3A Rated µPOL™ Buck Regulator with Integrated Inductor

Features

- µPOL™ package with output inductor included
- Small size: 2.5mm x 2.5mm x 1.2mm
- 3A load continuous capability
- Plug and play: no external compensation required
- Input voltage range: 2.75V–5.5V
- Adjustable output voltage: 0.4V–3.3V
- ±0.5% initial accuracy
- Enable and Power Good
- Over current and short circuit protection
- Open-drain power-good indicator
- Operating temperature from -40°C to +125°C
- Lead-free and halogen-free
- Compliant with EU Directives REACH and RoHS

Applications

- Optical networking systems
- FPGA, ASIC and SOC
- Storage applications
- Industrial applications
- LDO replacement at higher efficiency
- Drones, robotics, IOT applications
- Portable applications

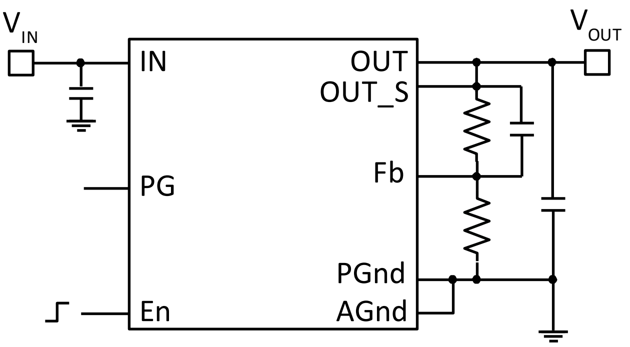
Description

The FS3303 is an easy-to-use, fully integrated and highly efficient micro-point-of-load (µPOL™) voltage regulator. The on-chip pulse-width modulation (PWM) controller and integrated MOSFETs, plus incorporated inductor, result in an extremely compact and accurate regulator. The low-profile package is suitable for automated assembly using standard surface-mount equipment.

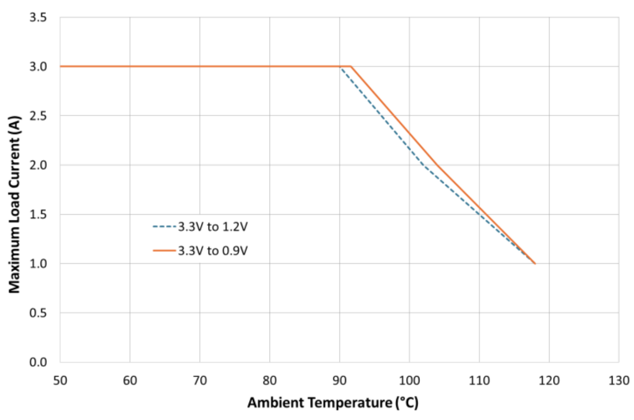
Developed by a cross-functional engineering team, the design exemplifies best practice and uses class-leading technologies. From early in the integrated circuit design phase, designers worked with application and packaging engineers to select compatible technologies and implement them in ways that reduce compromise. Developing and optimizing all of these elements together has yielded the smallest, most efficient and fully featured µPOL™ currently available.

The built-in protection features include soft-start protection, over-voltage protection, thermally compensated over-current protection with hiccup mode, and thermal shut-down with auto-recovery.

Simple Application Circuit



Thermal Derating Curve



Pin Configuration

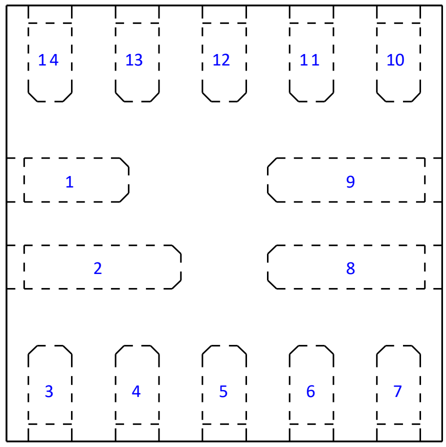


Figure 1 Pin layout (top view)

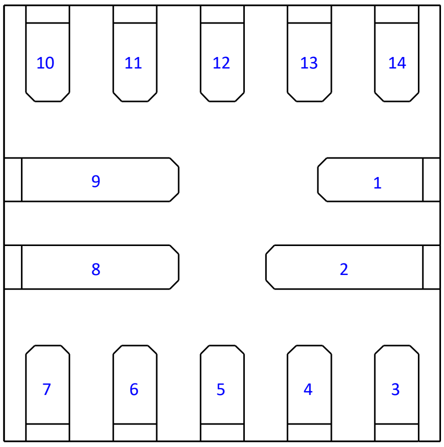


Figure 2 Pin layout (bottom view)

Pin Functions

Pin Number	Name	Description
1	SW	SW test pin
2, 7, 8	PGnd	Power ground
3	En	Enable
4	AGnd	Signal ground
5	Fb	Feedback
6	OUT_S	Output voltage sense
9,10	OUT	Regulator output voltage
11	PG	Power good status
12, 13, 14	IN	Power input

Block Diagram

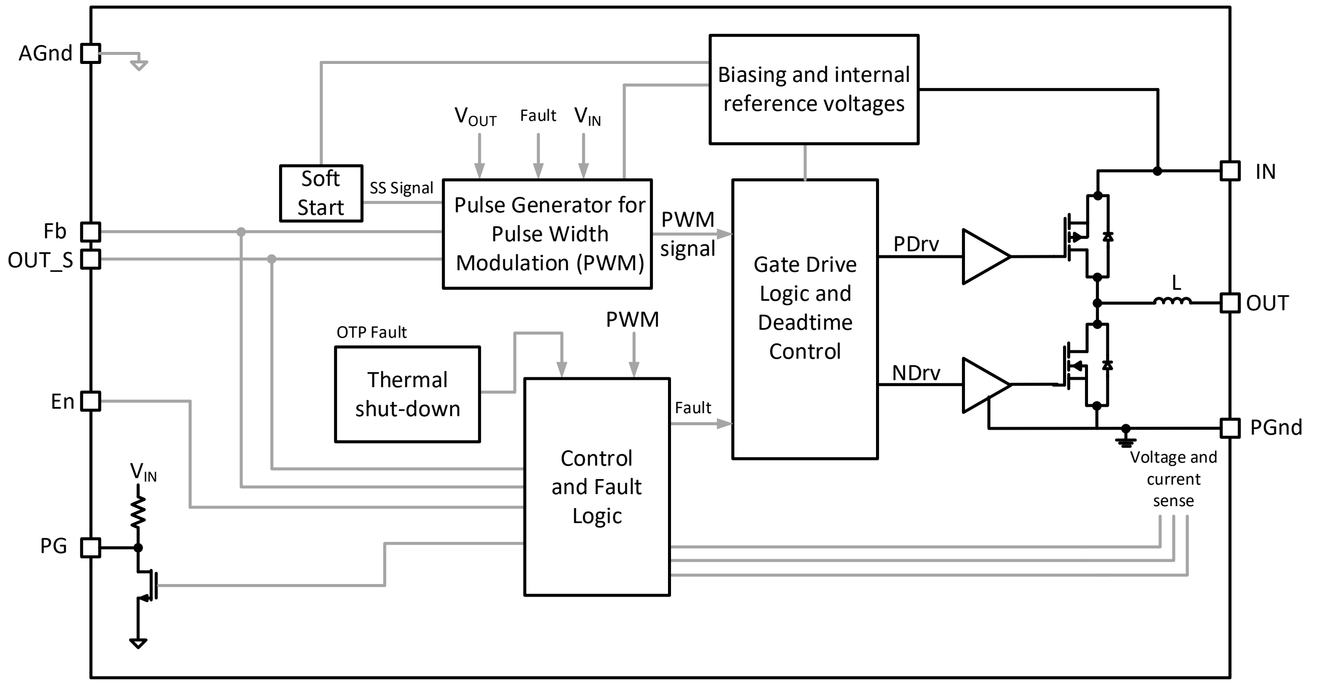


Figure 3 FS3303 µPOL™

Typical Application

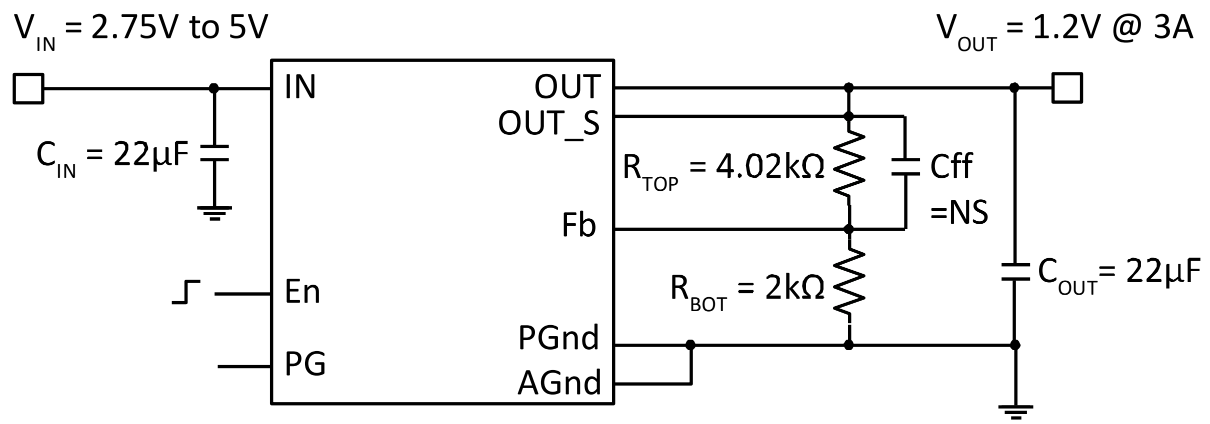


Figure 4 FS3303 typical application circuit

Absolute Maximum Ratings

Warning: Stresses beyond those shown may cause permanent damage to the FS3303.

Note: Functional operation of the FS3303 is not implied under these or any other conditions beyond those stated in the FS3303 specification.

Reference	Range
V_{IN} to PGnd	-0.3V to 6V (Note 1, Note 3)
Fb, En, OUT_S to AGnd	-0.3V to 6V (Note 2)
PG to AGnd	-0.3V to V_{IN} (Note 2)
PGnd to AGnd	-0.3V to +0.3V
ESD Classification	2kV (HBM JESD22-A114)
Moisture Sensitivity Level	MSL 3 (JEDEC J-STD-020)

Thermal Information	Range
Junction-to-Ambient Thermal Resistance Θ_{JA}	48 °C/W
Junction-to-PCB Thermal Resistance $\Theta_{J\text{-}PCB}$	7 °C/W
Storage Temperature Range	-65°C to 150°C
Junction Temperature Range	150°C
Note: Θ_{JA} : FS3303 evaluation board and JEDEC specifications JESD 51-2A $\Theta_{J\text{-}c\ (bottom)}$: JEDEC specification JESD 51-8	

Notes

1 PGnd pin and AGnd pin are connected together on the PCB
2 Must not exceed 6V
3 Maximum switch node voltage should not exceed 12V
4 Hot and cold temperature performance is assured by correlation using statistical quality control, but not tested in production; performance at 25°C is tested and guaranteed in production environment
5 Guaranteed by design but not tested in production

Order Information

Package Details

The FS3303 uses a µPOL™ 2.5mm x 2.5mm package delivered in tape-and-reel format. For more information on the tape-and-reel specification, go to:

https://product.tdk.com/en/products/power/switching-power/micro-pol/designtool.html

Standard Part Number

Part Number	V_{OUT} (V)	Quantity per Reel	Package Description*	Package Designator
FS3303-0400-AL	0.40	2500	14L LGA-SiP	A05

* Compliant with EU Directives REACH and RoHS. RoHS is defined as semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances.

Recommended Operating Conditions

Definition	Symbol	Min	Max	Units
Input Voltage Range	IN	2.75	5.5	V
Output Voltage Range	OUT	0.4	5	V
Continuous Output Current Range	I_O	0	3	A
Enable Pin Voltage Range	En	0	0.5*IN	V
Operating Junction Temperature	T_J	-40	125	°C

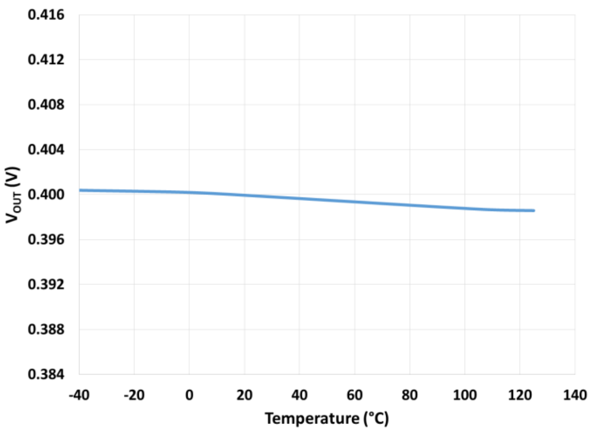
Electrical Characteristics

ELECTRICAL CHARACTERISTICS						
Unless otherwise stated, these specifications apply to V_{IN} = 3.6V, -40°C < T < 125°C **Typical values are specified at T_A = 25°C**						
Parameter	**Symbol**	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Supply Current						
Supply Current (shutdown)		En = 0V, T_J = 25°C	0		2	µA
Supply Current (quiescent)		En = 2V, Fb = 0.43V, IN = 3.6V	960	1080	1200	
Soft-Start						
Soft-Start Time	SStartRate	V_{OUT} = 0.4V	0.195	0.23	0.275	V/ms
Soft-Stop Time	SStopRate	V_{OUT} = 0.4V	0.22	0.26	0.3	
Output Voltage						
Accuracy		T_J = 25°C, 2.75V ≤ IN ≤ 5.5V, V_{OUT} = 0.4V	-0.8		0.8	%
		-40°C ≤ T_J ≤ 125°C, 2.75V ≤ IN ≤ 5.5V, V_{OUT} = 0.4V	-1.1		1.1	
On-Time Timer Control						
On Time	T_{ON}	IN = 3.6V, V_{OUT} = 0.4V, F_{SW} = 1.05MHz	80	105	130	ns
Minimum On-Time	T_{ON}	IN = 3.6V		48		
Thermal Shut-Down						
Thermal Shut-Down	TSD (default)			150		°C
Hysteresis				35		
Under-Voltage Lock-Out						
IN Start Threshold	V_{IN}_UVLO(START)	IN Rising Trip Level	2.36	2.53	2.7	V
IN Stop Threshold	V_{IN}_UVLO(STOP)	IN Falling Trip Level	1.92	2.2	2.48	V
Enable Threshold	En(HIGH)	Ramping Up	0.80	0.88	0.96	V
	En(LOW)	Ramping Down	0.75	0.83	0.91	V
Current Limit						
Current Limit Threshold	I_{OC} (default)	T_J = 25°C	3.95	4.5	5.05	A
Hiccup Blanking Time	$T_{BLK(HICCUP)}$			20		ms

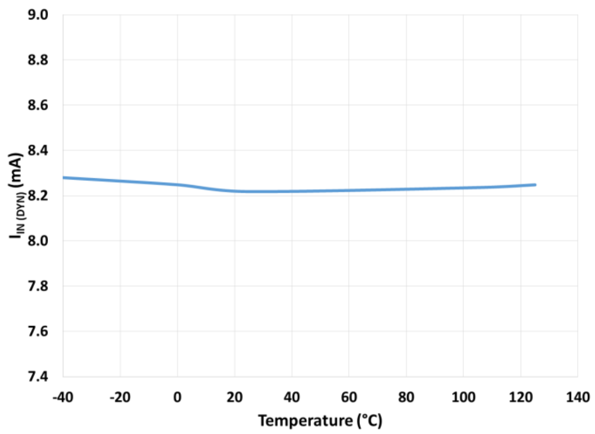
ELECTRICAL CHARACTERISTICS						
Unless otherwise stated, these specifications apply to V_{IN} = 3.6V, -40°C < T < 125°C **Typical values are specified at T_A = 25°C**						
Parameter	**Symbol**	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Over-Voltage Protection						
Output Over-Voltage Protection Threshold	V_{OVP} (default)	Fb voltage in respect to V_{OUT}	105	115	125	%
Output Over-voltage Protection Delay	T_{OVPDEL}			100		µs
Power Good (PG)						
Power Good Upper Threshold	$V_{PG(UPPER)}$ (default)	Fb voltage in respect to V_{OUT}	79	88	97	%
Power Good Hysteresis	$V_{PG(LOWER)}$		75	83	90	
Power Good Sink Current	I_{PG}	PG=0.4V	5	7	9	mA
Power Good Delay		PG falling		100		µs
Power Good Internal pull-up resistor				440		kΩ

Temperature Characteristics

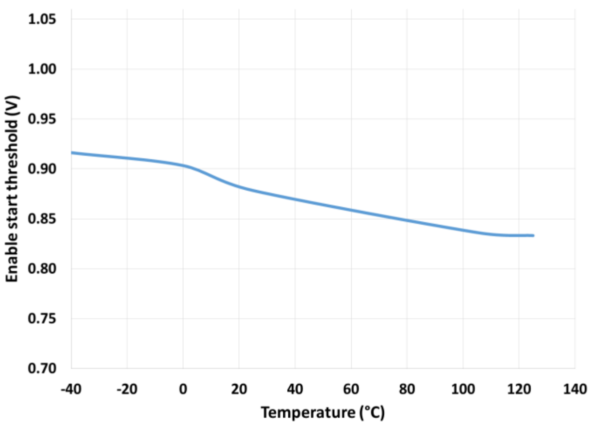
Output Voltage: 0.4V



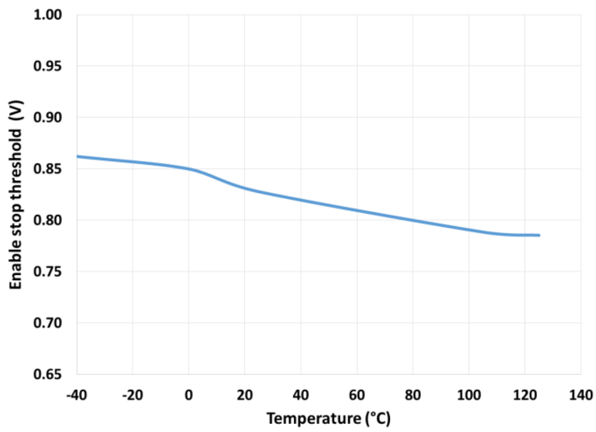
V_{IN} Supply Current (Dynamic)



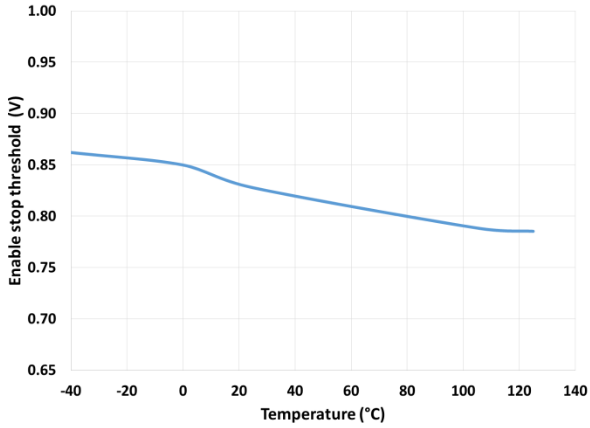
Enable Start Threshold



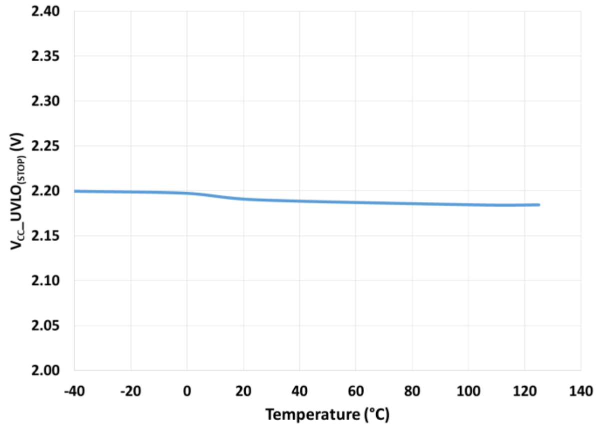
Enable Stop Threshold



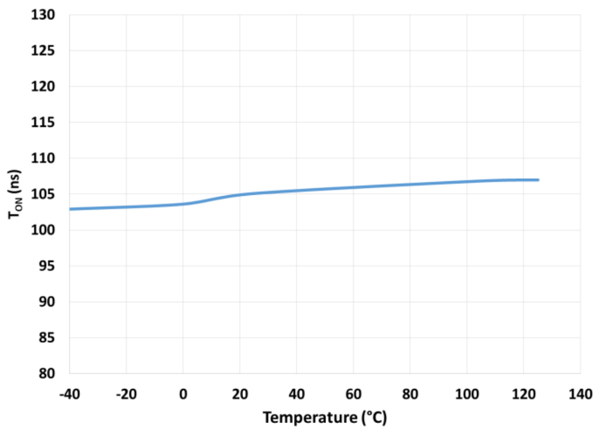
V_{CC} Start Threshold



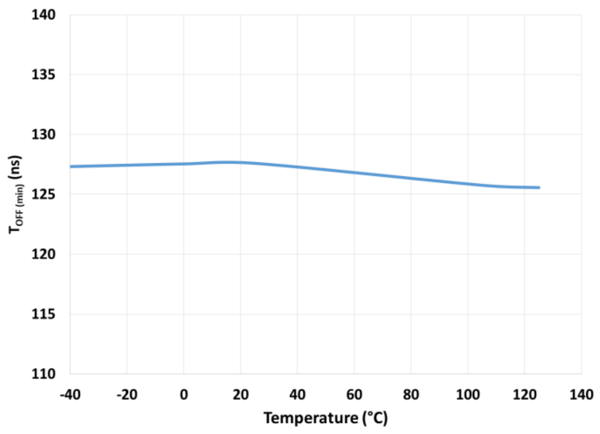
V_{CC} Stop Threshold



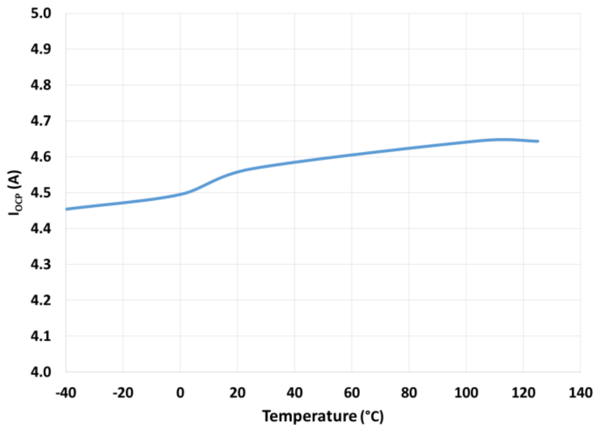
On Time



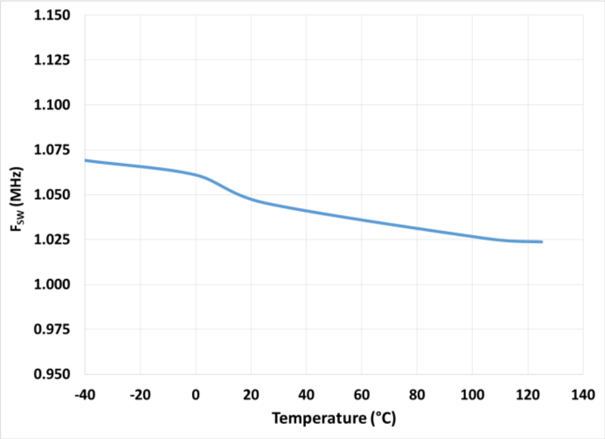
Off Time



Over-Current Protection



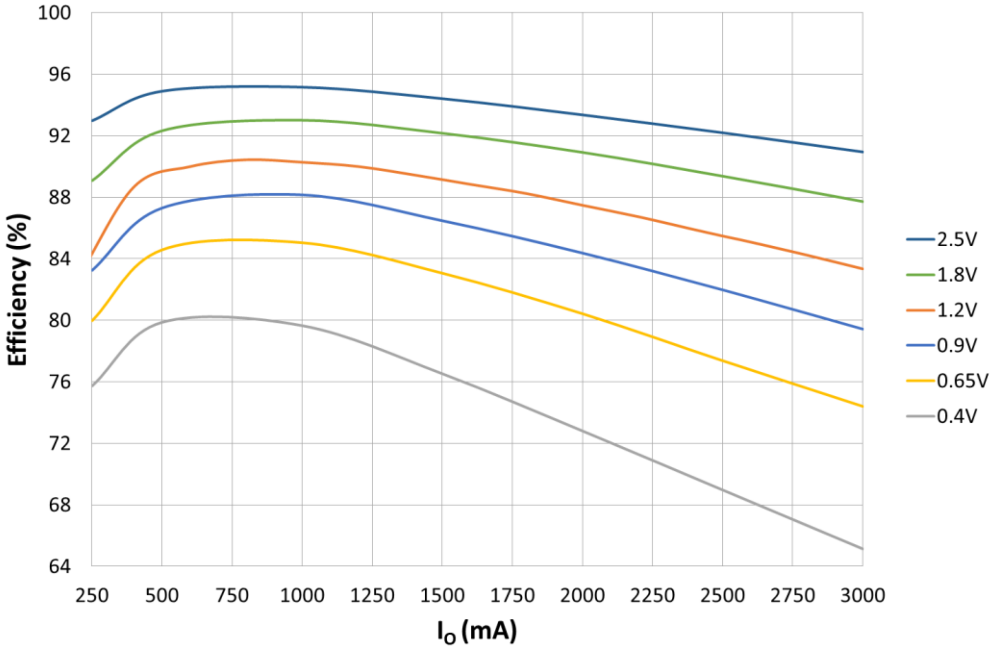
Switching Frequency

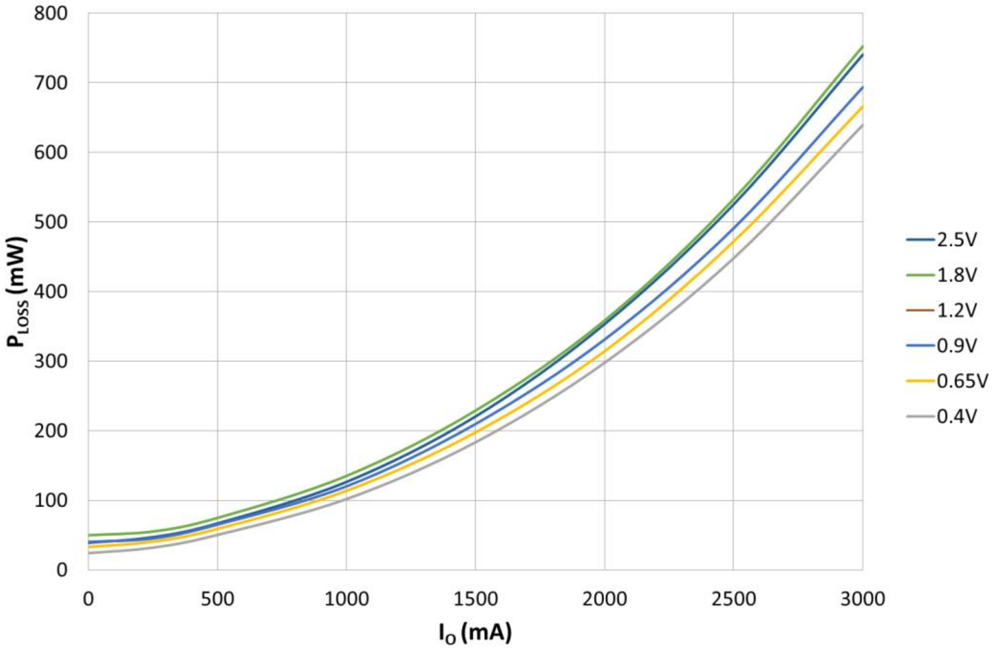


Efficiency Characteristics

Typical efficiency and power loss at PV_{IN} = 3.3V

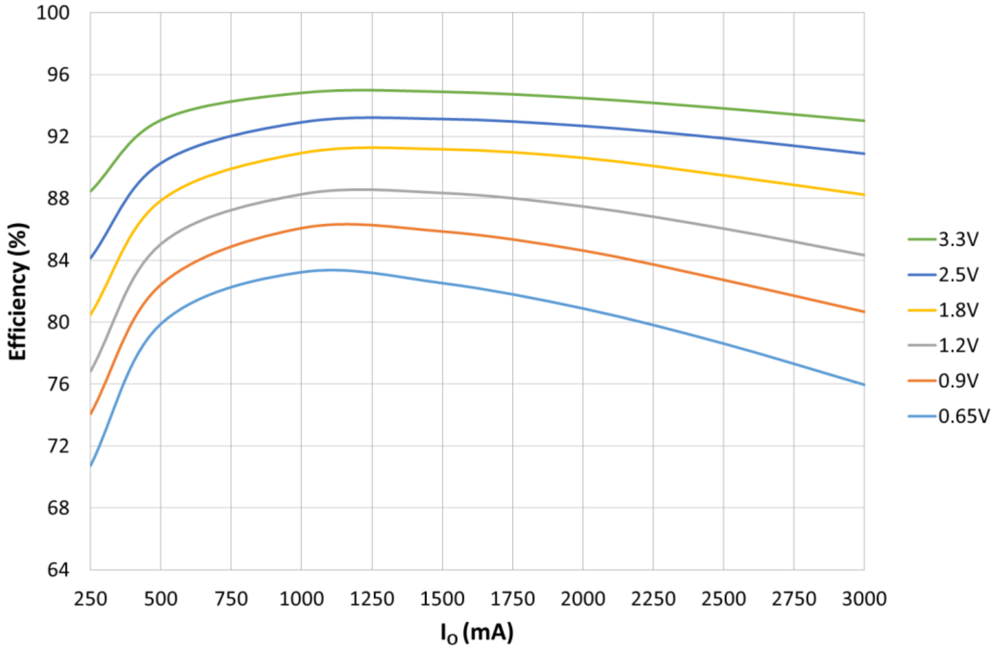
V_{IN} = 3.3V, V_{OUT} =0.4V to 2.5V, I_O = 0A–3A, room temperature, no air flow, all losses included

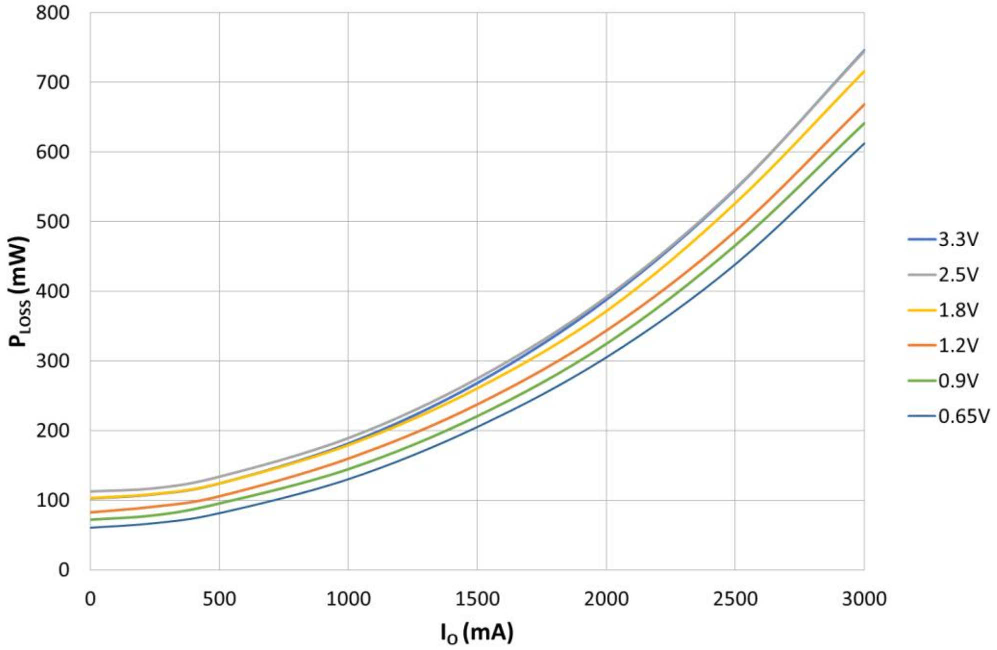




Typical efficiency and power loss at PV_{IN} = 5V

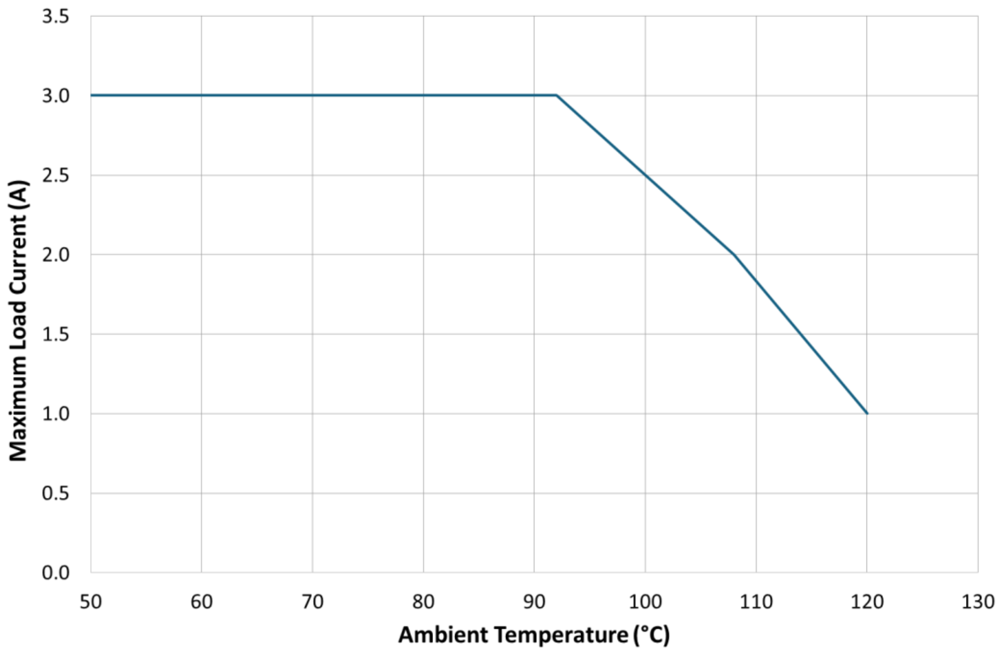
PV_{IN} = 5V, V_{OUT} =0.65V to 3.3V, I_O = 0A–3A, room temperature, no air flow, all losses included



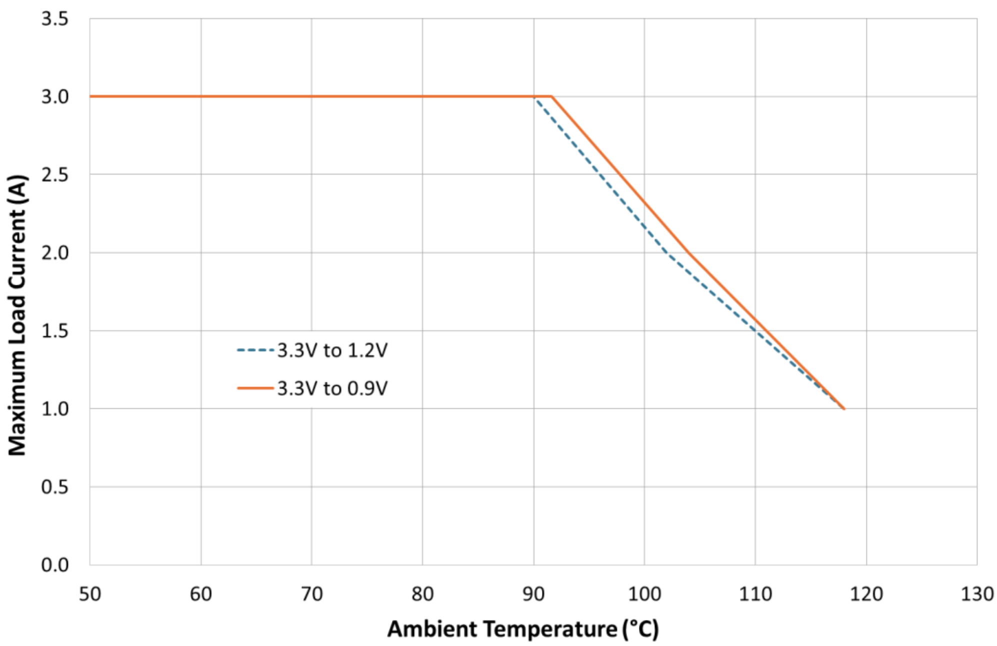


Thermal Derating Curves

V_{IN} = 5V, V_{OUT}=3.3V, I_O = 0A–3A, room temperature, no air flow, all losses included



V_{IN} = 3.3V, V_{OUT}=1.2V or 0.9V, I_O = 0A–3A, room temperature, no air flow, all losses included



Applications Information

Overview

The FS3303 is an easy-to-use, fully integrated, and highly efficient DC/DC regulator. It uses a proprietary modulator to deliver fast transient response and supports operation at 100% duty cycle. The modulator is internally compensated so that it can be used in a wide range of applications, with various types of output capacitors, without loop stability issues. An added servo loop ensures precise output voltage regulation.

Input Voltage and Output Voltage

The FS3303 supports a wide range of input voltages from 2.75V to 5.5V and needs only a single input decoupling capacitor. It can handle conversion at a 100% duty cycle and supports output voltages as low as 0.4V.

Soft-Start, Soft-Stop and Target Output Voltage

The FS3303 has an internal digital soft-start circuit to control output voltage rise-time and limit current surge at start-up. Soft-start is initiated when V_{IN} rises above its under-voltage lockout threshold (UVLO = 2.5V), and En > 0.88V (En not to exceed 0.5*IN for OUT ≥ 0.5*IN).

During initial start-up, the FS3303 operates with minimum-width high-drive (HDrv) pulses until the output voltage increases. On-time is increased until V_{OUT} reaches the target value defined by

$$OUT = 0.4\left(1 + \frac{R_{TOP}}{R_{BOTTOM}}\right)$$

During this interval, the Synchronous MOSFET is not allowed to turn on, making the device inherently capable of turning on into a pre-biased output. The soft start slew rate (SS_rate) is nominally 0.23V/ms for V_{OUT} = 0.4V. Even for a higher output voltage (realized with a resistor divider), the rise time will always be 0.4V/SS_rate ≈ 1.8ms (typical).

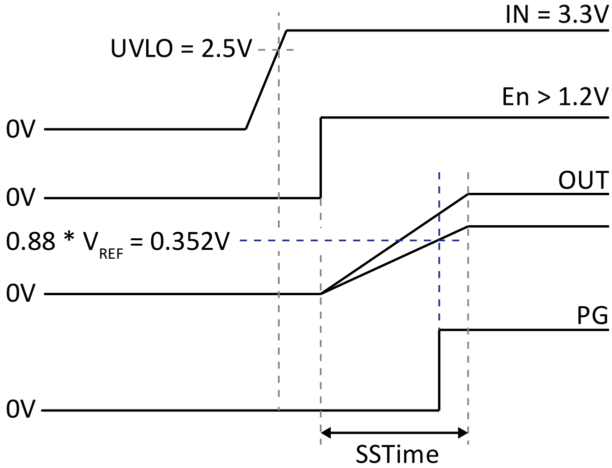


Figure 5 Theoretical operational waveforms during soft-start

Over-current protection (OCP) and over-voltage protection (OVP) is enabled during soft-start to protect the FS3303 from short circuits and excess voltages respectively.

Shut-down Mechanisms

The FS3303 has two shut-down mechanisms:

- *Hard shut-down or decay according to load*
  Initiated by de-asserting the V_{IN} pin. Both drivers switch off and the digital-to-analog converter (DAC) and soft-start are pulled down instantaneously.
- *Soft-stop, or controlled ramp down, in 1.54ms*
  Initiated by pulling Enable low (<0.83V).

Switching Frequency and Minimum Values for On-time, Off-time and V_{IN}

The FS3303 senses the input and output voltage and maintains the switching frequency at a nearly constant 1.05MHz over line and output voltage.

When input voltage is high relative to target output voltage, the Control MOSFET is switched on for shorter periods. The shortest period for which it can reliably be switched on is defined by minimum on-time ($T_{ON(MIN)}$) , nominally 48ns. During start-up, when the output voltage is very small, the FS3303 operates with minimum on-time.

When input voltage is low relative to target output voltage, the Control MOSFET is switched on for longer periods. The shortest period for which it can be switched off is defined by minimum off-time ($T_{OFF(MIN)}$), nominally 100ns. If the conversion ratio demands an off-time below 100ns, the FS3303 switches at a lower frequency to meet the output voltage requirement; it is capable of operating at 100% duty cycle if necessary.

Over-current Protection (OCP)

Over-current protection (OCP) is provided by sensing the current through the $R_{DS(on)}$ of the Control MOSFET.

This method provides several benefits:

- Provides accurate over-current protection without reducing converter efficiency (the current sensing is lossless)
- Reduces cost by eliminating a current-sense resistor
- Reduces any layout-related noise issues.

When three consecutive over-current events are detected (peak current exceeds 4.5A), the PG and SS signals are pulled low and the converter enters a hiccup mode. The counter that tracks these over-current events resets to zero if an over-current is not detected in its sensing interval during the on-time of the Control FET. Thus, the FS3303 can operate through brief, transient over-current events without shutting down, while still providing over-current protection if a sustained over-current condition (more than three events) persists.

At the same time, the FS3303 also offers protection against catastrophic over-current and short circuits by bypassing the three-event counter. It immediately pulls SS and PG low and enters hiccup mode if the peak current exceeds 6A. The Synchronous MOSFET remains on for a short interval to allow the inductor current to decay, then the FS3303 enters hiccup mode (Figure 6). Both the Control MOSFET and the Synchronous MOSFET remain off for the hiccup-blanking time. After this time, the FS3303 tries to restart. If an over-current fault is still detected, the preceding actions are repeated. The FS3303 remains in hiccup mode until the over-current condition is remedied.

It should be noted that the over-current and short circuit thresholds are internally temperature compensated so that they remain almost constant at different ambient temperatures.

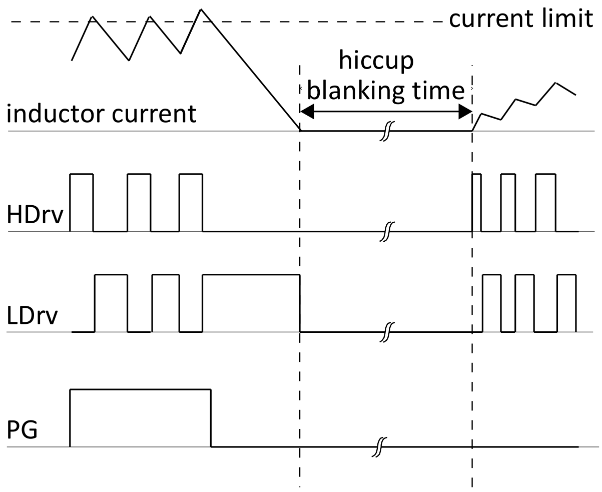


Figure 6 Illustration of OCP in hiccup mode

Over-voltage Protection (OVP)

Over-voltage protection (OVP) is provided by sensing the voltage at the Fb pin. When Fb exceeds the output OVP threshold (460mV) for longer than the output OVP delay (typically 100µs), a fault condition is generated.

The Control MOSFET is switched off immediately and the PG pin is pulled low. The Synchronous MOSFET is switched on to discharge the output capacitor.

The Control MOSFET remains latched off until reset by cycling En. The voltage at the Fb pin falling below the output OVP threshold (with 5% hysteresis) does not switch on the Control MOSFET but it does switch off the Synchronous MOSFET to prevent build-up of negative current. The FS3303 also incorporates negative over-current protection to prevent build-up of large negative currents. If a negative over-current condition is detected, the synchronous MOSFET is switched off; it remains off until the device is reset, regardless of whether the Fb pin has dropped 5% below the OVP threshold.

Over-temperature Protection (OTP)

The FS3303 senses the die temperature and detects an over-temperature condition when the die temperature exceeds the over-temperature threshold (150°C). When an over-temperature condition is detected, thermal shut-down switches off both MOSFETs and resets the internal soft-start.

Automatic restart is initiated when the sensed temperature drops within the operating range. There is a 35°C hysteresis in the OTP threshold.

Servo Loop and Precision Output Voltage

The FS3303 has an internal servo loop to minimize V_{OUT} error at steady state. Load and line regulation of better than ±1% is achieved.

Power Good (PG)

The PG signal is asserted when:

- En and V_{IN} are both above their thresholds
- No fault has occurred
  (including over-current, over-voltage and over-temperature)
- Fb rises above the PG threshold (352mV); hysteresis of 5% is applied to the threshold, so that PG will de-assert only if Fb then drops below 332mV.

Design Example

Let us now consider a simple design example, using the FS3303 for the following design parameters:

- V_{IN} = 3.3V
- V_{OUT} = 1.2V
- C_{OUT} = 1 x 22µF
- C_{IN} = 1 x 22µF
- Ripple Voltage = ± 0.5% * V_{OUT}
- $\Delta V_{OUT(MAX)}$ = ±3% * V_{OUT}
  (for 1.5A load transient)

Input Capacitor

The input capacitor selected for this design must:

- Handle the peak and root mean square (RMS) input currents required by the FS3303
- Have low equivalent series resistance and inductance (ESR and ESL) to reduce input voltage ripple

MLCCs (multi-layer ceramic capacitors) are ideal. Typically, in 0805 case size, they can handle 2A RMS current with less than 5°C temperature rise.

For the FS3303 converter operating at duty cycle D and output current I_O, the RMS value of the input current is:

$$I_{RMS} = Io\sqrt{D(1-D)}$$

In this application, I_O = 3A and $D = \frac{V_{OUT}}{V_{IN}} = 0.3636$, so I_{RMS} = 1.44A.

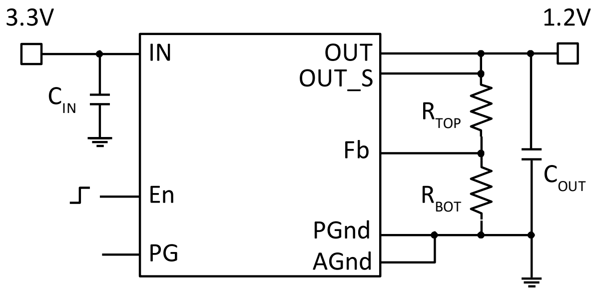
Therefore, one 22µF 25V ceramic input capacitors is adequate.

If the FS3303 is not located close to the 3.3V power supply, a bulk capacitor (68–330µF) may be used in addition to the ceramic capacitors.

Output Voltage and Output Capacitor

The FS3303 is trimmed at the factory to provide a 0.4V output in closed loop. When using a resistor divider, as in this design example, we select the values in accordance with the discussion on page 13. Therefore, R_{TOP} = 4.02kΩ and R_{BOTTOM} = 2kΩ. A placeholder for C_{FF} is recommended but not required.

The design requires minimal output capacitance to meet the target output voltage ripple and target maximum output voltage deviation under load transient conditions. We use one C2012X5R0J476 M125AC from TDK (a 22µF MLCC, 0805 case size, rated at 6.3V).



C_{IN}	22µF/0805/10V
C_{OUT}	22µF/0805/10V
R_{TOP}	4.02kΩ
R_{BOTTOM}	2kΩ

Figure 7 Application circuit
(V_{IN} =3.3V, V_{OUT} = 1.2V, I_O = 3A)

Typical Performance

Figure 8 to Figure 23 show typical operating waveforms for the evaluation board, while Figure 24 shows thermal images of the board in operation. In all cases, the board is operating at room temperature with no airflow; V_{IN} is 3.3V, V_{OUT} is 1.2V and I_O is 0–3A.

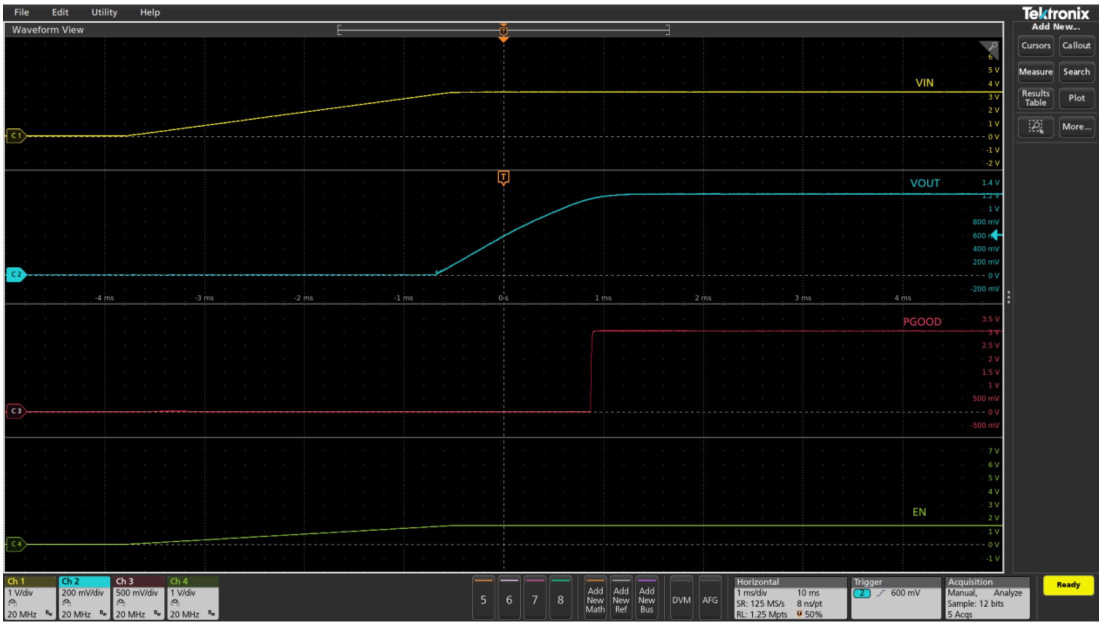


Figure 8 ***V_{IN} Startup with no load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)***

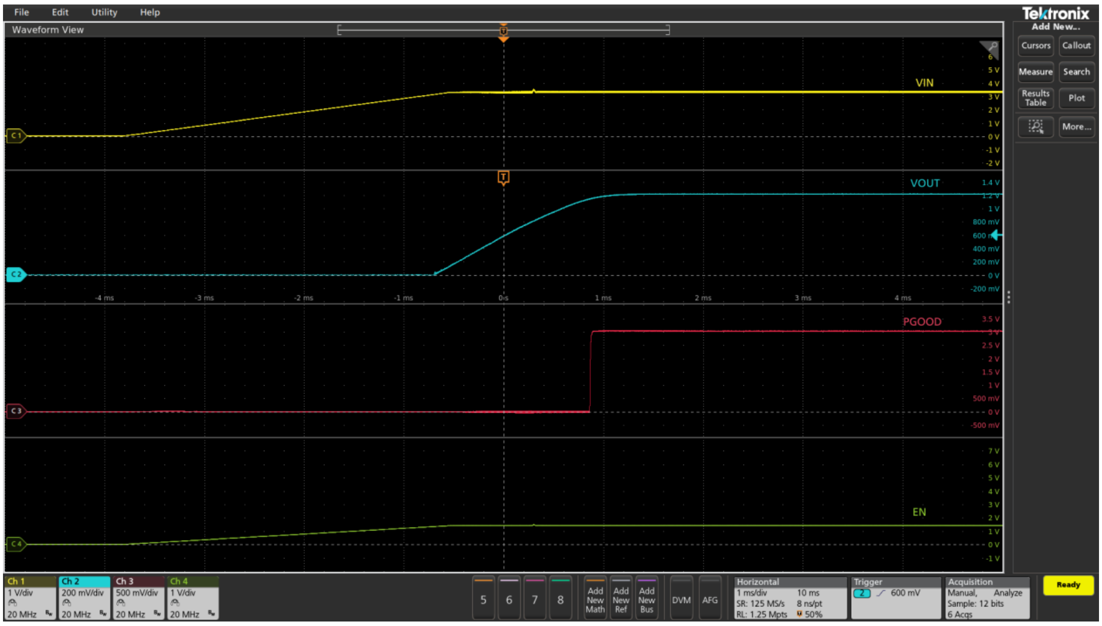


Figure 9 ***V_{IN} Startup with 3A load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)***

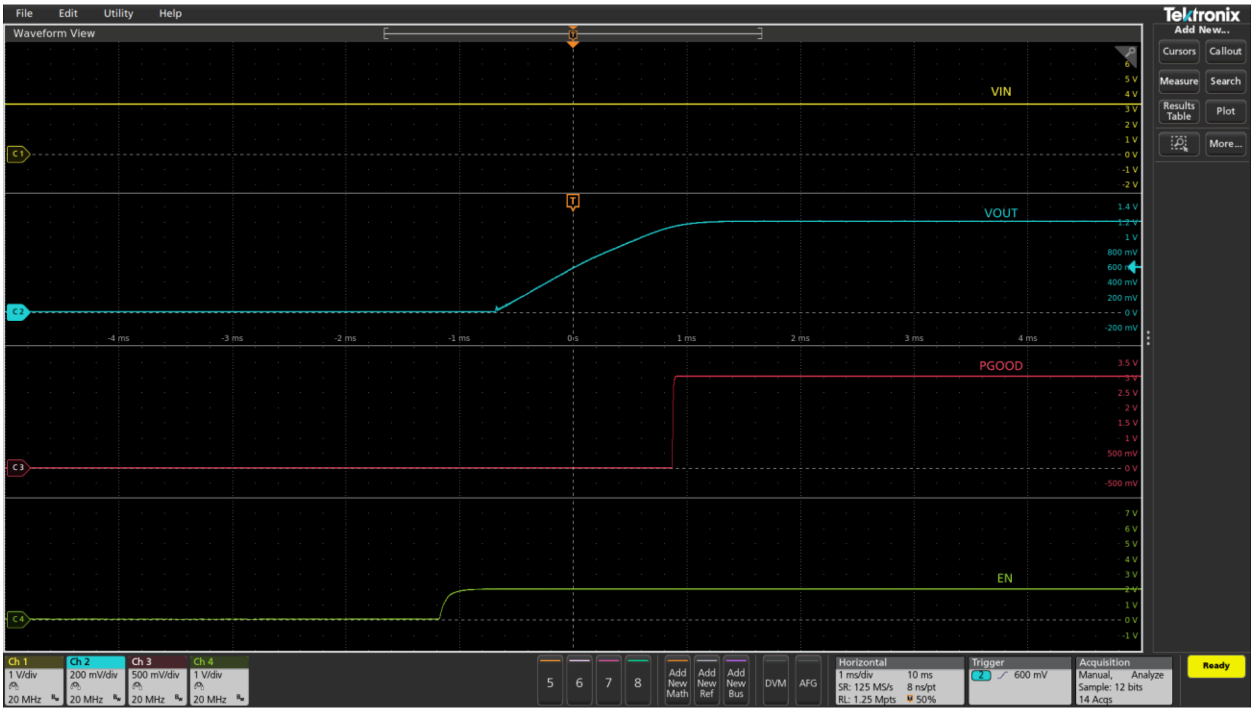


Figure 10 Startup with no load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

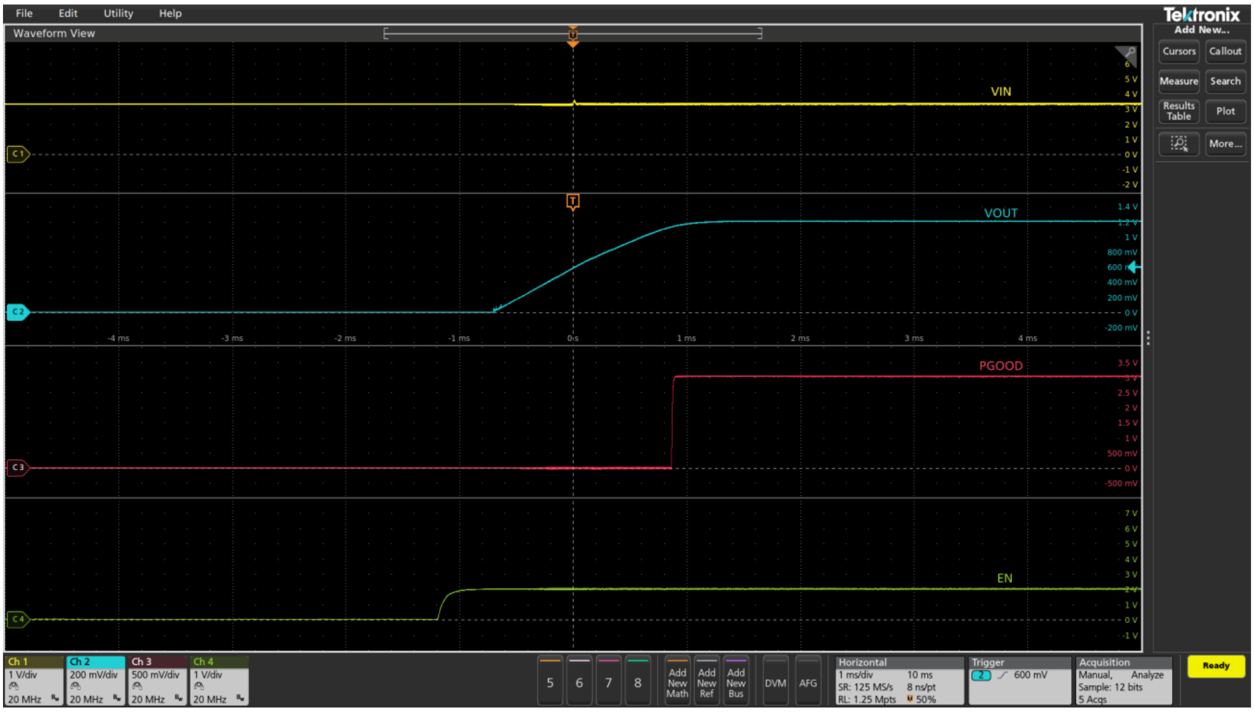


Figure 11 Enable Startup with 3A load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

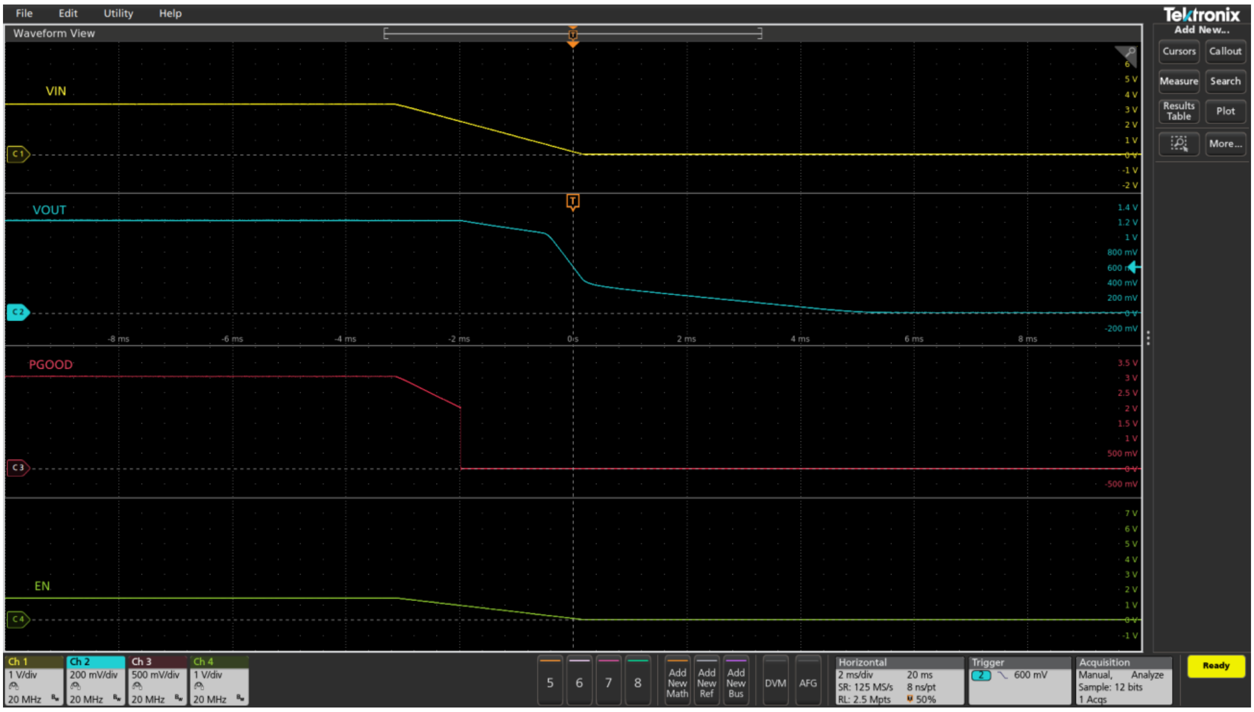


Figure 12 V_{IN} Shutdown with no load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

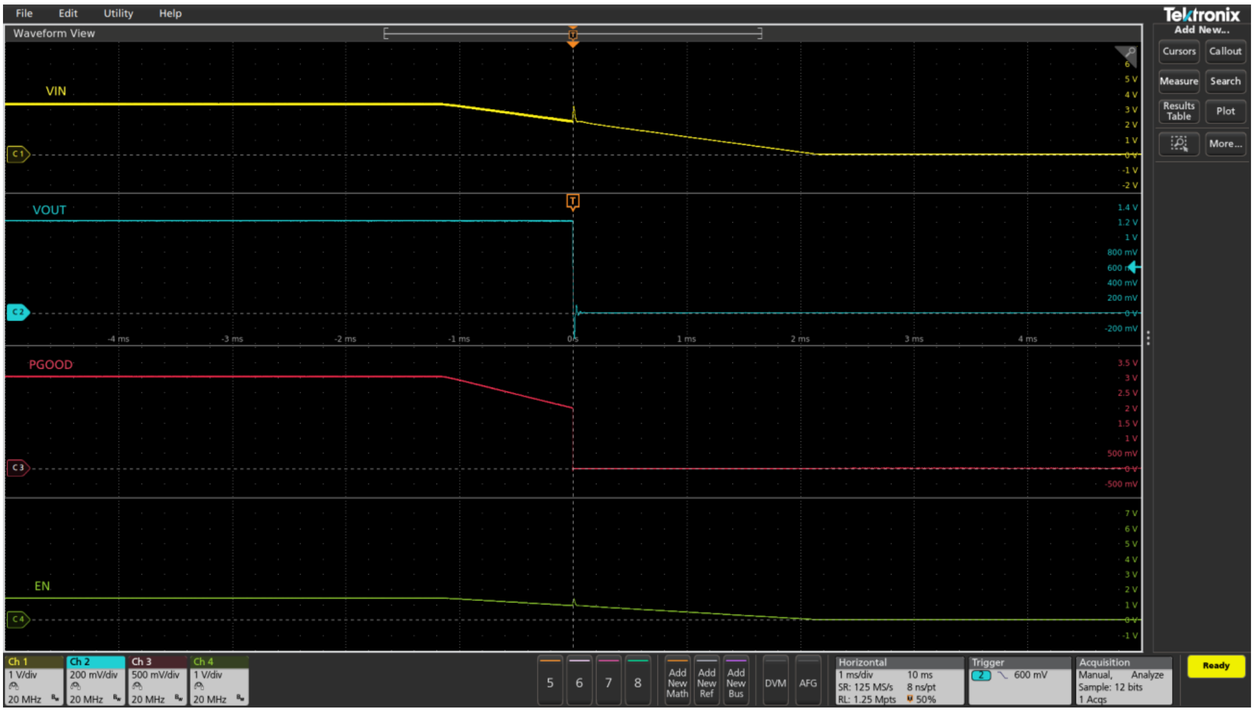


Figure 13 V_{IN} Shutdown with 3A load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

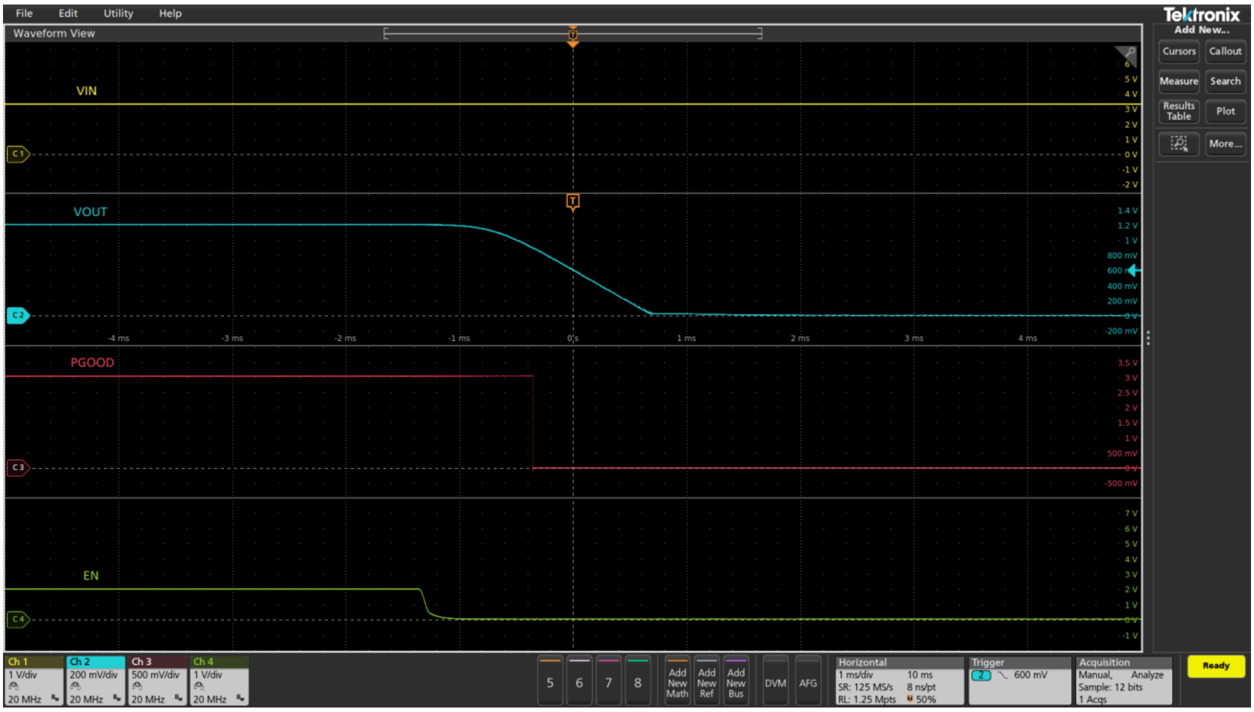


Figure 14 En Shutdown with no load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

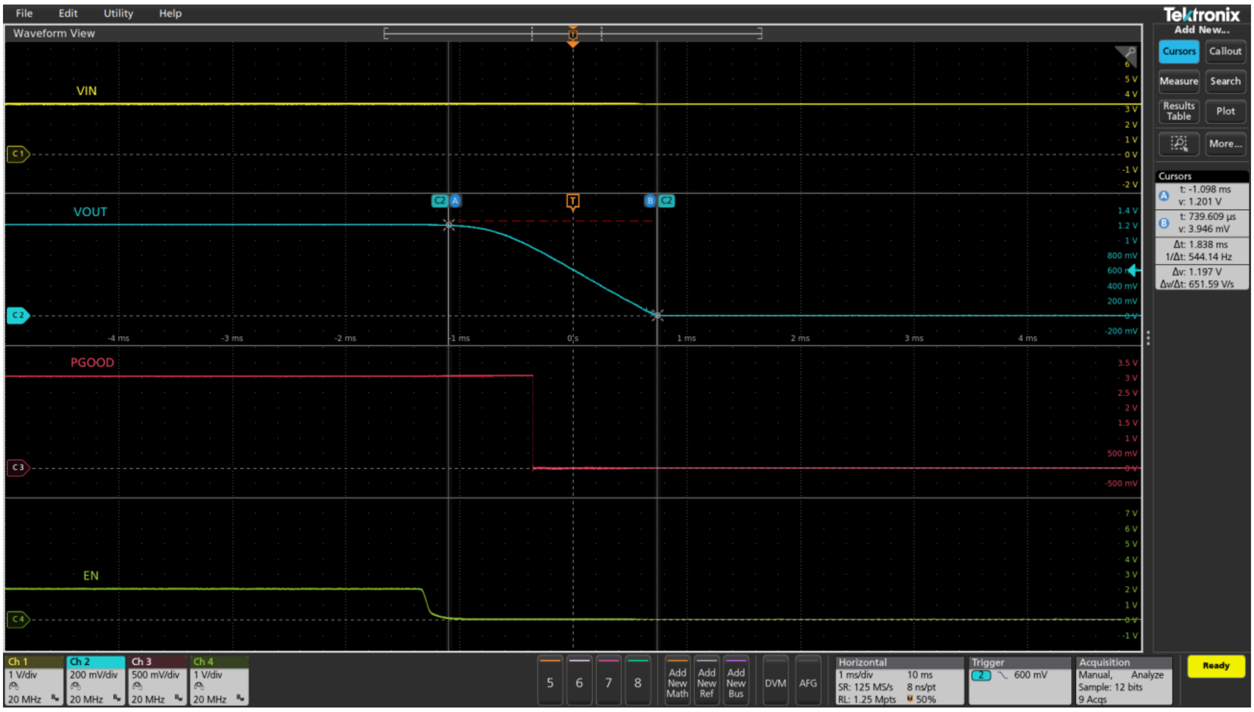


Figure 15 V_{IN} Shutdown with 3A load (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

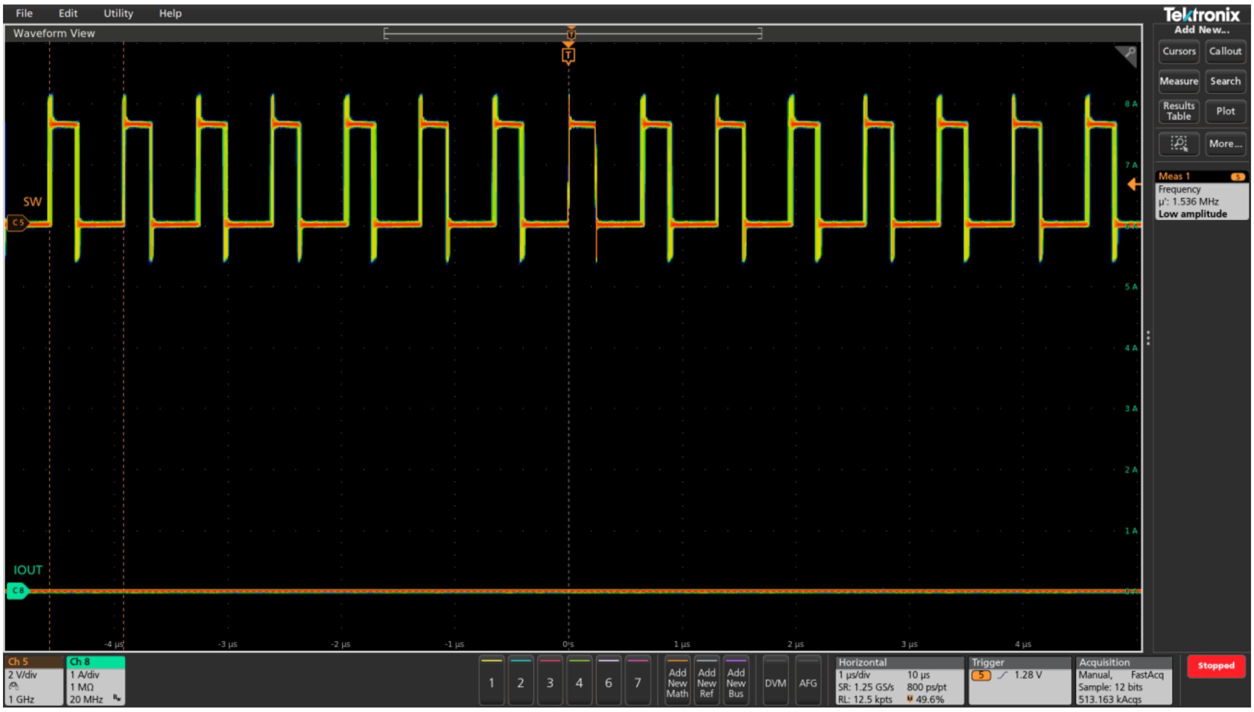


Figure 16   Switch node waveforms at no load

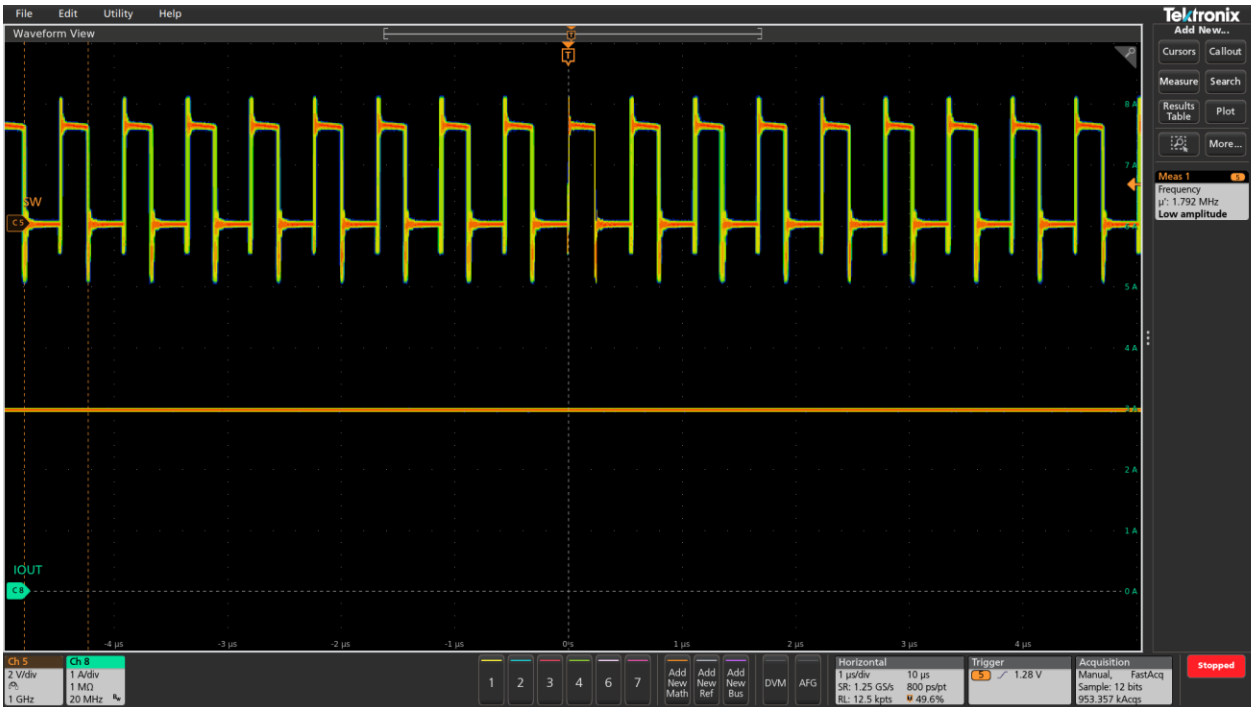


Figure 17   Switch node waveforms at 3A load

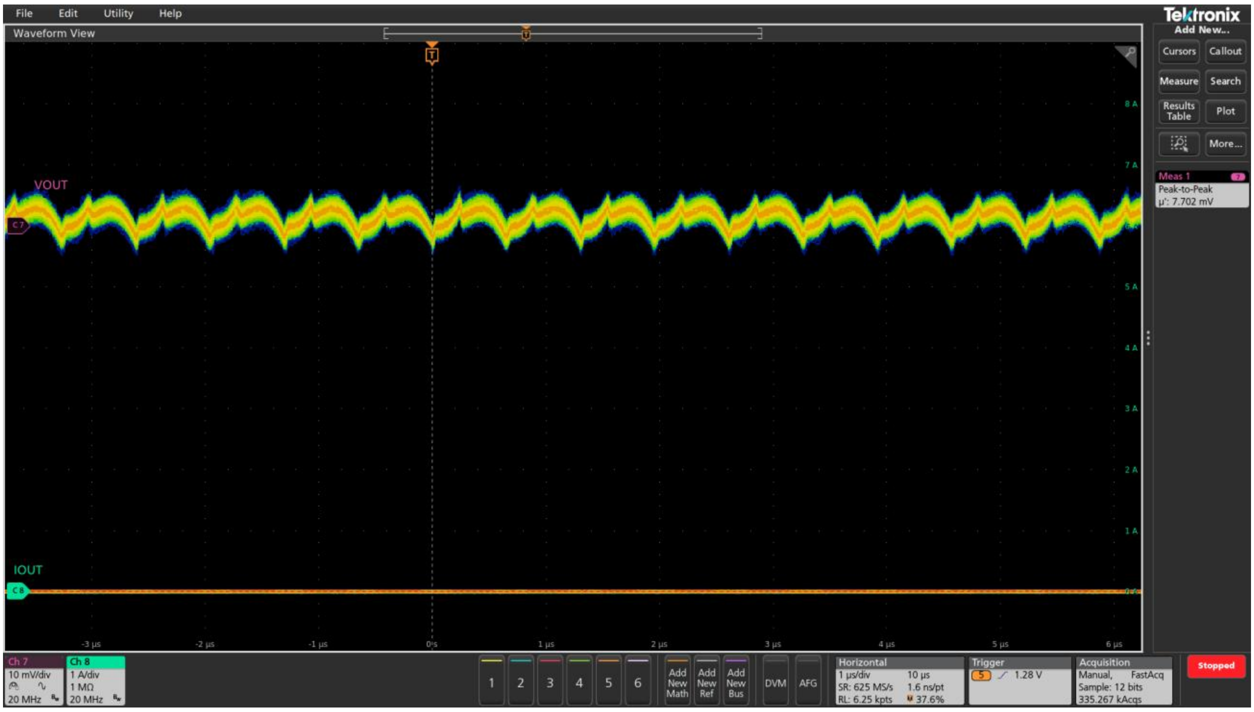


Figure 18 ***V_{OUT} ripple at 0A (Ch7: V_{OUT}, Ch8: I_O), peak-peak V_{OUT} ripple = 7.7mV***

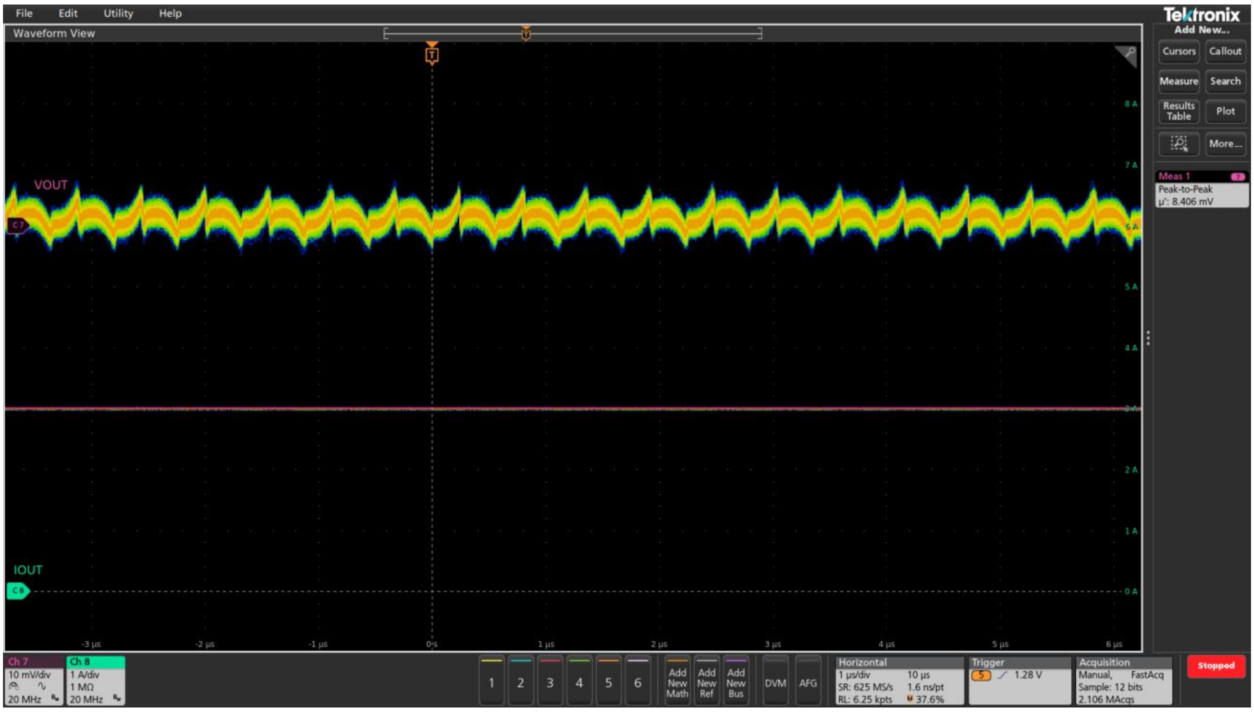


Figure 19 ***V_{OUT} ripple at 0A (Ch7: V_{OUT}, Ch8: I_O), peak-peak V_{OUT} ripple = 8.4mV***

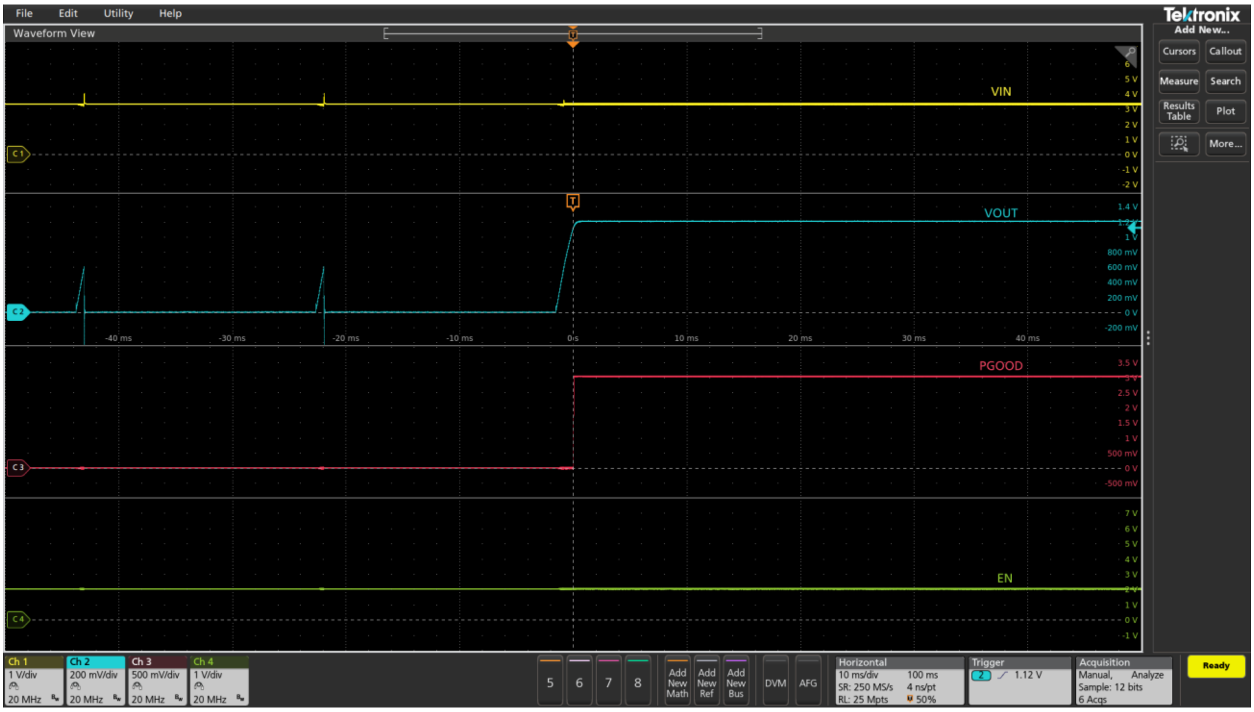


Figure 20 OCP Recovery to 3A (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

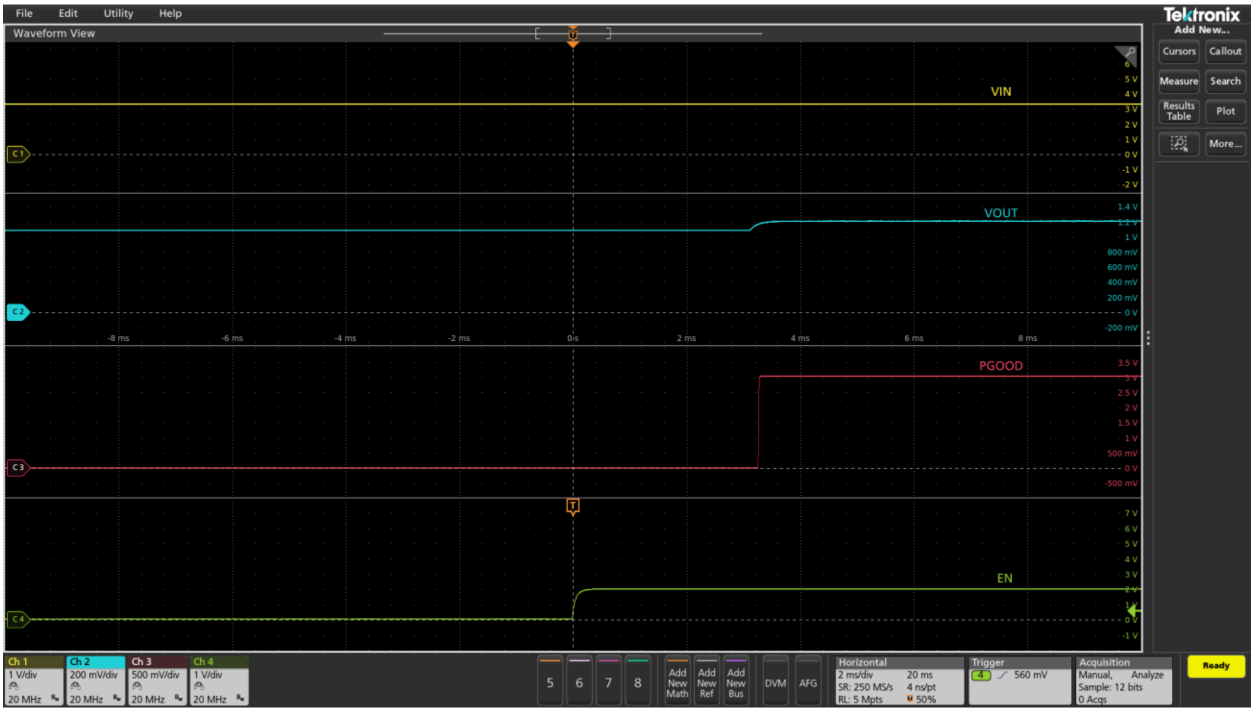


Figure 21 Startup into 90% Prebias (Ch1: V_{IN}, Ch2: V_{OUT}, Ch3: PGood, Ch4: Enable)

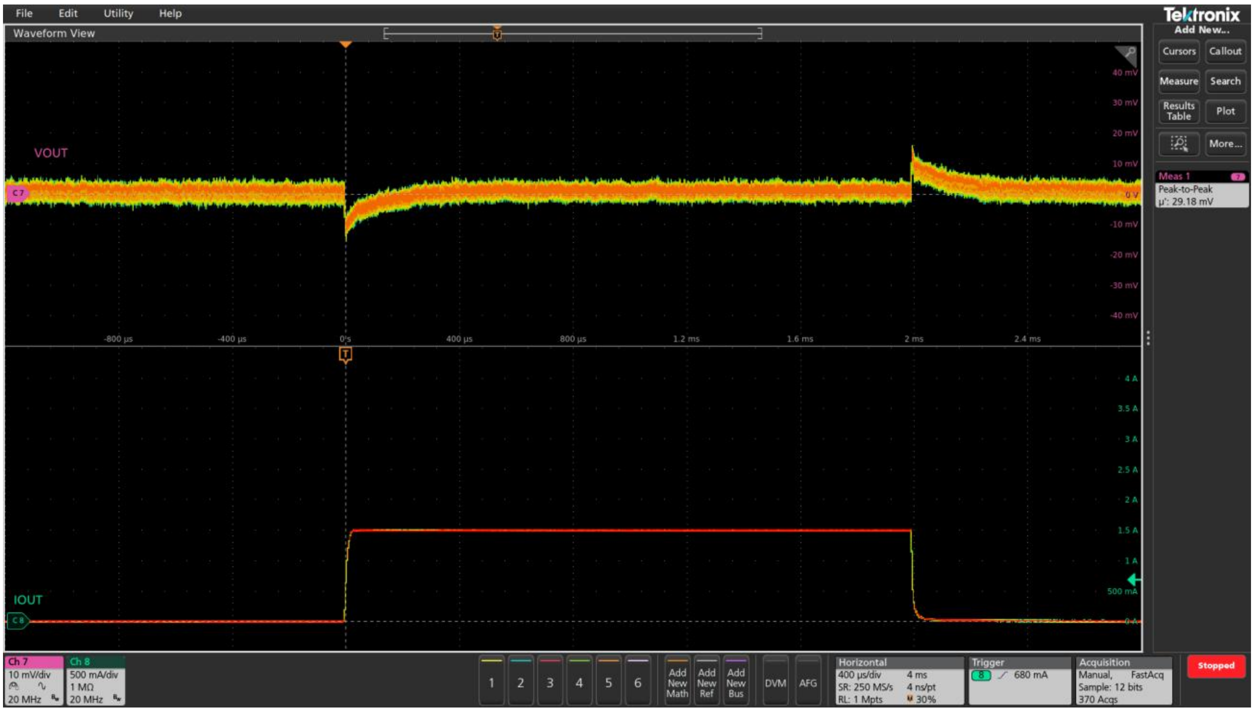


Figure 22 Transient response 0A–1.5A (Ch7: V_{OUT}, Ch8: I_O), peak-peak deviation = 29mV

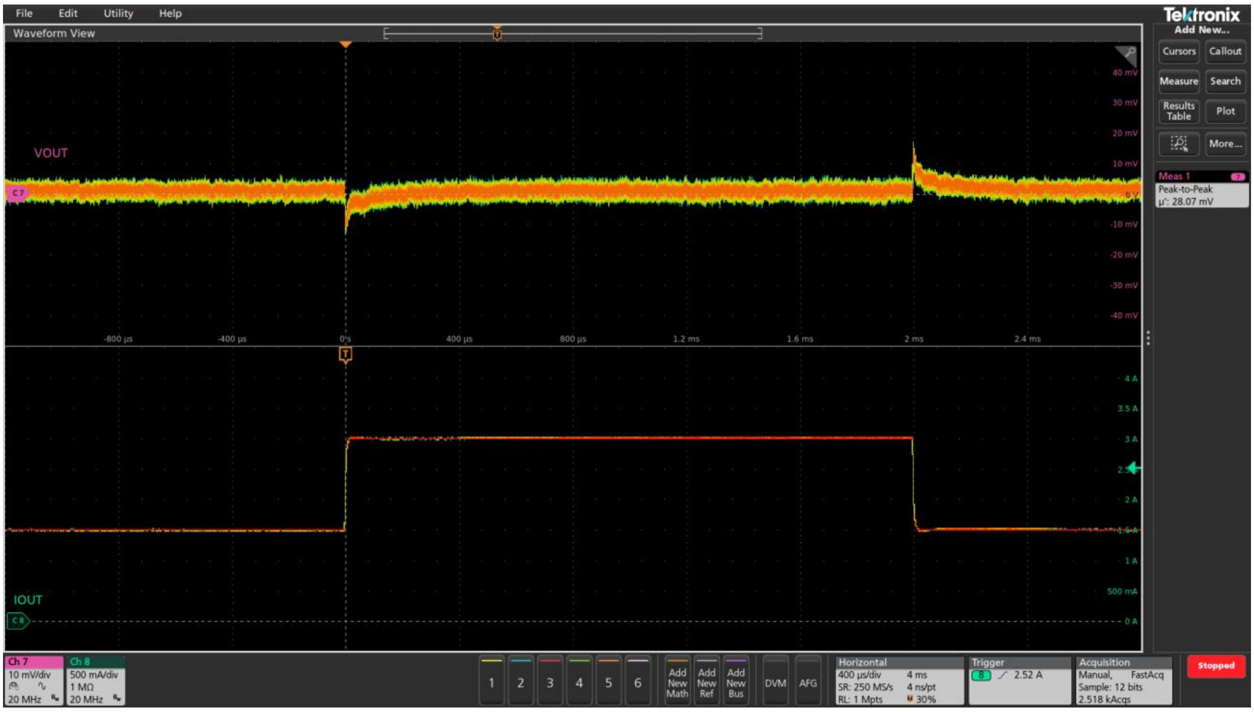


Figure 23 Transient response 1.5–3A (Ch7: V_{OUT}, Ch8: I_O), peak-peak deviation = 28mV

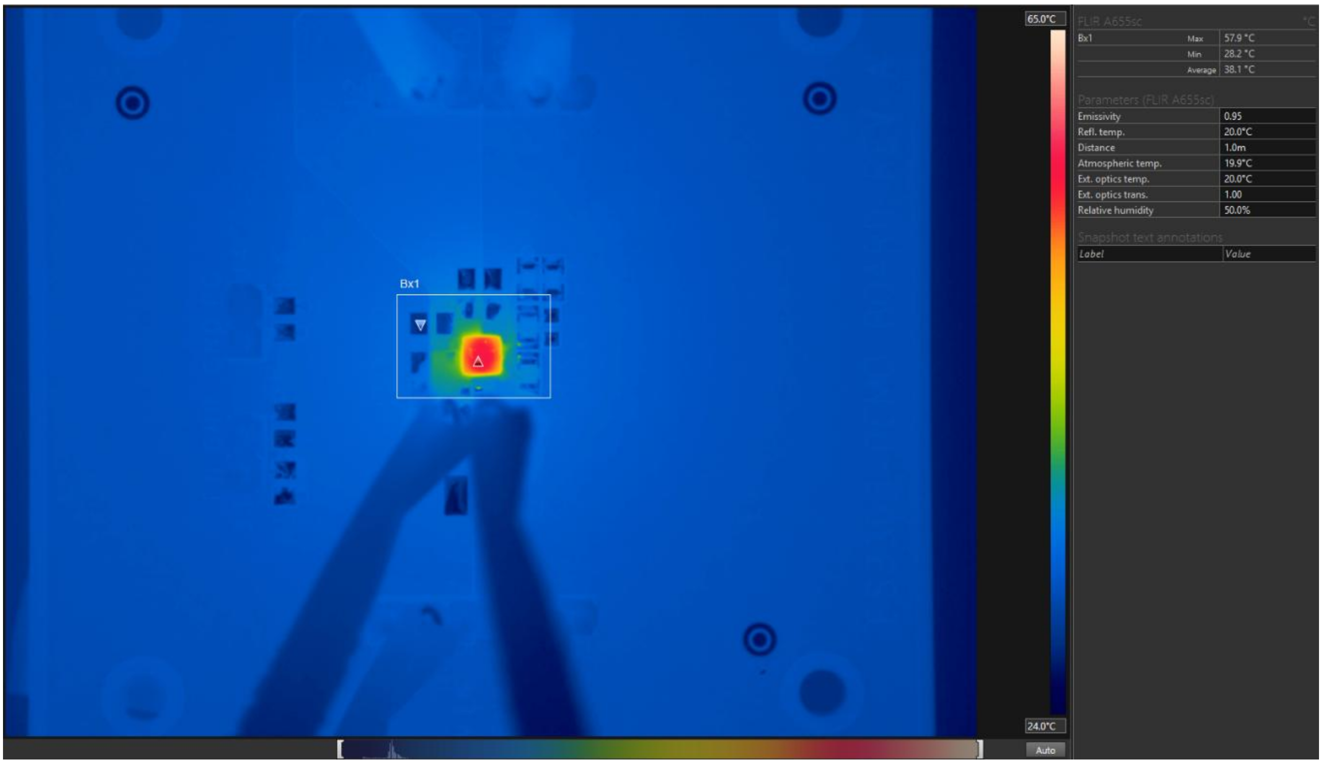


Figure 24 Thermal image at PV_{IN} = 3.3V, V_{OUT} = 1.2V, I_O = 3A, room temperature, no airflow, maximum temperature rise = 33°C

Layout Recommendations

FS3303 is a highly integrated device with very few external components, which simplifies PCB layout. However, to achieve the best performance, these general PCB design guidelines should be followed:

- Bypass capacitors (0805-size), including input/output capacitors, should be placed as close as possible to the FS3303 pins.
- Output voltage should be sensed with a separated trace directly from the output capacitor.
- The external feedback resistor should be placed as close as possible to the Fb pin.
- Through-hole vias should be used to connect the analog ground to the power ground plane.

Thermal considerations

The FS3303 has been thermally tested and modeled in accordance with JEDEC specifications JESD 51-2A and JESD 51-8. It has been tested using a 4-layer application PCB, with thermal vias under the device to assist cooling (for details of the PCB, refer to the application notes).

The FS3303 has two significant sources of heat:

- The power MOSFET section of the IC
- The inductor

The IC is well coupled to the PCB, which provides its primary cooling path. Although the inductor is also connected to the PCB, its primary cooling path is through convection. The cooling process for both heat sources is ultimately through convection. The PCB can be seen as a heat-spreader or, to some degree, a heat-sink.

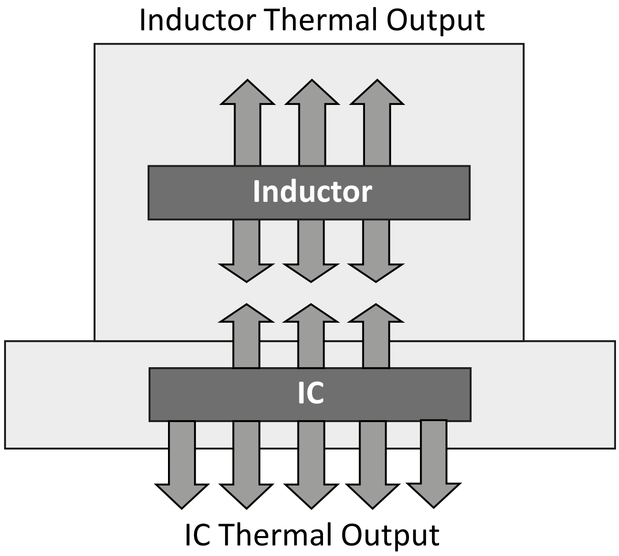


Figure 25 Heat sources in the FS3303

Figure 26 shows the thermal resistances in the FS3303, where:

- Θ_{JA} is the measure of natural convection from the assembled test sample within a confined enclosure of approximately 30x30x30cm. The air is passive within this environment and the only air movement is due to convection from the device on test.
- $\Theta_{JCbottom}$ is the heat flow from the IC to the bottom of the package, to which it is well coupled. The testing method adopts the method outlined in JESD 51-8, where the test PCB is clamped between cold plates at defined distances from the device.
- Θ_{JCtop} is theoretically the heat flow from the IC to the top of the package. This is not representative for the FS3303 for two reasons: firstly, it is not the primary conduction path of the IC and, more importantly, the inductor is positioned directly over the IC. As the inductor is a heat source, generating a similar amount of heat to the IC, a meaningful value for junction-to-case (top) cannot be derived.

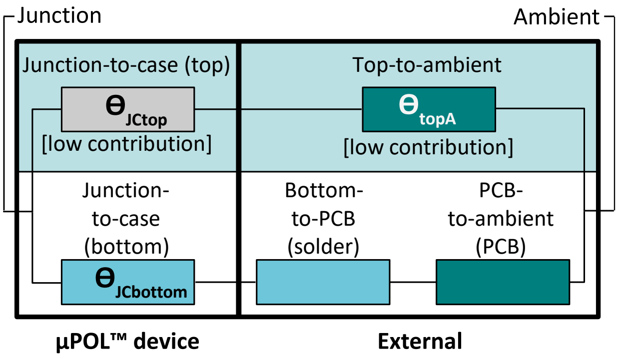


Figure 26 Thermal resistances of the FS3303

The values of the thermal resistances are:

- Junction-to-ambient, Θ_{JA} = 48°C/W
- Junction-to-PCB, $\Theta_{J\text{-}PCB}$ = 7°C/W

Although these values indicate how the FS3303 compares with similar point-of-load products tested using the same conditions and specifications, they cannot be used to predict overall thermal performance. For accurate modeling of the µPOL™'s interaction with its environment, computational fluid dynamics (CFD) simulation software is needed to calculate combined routes of conduction and convection simultaneously.

Note: In all tests, airflow has been considered as passive or static; applications using forced air may achieve a greater cooling effect.

Package Description

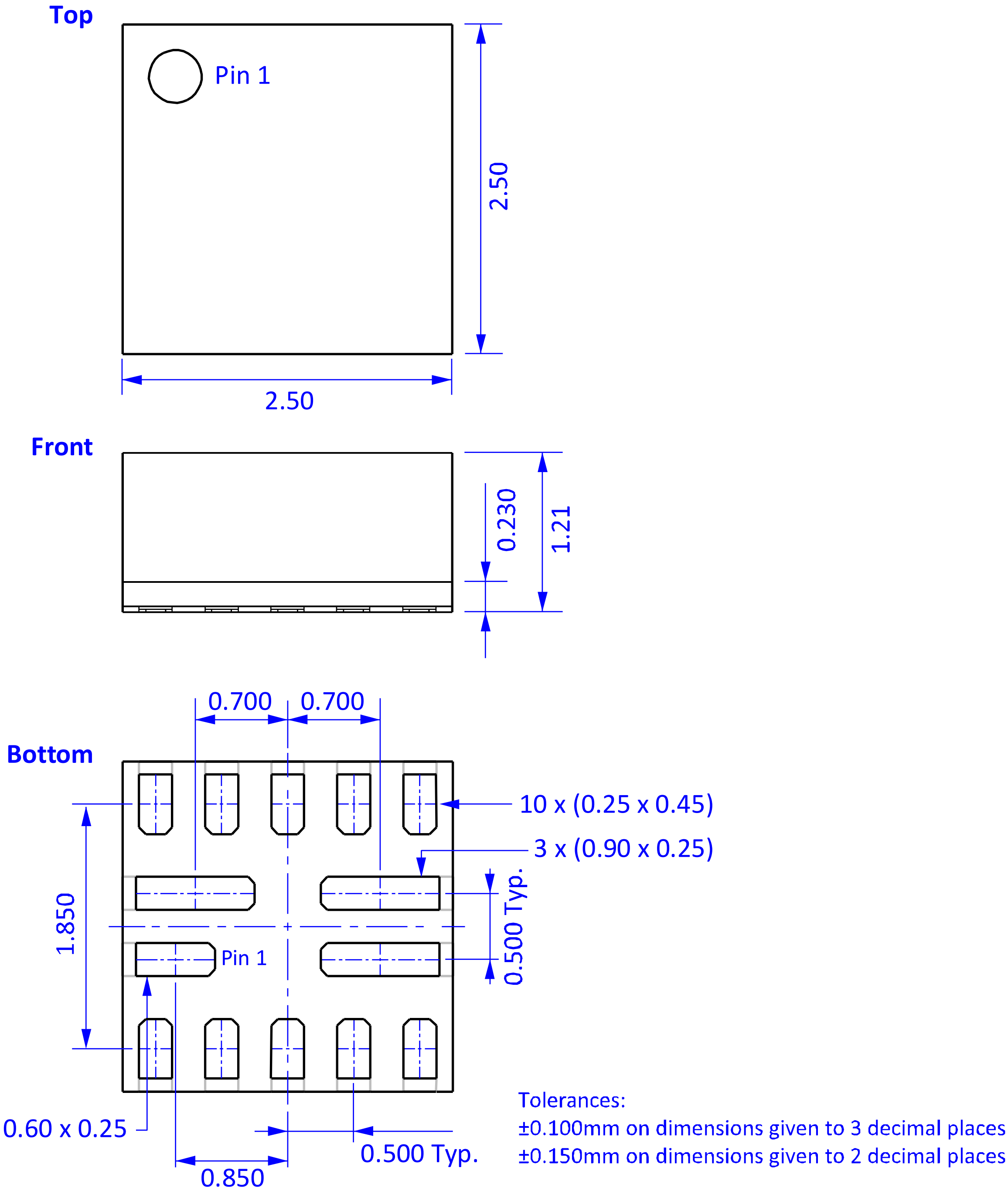


Figure 27 Package outline drawing

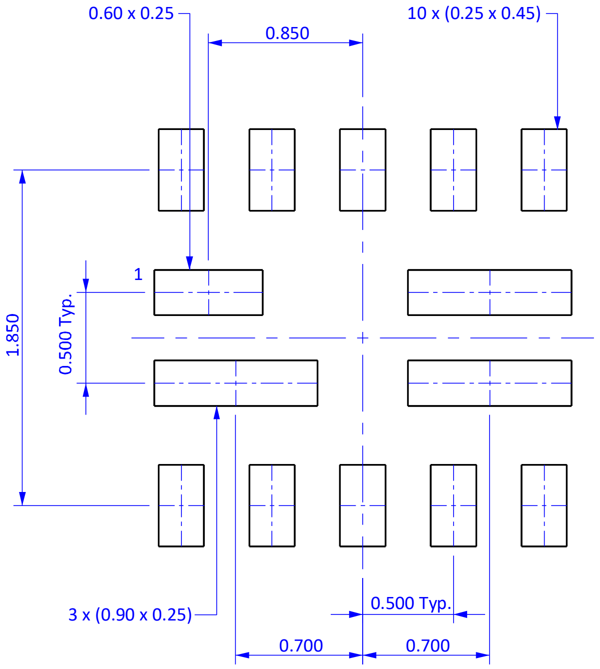


Figure 28 PCB layout

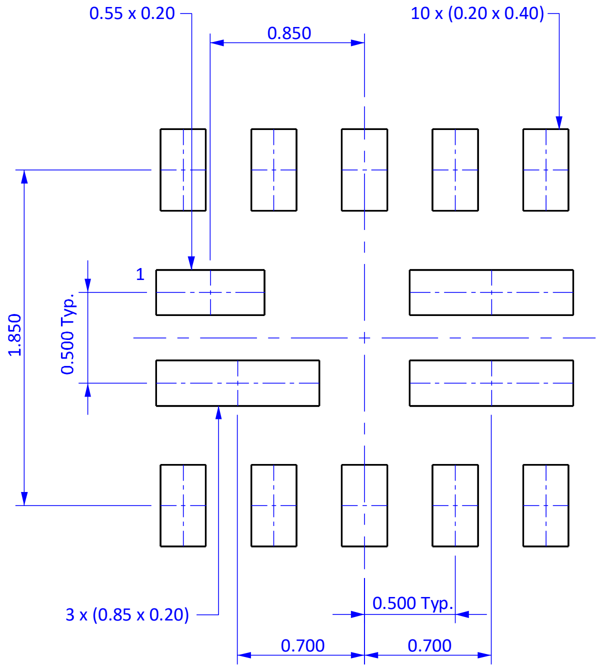


Figure 29 Solder stencil

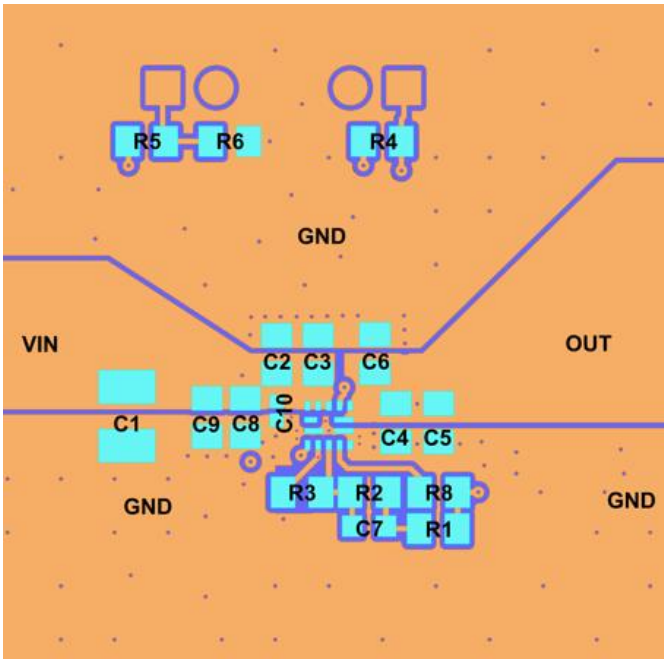
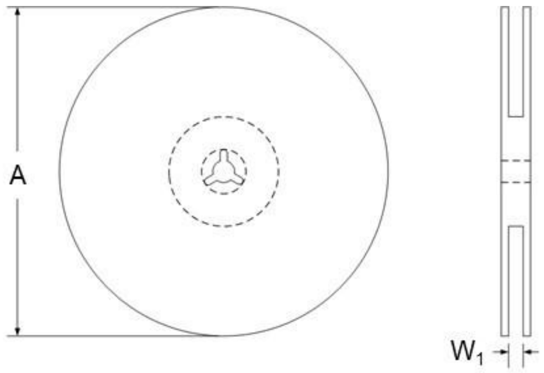


Figure 30 Copper pads and tracks

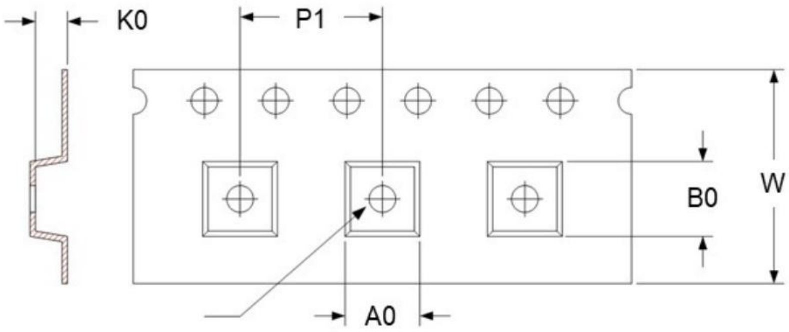
Tape and Reel Information

Reel Dimensions



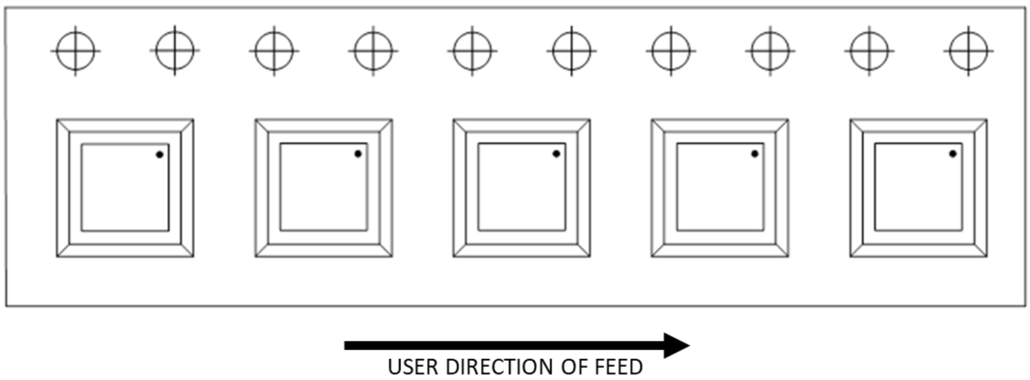
Reel Diameter A (mm)	Reel Width W_1 (mm)
330	12.8

Tape Dimensions



Dimension	(mm)
P1	8.00
W	12.00
A0	2.80
B0	2.80
K0	1.51

Pin 1 Orientation in Carrier Tape



REMINDERS FOR USING THESE PRODUCTS

Before using these products, be sure to request the delivery specifications.

SAFETY REMINDERS

Please pay sufficient attention to the warnings for safe designing when using these products.

REMINDER

The products listed on this specification sheet are intended for use in general electric equipment (AV equipment, telecommunication equipment, home appliances, amusement equipment, computer equipment, personal equipment, office equipment, measurement equipment, industrial robots) under a normal condition and use condition.

The products are not designed or warranted to meet the requirements of the applications listed below, whose performance and/or quality require a more stringent level of safety or reliability, or whose failure, malfunction or trouble could cause serious damage to sociality, person or property. Please understand that we are not responsible for any damage or liability caused by use of the products in any of the applications below or for any other use exceeding the range or conditions set forth in this specification sheet.

1. Aerospace/Aviation equipment
2. Transportation equipment (cars, electric trains, ships, etc.)
3. Medical equipment
4. Power-generation control equipment
5. Atomic energy related equipment
6. Seabed equipment
7. Transportation control equipment
8. Public Information-processing equipment
9. Military equipment
10. Electric heating apparatus, burning equipment
11. Disaster prevention/crime prevention equipment
12. Safety equipment
13. Other applications that are not considered general-purpose applications

When using this product in general-purpose application, you are kindly requested to take into consideration securing protection circuit/ equipment or providing backup circuits, etc., to ensure higher safety.