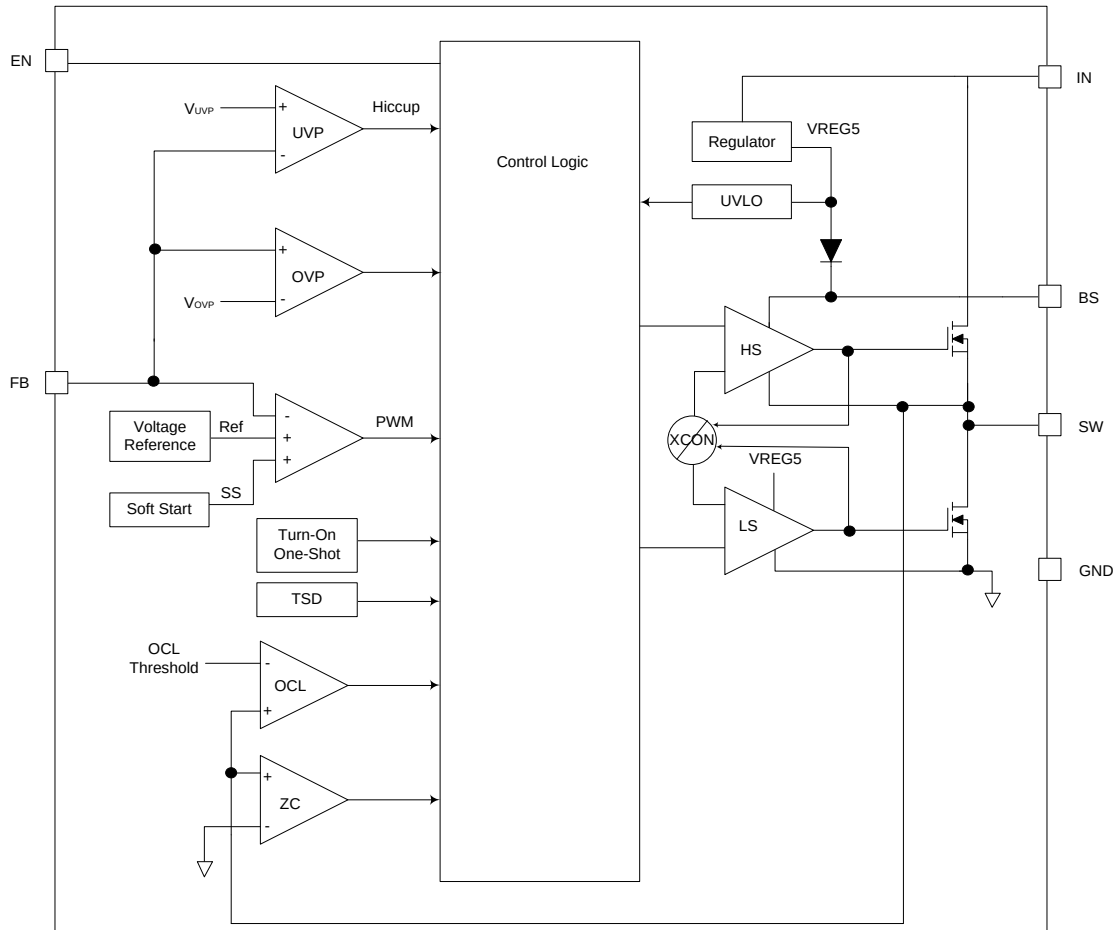
7.5 Typical Characteristics

$V_{IN} = 12\text{ V}$, $V_{EN} = V_{IN}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted).



8 Detailed Description

8.1 Functional Block Diagram



8.2 Feature Description

8.2.1 Adaptive On-Time Control and PWM Operation

The main control loop of the UM5485 is adaptive on-time pulse width modulation (PWM) controller that called ACOT. The ACOT control scheme combines adaptive on-time control with an internal compensation circuit for pseudo-fixed frequency and low external component count configuration with both low-ESR and ceramic output capacitors. It is stable even with virtually no ripple at the output.

At the beginning of each cycle, the high-side MOSFET is turned on. This MOSFET is turned off after internal one shot timer expires. This one shot duration is set proportional to the converter input voltage, V_{IN} , and inversely proportional to the output voltage, V_{OUT} , to maintain a pseudo-fixed frequency over the input voltage range, hence it is called adaptive on-time control. The one-shot timer is reset and the high-side MOSFET is turned on again when the feedback voltage falls below the reference voltage. An internal ramp is added to reference voltage to simulate output ripple, eliminating the need for ESR induced output ripple from ACOT control.

8.2.2 Pulse Skip Control

The UM5485 is designed with advanced Eco-mode to maintain high light load efficiency. As the output current decreases from heavy load condition, the inductor current is also reduced and eventually comes to point that its rippled valley touches zero level, which is the boundary between continuous conduction and discontinuous conduction modes. The rectifying MOSFET is turned off when the zero inductor current is detected. As the load current further decreases the converter runs into discontinuous conduction mode. The on-time is kept almost the same as it was in the continuous conduction mode so that it takes longer time to discharge the output capacitor with smaller load current to the level of the reference voltage. This makes the switching frequency lower, proportional to the load current, and keeps the light load efficiency high. The transition point to the light load operation $I_{OUT(LL)}$ current can be calculated in Equation 1.

$$I_{OUT(LL)} = \frac{1}{2 \times L \times f_{SW}} \times \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{V_{IN}} \quad (1)$$

8.2.3 Soft Start and Pre-Biased Soft Start

The UM5485 have an internal 1.1-ms soft-start. When the EN pin becomes high, the internal soft-start function begins ramping up the reference voltage to the PWM comparator.

If the output capacitor is pre-biased at startup, the devices initiate switching and start ramping up only after the internal reference voltage becomes greater than the feedback voltage V_{FB} . This scheme ensures that the converters ramp up smoothly into regulation point.

8.2.4 Current Protection

The output over-current limit (OCL) is implemented using a cycle-by-cycle valley detect control circuit. The switch current is monitored during the OFF state by measuring the low-side FET drain to source voltage. This voltage is proportional to the switch current. To improve accuracy, the voltage sensing is temperature compensated.

During the on time of the high-side FET switch, the switch current increases at a linear rate determined by V_{IN} , V_{OUT} , the on-time and the output inductor value. During the on time of the low-side FET switch, this current decreases linearly. The average value of the switch current is the load current I_{OUT} . If the monitored current is above the OCL level, the converter maintains low-side FET on and delays the creation of a new set pulse, even the voltage feedback loop requires one, until the current level becomes OCL level or lower. In subsequent switching cycles, the on-time is set to a fixed value and the current is monitored in the same manner.

There are some important considerations for this type of over-current protection. The load current is higher than the over-current threshold by one half of the peak-to-peak inductor ripple current. Also, when the current is being limited, the output voltage tends to fall as the demanded load current may be higher than the current available from the converter. This may cause the output voltage to fall. When V_{FB} falls below the UVP threshold voltage, the UVP comparator detects it. And then, the device will shut down after the UVP delay time (typically 50 μ s) and re-start after the hiccup time (typically 14 ms).

When the over current condition is removed, the output voltage returns to the regulated value.

8.2.5 Undervoltage Lockout (UVLO) Protection

UVLO protection monitors the internal regulator voltage. When the voltage is lower than UVLO threshold voltage, the device is shut off. This protection is non-latching.

8.2.6 Thermal Shutdown

The device monitors the temperature of itself. If the temperature exceeds the threshold value (typically 165°C), the device is shut off. This is a non-latch protection.

8.3 Device Functional Modes

8.3.1 Normal Operation

When the input voltage is above the UVLO threshold and the EN voltage is above the enable threshold, the UM5485 can operate in the normal switching modes.

8.3.2 Pulse skip mode Operation

When the UM5485 are in the normal CCM operating mode and the switch current falls to 0A, the UM5485 begin operating in pulse skipping mode. Each switching cycle is followed by a period of energy saving sleep time. The sleep time ends when V_{FB} falls below the Ecomode threshold voltage. As the output current decreases, the perceived time between switching pulses increases.

8.3.3 Standby Operation

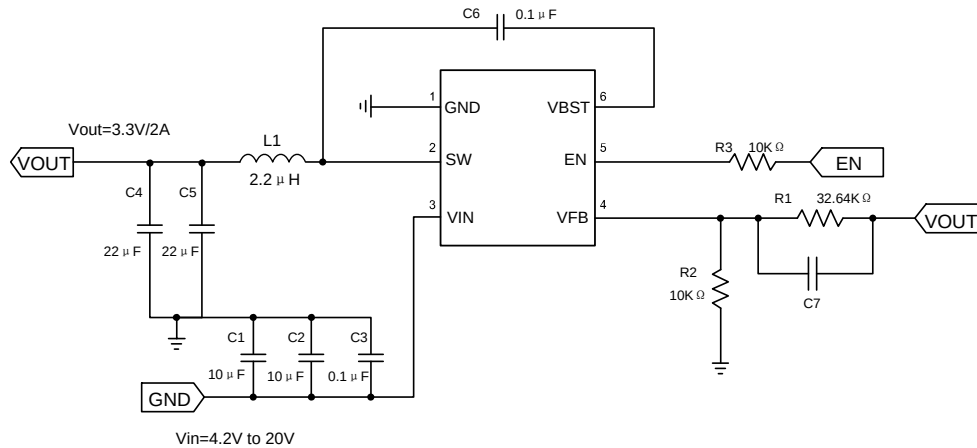
When the UM5485 are operating in either normal CCM or Pulse-skip-mode, they may be placed in standby by asserting the EN pin low.

9 Application and Implementation

9.1 Typical Application

The application schematic in Figure below was developed to meet the previous requirements. This circuit is available as the evaluation module (EVM). The sections provide the design procedure.

Figure below shows the UM5485FSB 4.2V to 20V input, 3.3V output converter schematics.



9.1.1 Design Requirements

Table 9-1. Design Requirements Example

Parameter	Example Value
Input voltage range	12 V
Output voltage	3.3 V
Transient response, 0.1A↔1.5A	$\Delta V_{OUT} = \pm 3\%$
Input ripple voltage	200 mV
Output ripple voltage	50 mV
Output current rating	2 A
Operating frequency	650 kHz

9.1.2 Detailed Design Procedure

9.1.2.1 Output Voltage Resistors Selection

The output voltage is set with a resistor divider from the output node to the FB pin. UNION recommends to use 1% tolerance or better divider resistors. Start by using Equation 2 to calculate VOUT. To improve efficiency at very light loads consider using larger value resistors, but too high of resistance will be more susceptible to noise.

$$V_{OUT} = 0.774 \times \left(1 + \frac{R1}{R2}\right) \quad (2)$$

9.1.2.2 Output BOMs Selection

Table 9-2. Recommended Component Values

Output Voltage (V)	R1 (kΩ)	R2 (kΩ)	L1 (μH)			C4 + C5 (μF)
			Min	Typ	Max	
1	2.92	10.0	1.5	2.2	4.7	30 to 68
1.2	5.5	10.0	1.5	2.2	4.7	30 to 68
1.8	13.26	10.0	1.5	2.2	4.7	30 to 68
2.5	22.3	10.0	2.2	2.2	4.7	30 to 68
3.3	33.63	10.0	2.2	2.2	4.7	30 to 68
5	54.6	10.0	3.3	3.3	4.7	30 to 68

The inductor peak-to-peak ripple current, peak current and RMS current are calculated using Equation 4, Equation 5, and Equation 6. The inductor saturation current rating must be greater than the calculated peak current and the RMS or heating current rating must be greater than the calculated RMS current.

$$I_{P-P} = \frac{V_{OUT}}{V_{IN(MAX)}} \times \frac{V_{IN(MAX)} - V_{OUT}}{L \times f_{SW}} \quad (4)$$

$$I_{PEAK} = I_O + \frac{I_{P-P}}{2} \quad (5)$$

$$I_{LO(RMS)} = \sqrt{I_O^2 + \frac{1}{12} I_{P-P}^2} \quad (6)$$

For this design example, the calculated peak current is 3.1 A and the calculated RMS current is 2.08A. The inductor used is a WE 74438377022HT with a peak current rating of 10.7 A and an RMS current rating of 11.4 A

The capacitor value and ESR determines the amount of output voltage ripple. The UM5485 are intended for use with ceramic or other low ESR capacitors. Recommended values range from 30 μF to 68 μF. Use Equation 7 to determine the required RMS current rating for the output capacitor

$$I_C = \frac{V_O \times (V_I - V_O)}{\sqrt{12} \times V_I \times L \times f_S} \quad (7)$$

For this design, two 22 μF output capacitors are used, each with a typical ESR of 2 mΩ.

9.1.2.3 Input Capacitor Selection

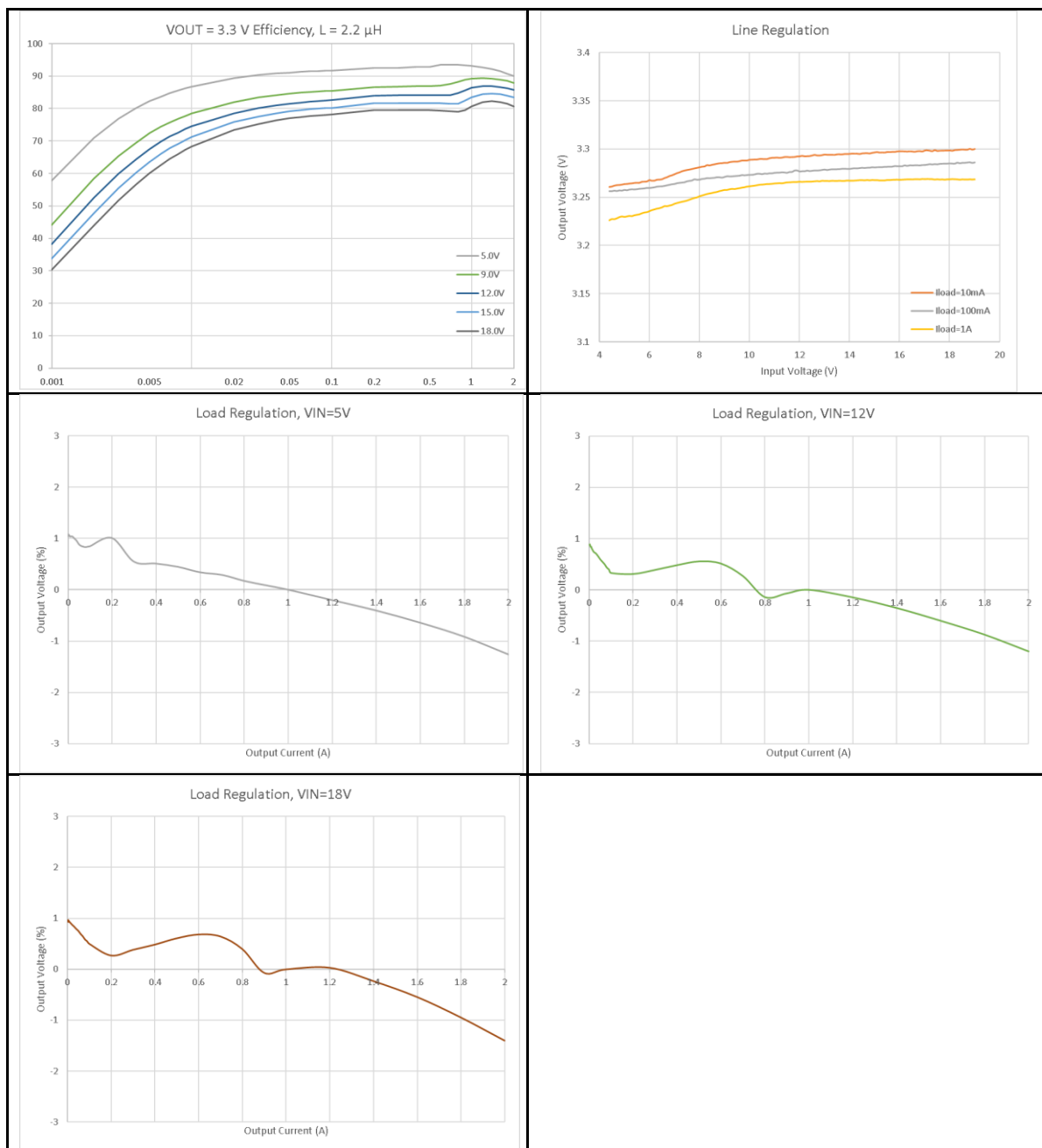
The UM5485 require an input decoupling capacitor and a bulk capacitor is needed depending on the application. UNION recommends a ceramic capacitor over 10 μF for the decoupling capacitor. An additional 0.1-μF capacitor (C3) from pin 3 to ground is optional to provide additional high frequency filtering. The capacitor voltage rating needs to be greater than the maximum input voltage.

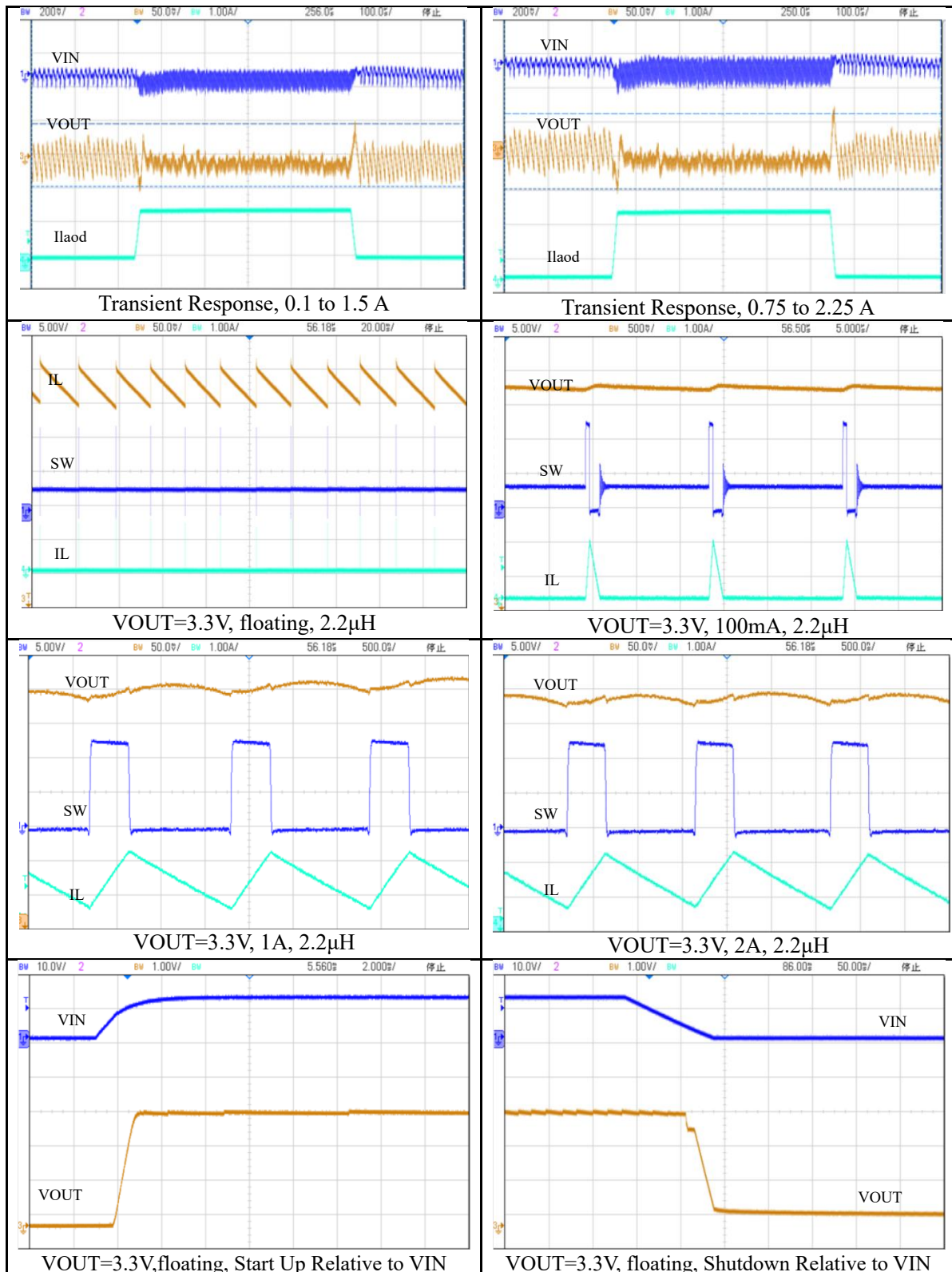
9.1.2.4 Bootstrap Capacitor Selection

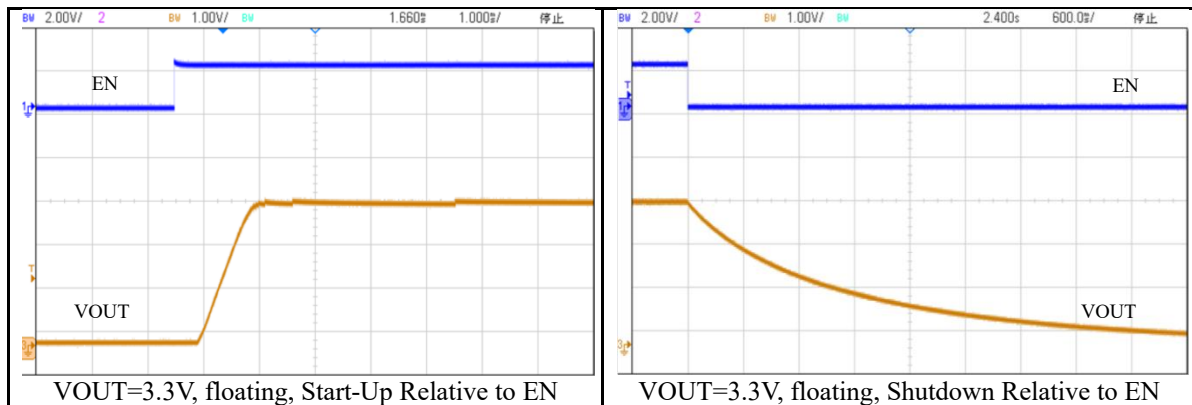
A 0.1 μF ceramic capacitor must be connected between the BST to SW pin for proper operation. UNION recommends to use a ceramic capacitor

Note: The UM5485 utilizes an Adaptive Constant On-Time (ACOT) control architecture, which is optimized for fast transient response. As with COT-family architectures, switching frequency exhibits a quasi-fixed characteristic and varies with V_{in} , V_{out} , load current, and temperature. Designers should reference the Min/Max frequency range and Typical Characteristics curves when performing EMI and component selection design

9.2 Application Curves







9.3 Power Supply Recommendations

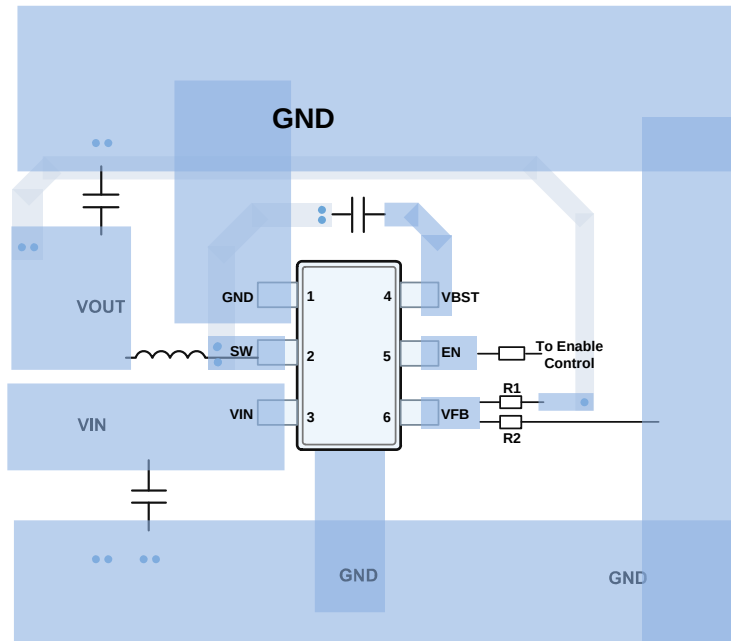
UM5485 are designed to operate from input supply voltage in the range of 4.2 V to 20 V. Buck converters require the input voltage to be higher than the output voltage for proper operation. The maximum recommended operating duty cycle is 70%. Using that criteria, the minimum recommended input voltage is $V_{OUT} / 0.7$.

9.4 Layout

9.4.1 Layout Guidelines

- VIN and GND traces must be as wide as possible to reduce trace impedance. The wide areas are also of advantage from the view point of heat dissipation.
- The input capacitor and output capacitor must be placed as close to the device as possible to minimize trace impedance.
- Provide sufficient vias for the input capacitor and output capacitor.
- Keep the SW trace as physically short and wide as practical to minimize radiated emissions.
- Do not allow switching current to flow under the device.
- A separate VOUT path must be connected to the upper feedback resistor.
- Make a Kelvin connection to the GND pin for the feedback path.
- Voltage feedback loop must be placed away from the high-voltage switching trace, and preferably has ground shield.
- The trace of the FB node must be as small as possible to avoid noise coupling.
- The GND trace between the output capacitor and the GND pin must be as wide as possible to minimize its trace impedance

9.4.2 Layout Example

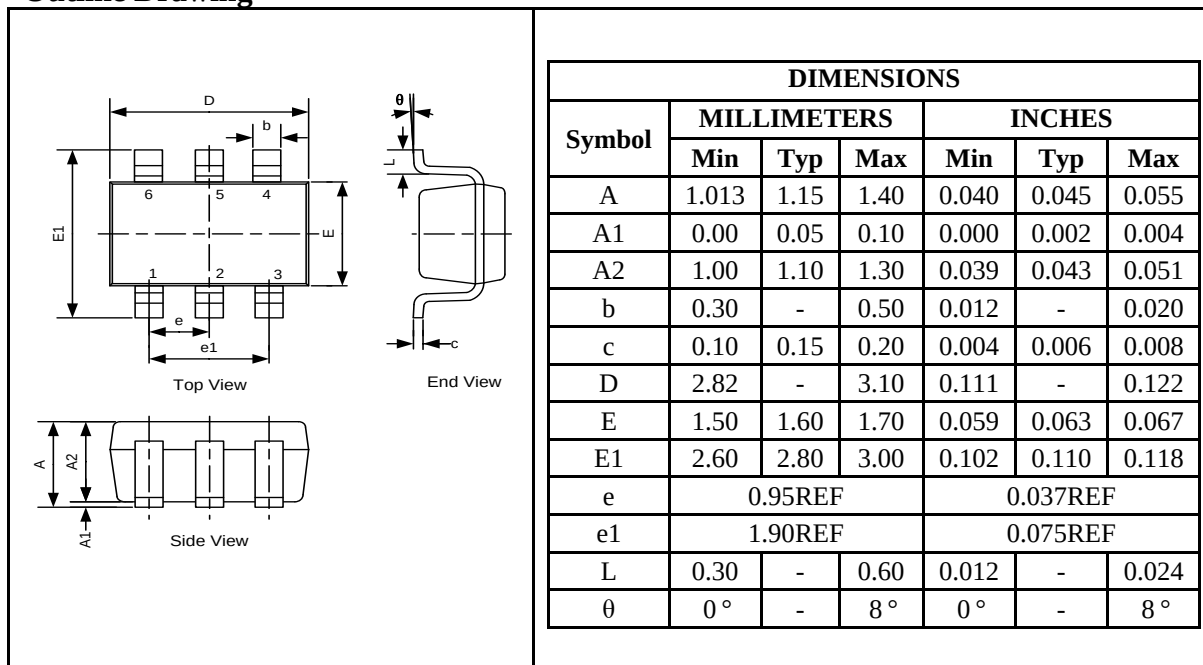


Note: Circuit diagram is for reference only.

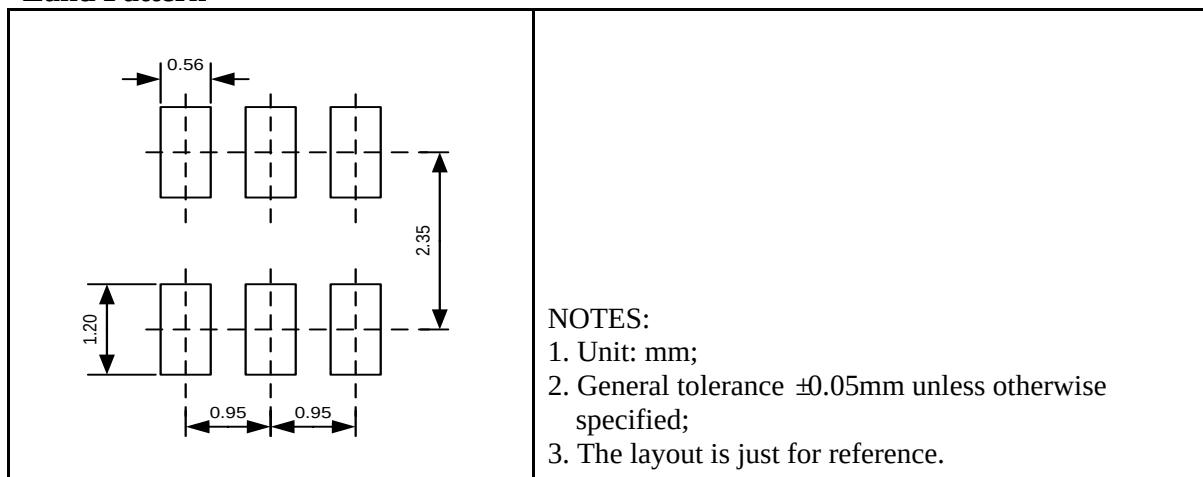
10 Package Information

SOT23-6

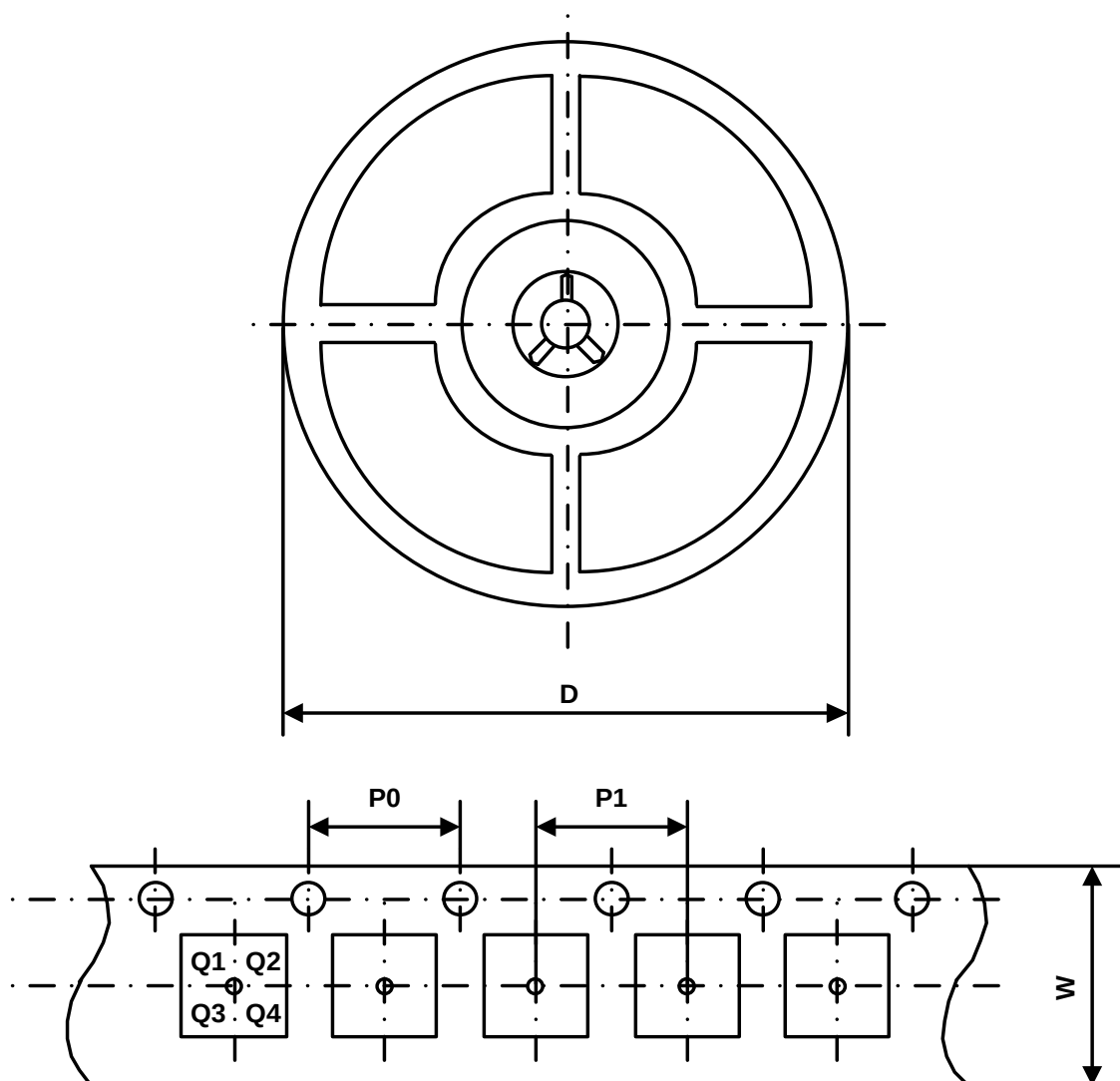
Outline Drawing



Land Pattern



11 Packing Information



Part Number	Package Type	Carrier Width (W)	Pitch (P0)	Pitch (P1)	Reel Size (D)	PIN 1 Quadrant
UM5485S	SOT23-6	8 mm	4 mm	4 mm	180 mm	Q3
UM5485FSB	SOT23-6	8 mm	4 mm	4 mm	180 mm	Q3

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