A 12-V/1-A Primary Side Regulated Isolated Flyback Converter for Automotive Applications

NCV12711PSRGEVB

SPECIFICATION

Devices	Applications	Input Voltage	Output Power	Topology	Board Size
NCV12711	Automotive	4 – 45 V dc	12 W	Current−Mode Flyback	100 x 47 x 15 mm
Output Spec.	**Turn on Time**	**Efficiency**	**Operating Temperature**	**Cooling**	**Standby Power**
12 V/1 A	< 100 ms	Peaks to 88 % @ full load	0 – 50°C	Open Frame in Still Air	See the tables on page 12

DESCRIPTION

This evaluation board user's manual provides elementary information about a primary−side−regulated flyback converter NCV12711PSRGEVB built with the NCV12711 operated in current−mode control at 100 kHz. This control circuit offers many features to build an energy−efficient converter with all the needed protections like cycle−by−cycle current limit with a 250−mV sense voltage, over−current protection (OCP) and over−voltage protection (OVP) on the VCC pin. The controller drives an N−channel MOSFET as with any classical flyback converter at a user−adjustable switching frequency. The secondary side hosts a low−V_f diode for efficient rectification in continuous conduction mode (CCM).

The primary−side section drives a transformer whose primary inductance is 8 μH. The current is sensed via two paralleled 40−mΩ resistors which limit the maximum output current to a safe value in fault condition. The board is rated to 12 W of continuous output power in free air at the lowest input voltage. This level is delivered down to a 4.5−V input. The converter is able to deliver output power up to 4−V input, which is the turn−off level adjusted by an UVLO resistor divider. At higher input voltages, the board may deliver more power but thermal runaway may happen and the board temperature must be monitored.

The regulation is ensured via an auxiliary winding, avoiding the use of an optocoupler. The winding is first filtered via R_{18}/C_{19} and helps lowering the leakage inductance peak naturally present in the transformer voltage. Then diode D_4 with capacitor C_{12} provide adequate rectification to build a clean dc voltage. The switches let you select different configurations to test the circuit:

1. *a* is closed, *b* open: in this mode, the VCC and VIN pin are connected together while the auxiliary dc serves for regulation purposes only. The maximum input voltage is 25 V; going beyond this value will trip the OVP on VCC pin.
2. *b* is closed, *a* open: in this mode, the controller is supplied by the VIN pin only during start−up sequence and V_{cc} is biased by the rectified auxiliary supply. The input voltage can go up to 45 V.
3. *a* and *b* are open: the controller is self−supplied via internal LDO and the auxiliary winding only serves for regulation purposes. The input voltage can go up to 45 V.

In the above three modes, 1. and 3. offer the best regulation figure because the load is constant across capacitor C_{12}. However, in 1. the input voltage is limited to 25 V while in 3., power dissipation might be at stake if you drive a large−Q_G MOSFET at a high switching frequency.

The internal operational amplifier coupled to external components ensures the realization of a type 2 compensator. Using the simulation model or a bench measurement, components values were adjusted to crossover above 1 kHz. The maximum crossover is limited by the right−half−plane−zero (RHPZ) which degrades the phase response at the lowest input voltage and the largest output current. The board is equipped with two connectors letting you easily connect the network analyzers probes for a convenient measurement. The collected graphs show a comfortable phase margin at crossover.

A simple front−end filter limits the amount of parasitic noise going back to the source and it must be properly damped to avoid interaction with the downstream converter. C_9 is providing that function with its equivalent series resistance (ESR).

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KEY FEATURES OF NCV12711

- Internal 20−mA current source for lossless start−up sequence and self−supply operation
- Smooth start−up sequence with frequency sweep
- Internal operational amplifier with precise 2.5−V reference voltage
- Current−mode control operation
- Short circuit protection
- Over voltage protection
- Input Voltage UVLO with Hysteresis
- Shutdown threshold for external disable
- 0% duty ratio mode for low standby power
- Single Resistor Programmable Oscillator
- User−Adjustable Soft−Start Ramp

BOARD PICTURES

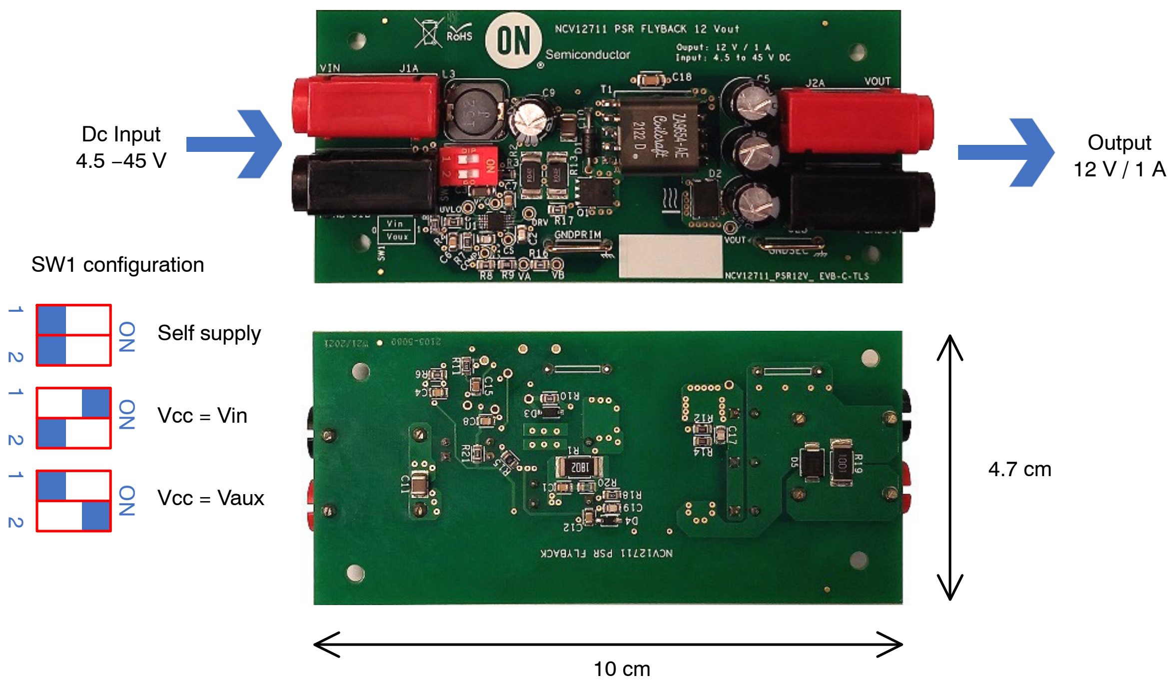

Figure 1. Top/Bottom Photo of the NCV12711PSRGEVB Evaluation Board

EVALUATION BOARD SCHEMATIC DIAGRAM

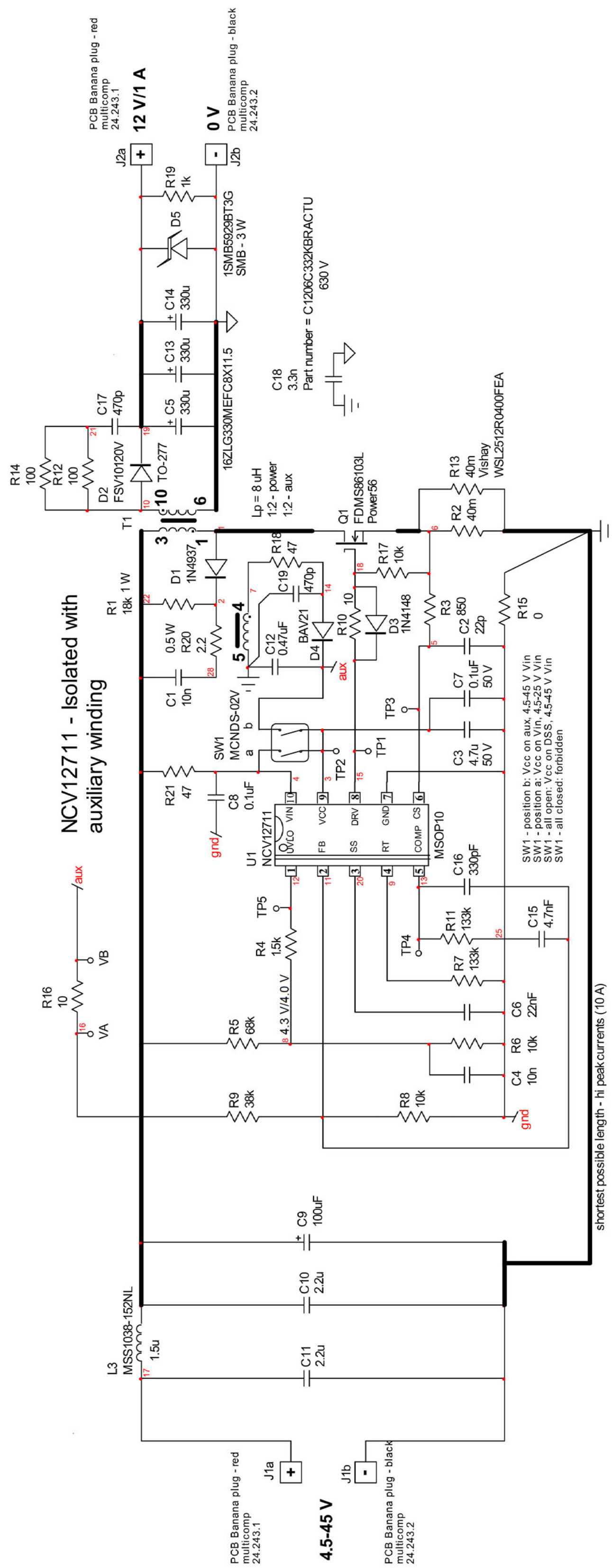

Figure 2. Schematic of the NCV12711PSRGEVB Evaluation Board

MAGNETICS DATA

ZA9654−AE from Coilcraft:

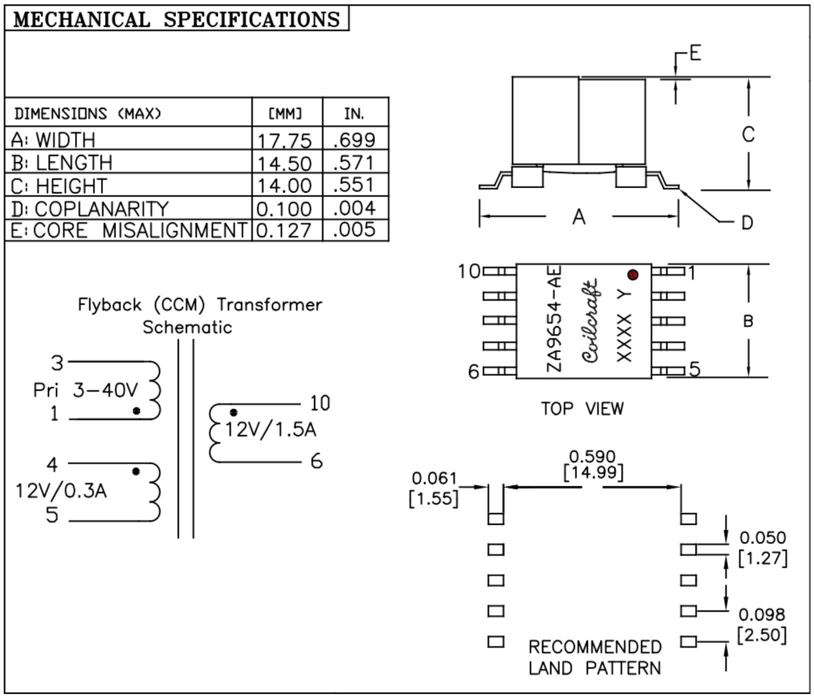

Figure 3. Mechanical Specifications

ELECTRICAL SPECIFICATIONS "ALL ELECTRICAL SPECIFICATIONS @ 25°C"

INDUCTANCE(uH) (CSC) 100%
300KHZ, 0.1 VRMS, 0/11ADC

PINS	MIN	MAX
1−3(0A)	7.6	8.4
1−3(11A)	7.0	

HI POT(1mA) 100%
(VRMS, Applied for 1 minute)

VOLTAGE:	FROM PINS	TO PINS
1500	3,4	6
750	ALL PINS	CORE
500	1	4

TRL 100%
Apply 0.05 Vrms, 30 KHZ to pins 1−3

MEASURE PINS:	MIN	MAX
10−6	1.940	2.060
4−5	1.940	2.060

DC RESISTANCE (OHMS) A/R

PINS		MAX
1−3		.044
10−6		.265
4−5		.550

LEAKAGE INDCTANCE(uH) A/R
300KHZ, 0.1 VRMS, 0 ADC

PINS	SHORT PINS	MAX
1−3	10−6	0.110
4−5	10−6	0.430

Figure 4. Electrical Specifications

TEST DATA

Startup Time

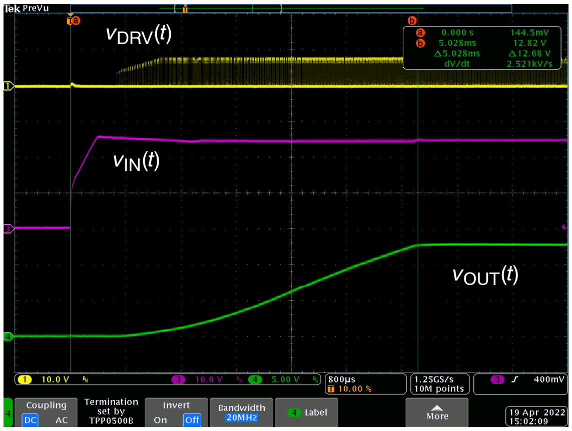

Figure 5. Self−supplied, V_{IN} = 25 V, I_{OUT} = 0 A, $t_{startup}$ = 5.0 ms

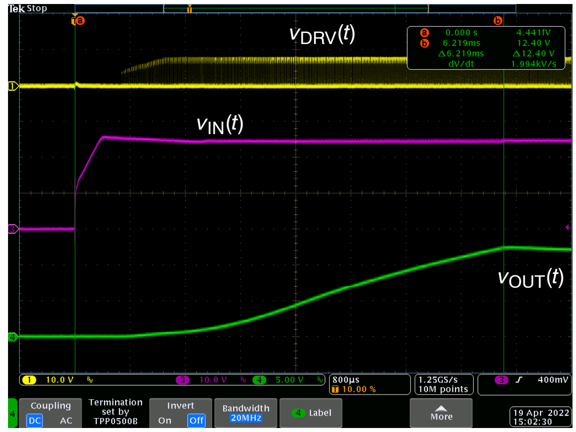

Figure 6. Self−supplied, V_{IN} = 25 V, I_{OUT} = 1 A, $t_{startup}$ = 6.2 ms

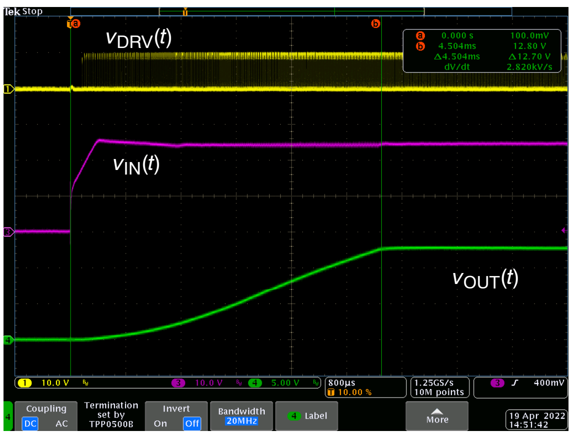

Figure 7. VCC = VIN, V_{IN} = 25 V, I_{OUT} = 0 A, $t_{startup}$ = 4.5 ms

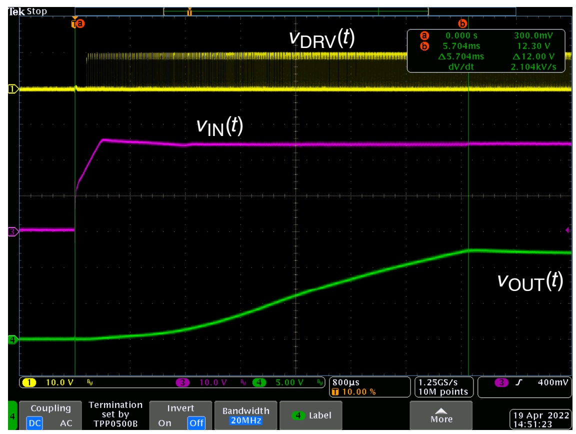

Figure 8. VCC = VIN, V_{IN} = 25 V, I_{OUT} = 1 A, $t_{startup}$ = 5.7 ms

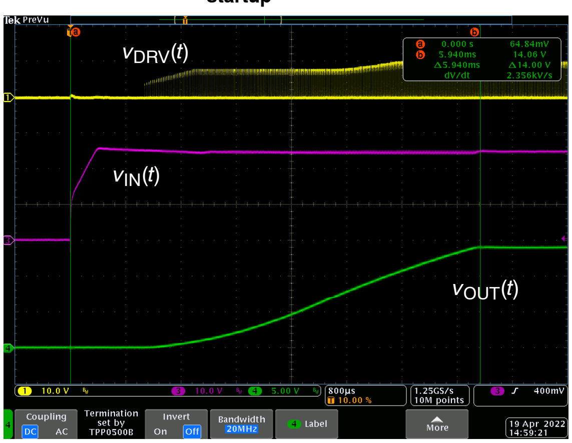

Figure 9. VCC = Vaux, V_{IN} = 25 V, I_{OUT} = 0 A, $t_{startup}$ = 5.9 ms

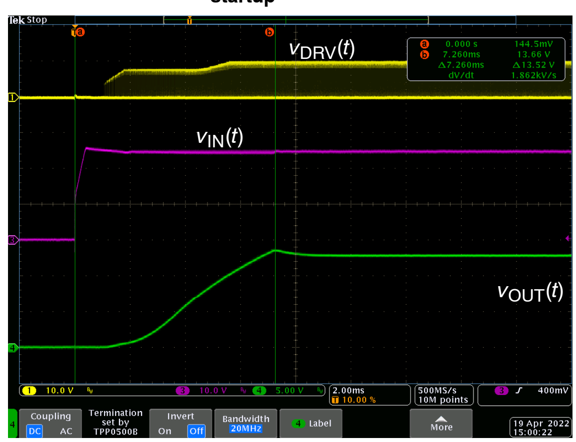

Figure 10. VCC = Vaux, V_{IN} = 25 V, I_{OUT} = 1 A, $t_{startup}$ = 7.3 ms

Steady−state Operation

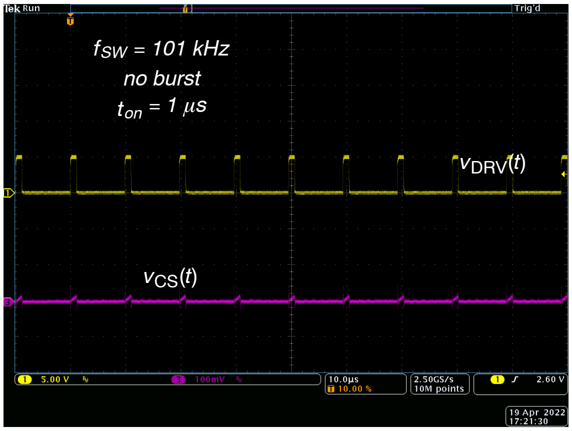

Figure 11. V_{IN} = 5.5 V, I_{OUT} = 0 A

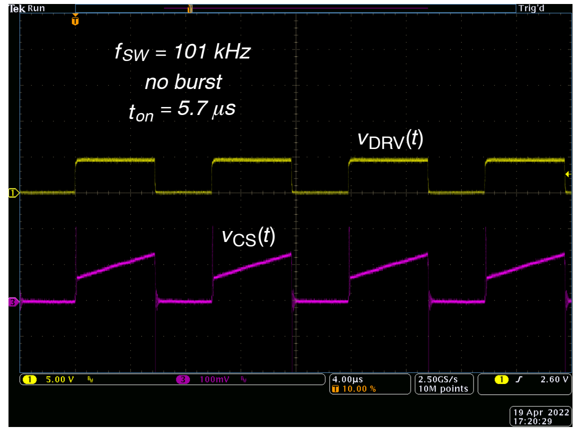

Figure 12. V_{IN} = 5.5 V, I_{OUT} = 1 A

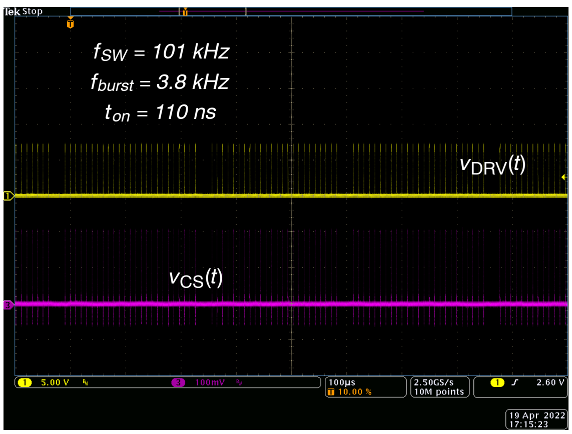

Figure 13. V_{IN} = 25 V, I_{OUT} = 0 A

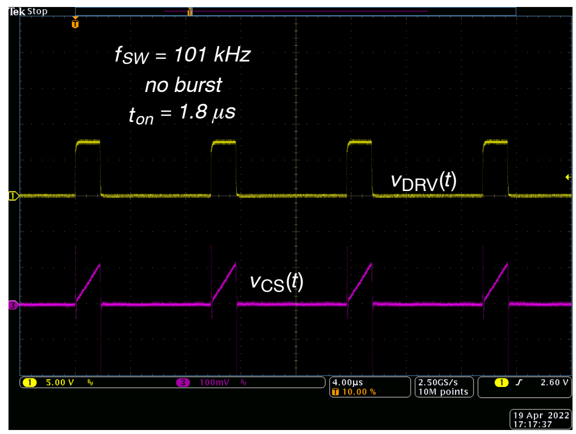

Figure 14. V_{IN} = 25 V, I_{OUT} = 1 A

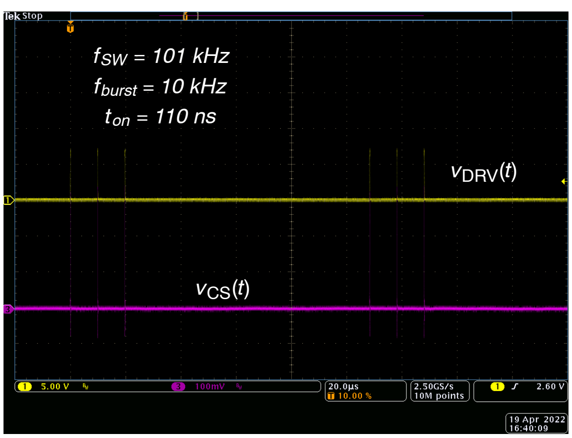

Figure 15. V_{IN} = 45 V, I_{OUT} = 0 A

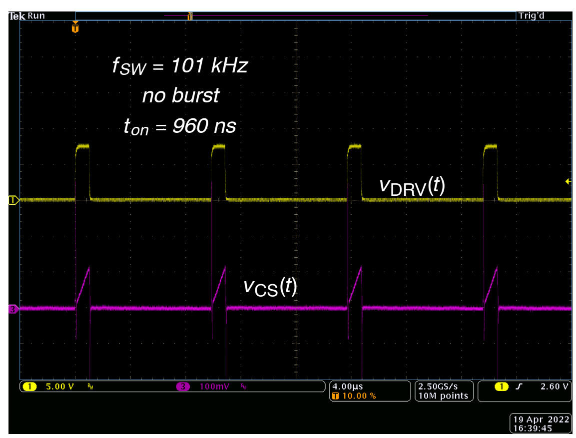

Figure 16. V_{IN} = 45 V, I_{OUT} = 1 A

Load Transient Response

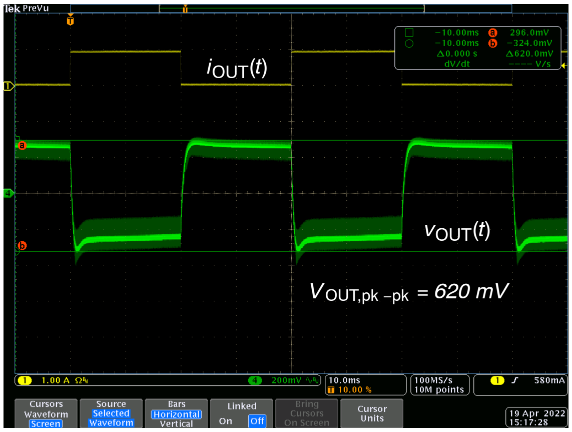

Figure 17. Self−supplied, V_{IN} = 25 V, I_{OUT} = from 0.1 A to 1 A, Slew Rate 0.5 A/μs

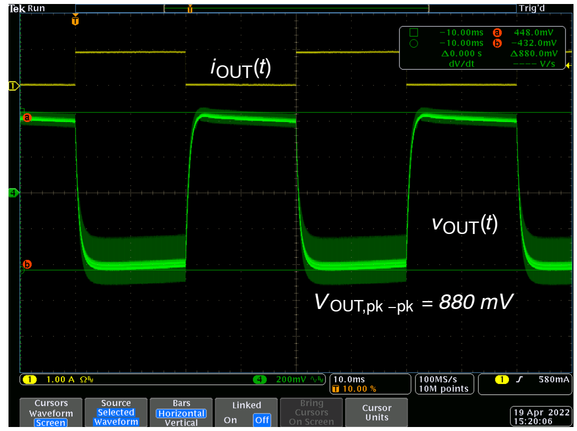

Figure 18. Self−supplied, V_{IN} = 5.5 V, I_{OUT} = from 0.1 A to 1 A, Slew Rate 0.5 A/μs

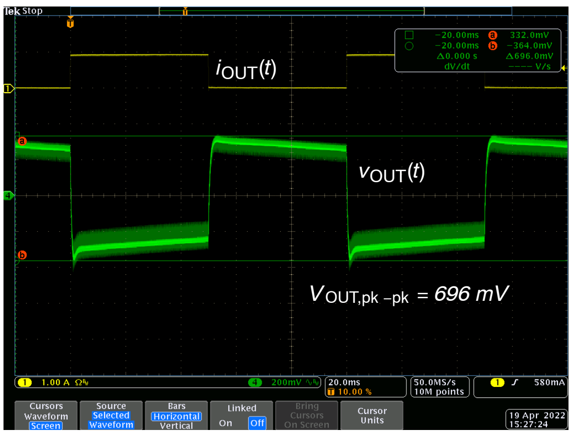

Figure 19. VCC = VIN, V_{IN} = 25 V, I_{OUT} = from 0.1 A to 1 A, Slew Rate 0.5 A/μs

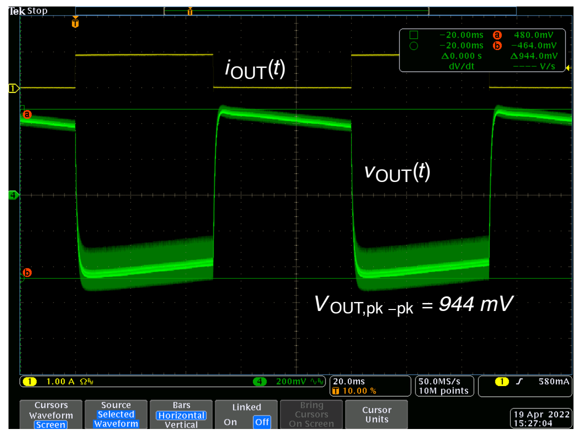

Figure 20. VCC = VIN, V_{IN} = 5.5 V, I_{OUT} = from 0.1 A to 1 A, Slew Rate 0.5 A/μs

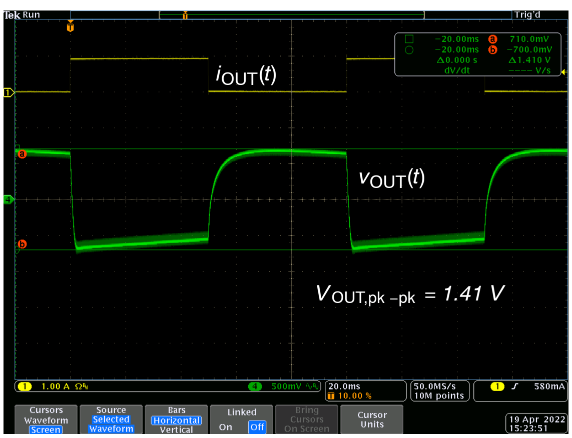

Figure 21. VCC = Vaux, V_{IN} = 25 V, I_{OUT} = from 0.1 A to 1 A, Slew Rate 0.5 A/μs

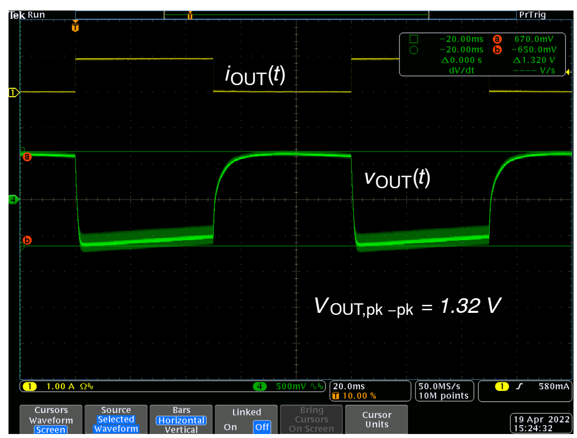

Figure 22. VCC = Vaux, V_{IN} = 5.5 V, I_{OUT} = from 0.1 A to 1 A, Slew Rate 0.5 A/μs

Output Voltage Ripple

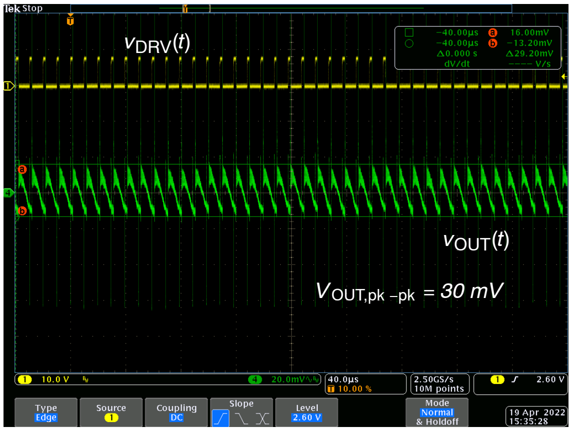

Figure 23. V_{IN} = 25 V, I_{OUT} = 1 A

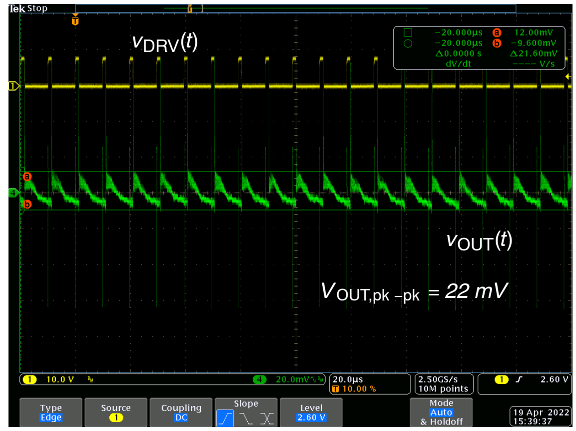

Figure 24. V_{IN} = 25 V, I_{OUT} = 0.5 A

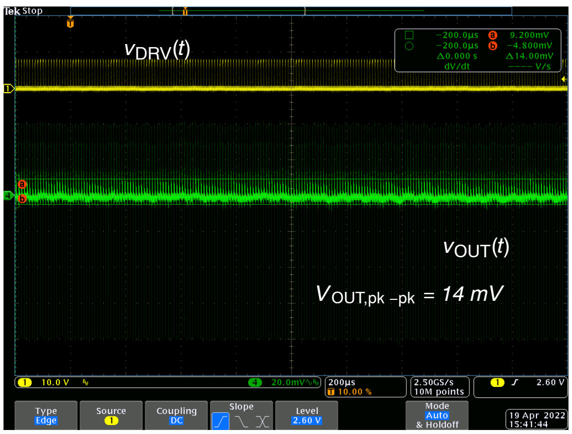

Figure 25. V_{IN} = 25 V, I_{OUT} = 0.1 A

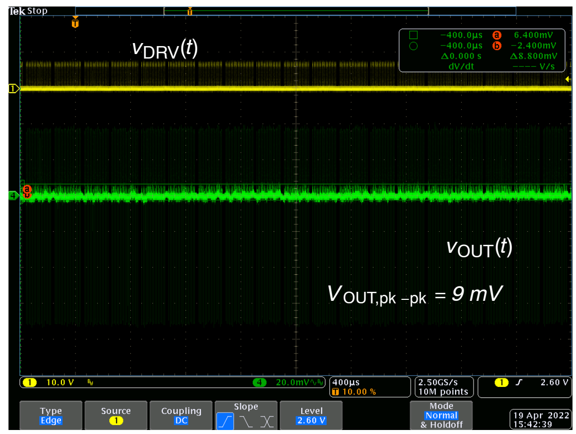

Figure 26. V_{IN} = 25 V, I_{OUT} = 0.0 A

Drain−Source Voltage

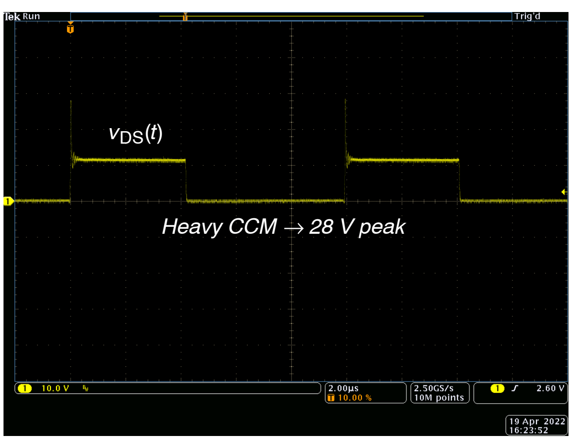

Figure 27. V_{IN} = 25 V, I_{OUT} = 1 A

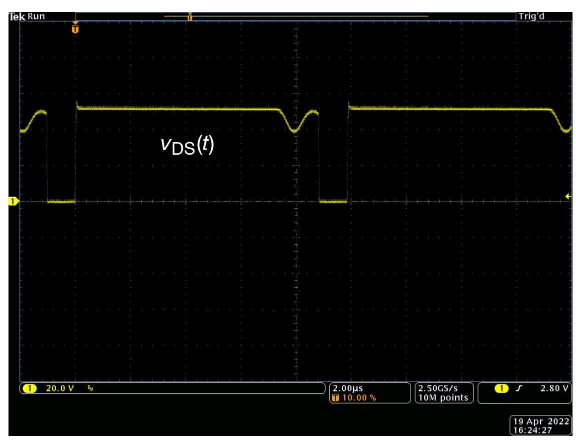

Figure 28. V_{IN} = 25 V, I_{OUT} = 0.5 A

Loop gain Bode plots:

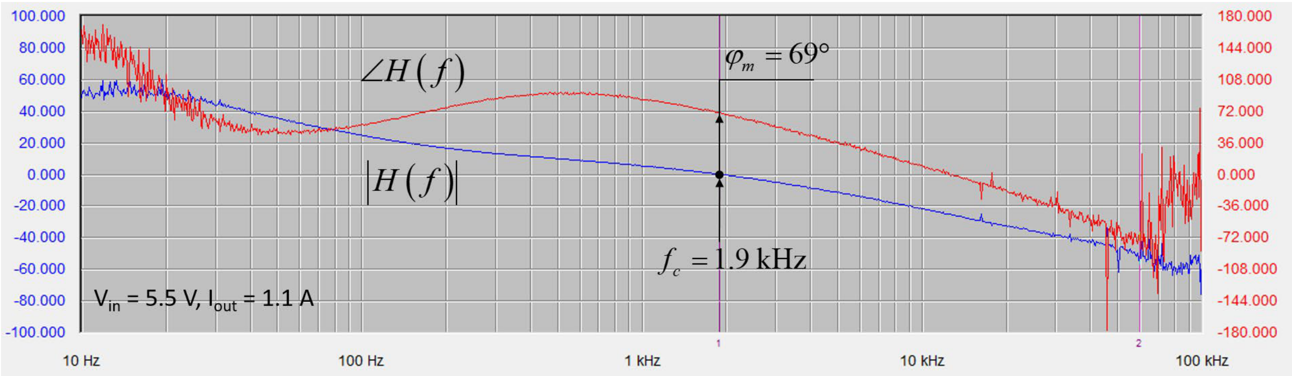

Figure 29. This is the Loop Gain when Probes across Test Points A and B. V_{in} = 5.5 V, Switch in Position *b*.

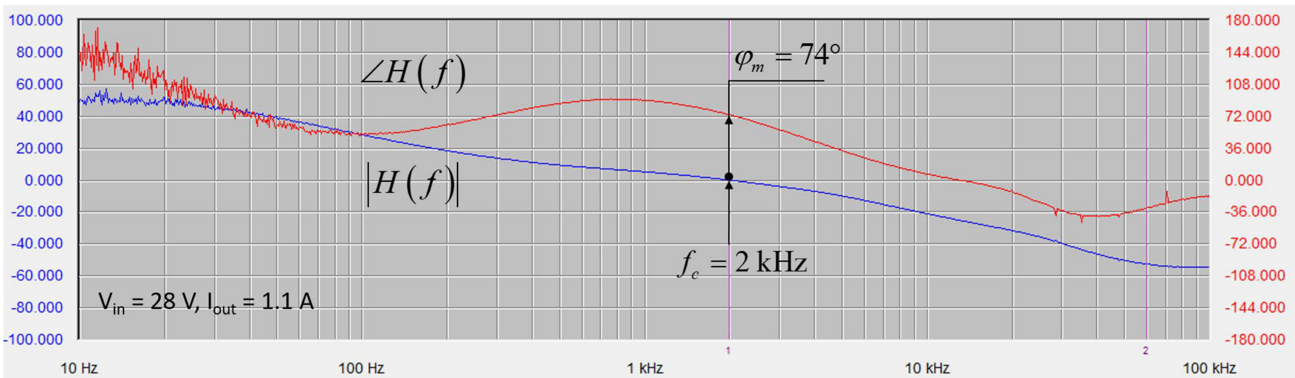

Figure 30. This is the Loop Gain when Probes across Test Points A and B. V_{in} = 28 V, Switch in Position *b*.

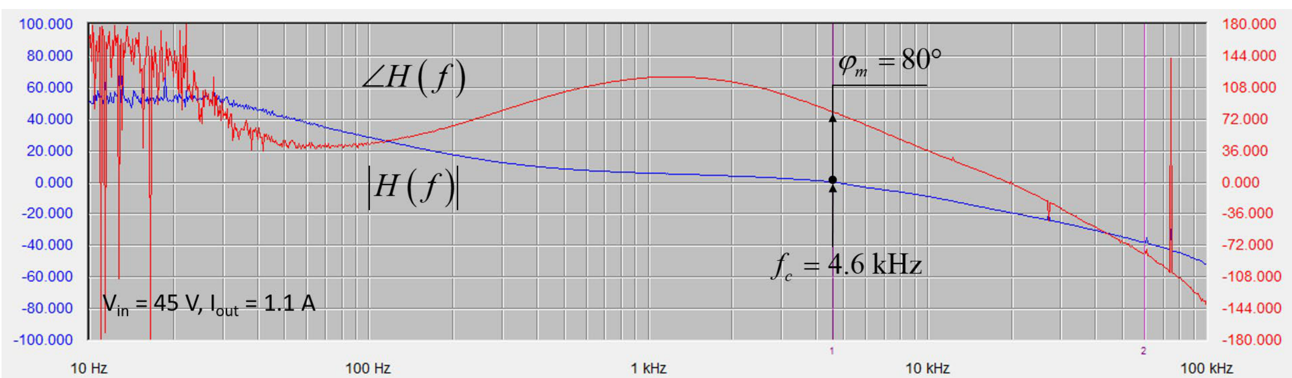

Figure 31. This is the Loop Gain when Probes across Test Points A and B. V_{in} = 45 V, Switch in Position *a*.

Regulation Data

For all regulation measurements, the dummy load 1 kΩ (R19) and Zener diode D5 were removed.

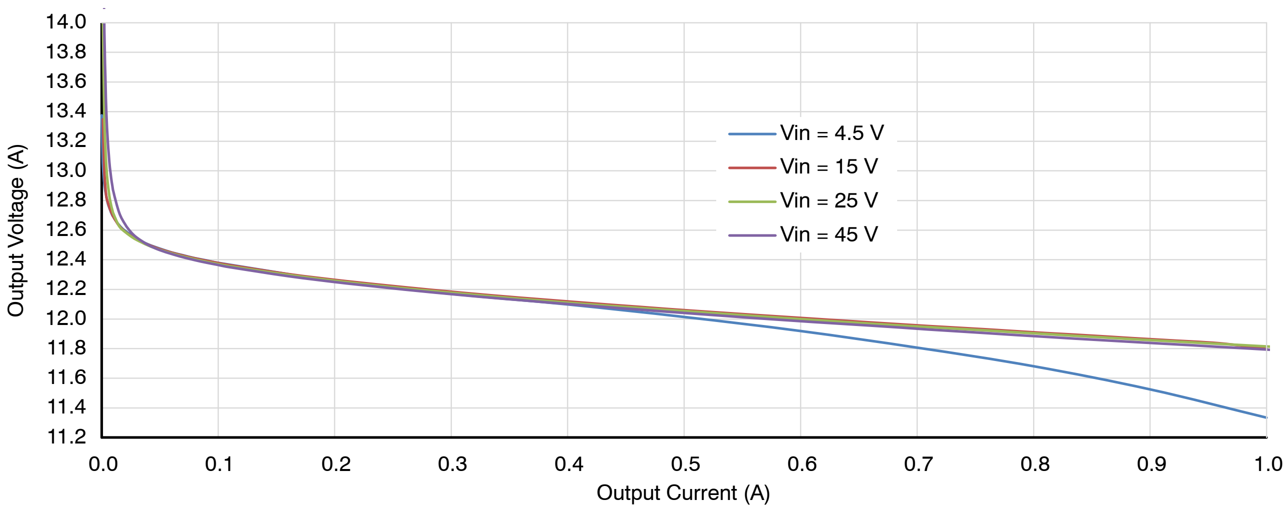

Figure 32. Output Voltage Variation with Load Current when IC is Self−supplied via LDO

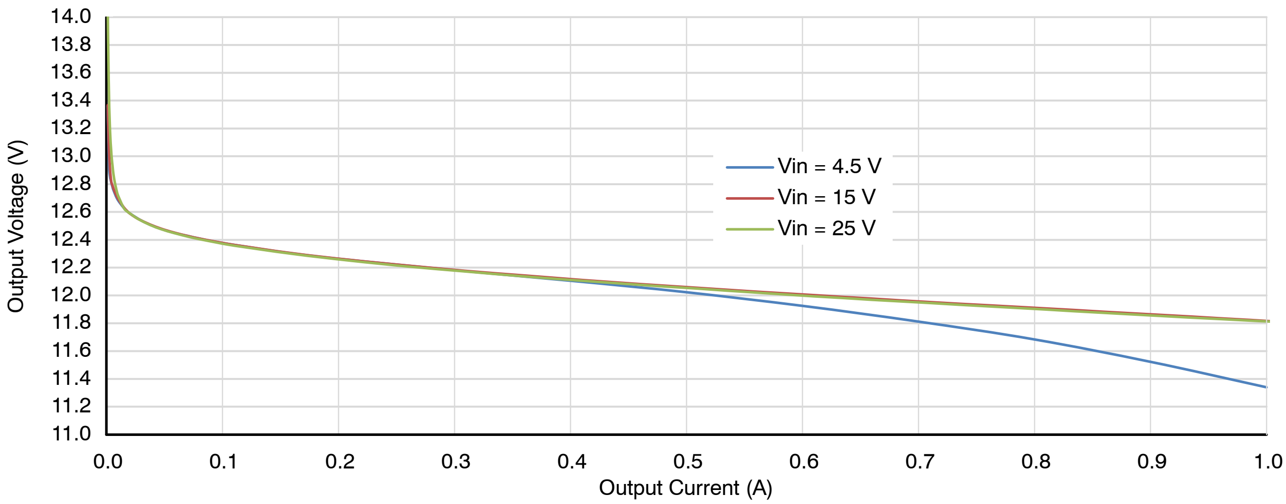

Figure 33. Output Voltage Variation with Load Current when VCC Pin is Connected to VIN Pin

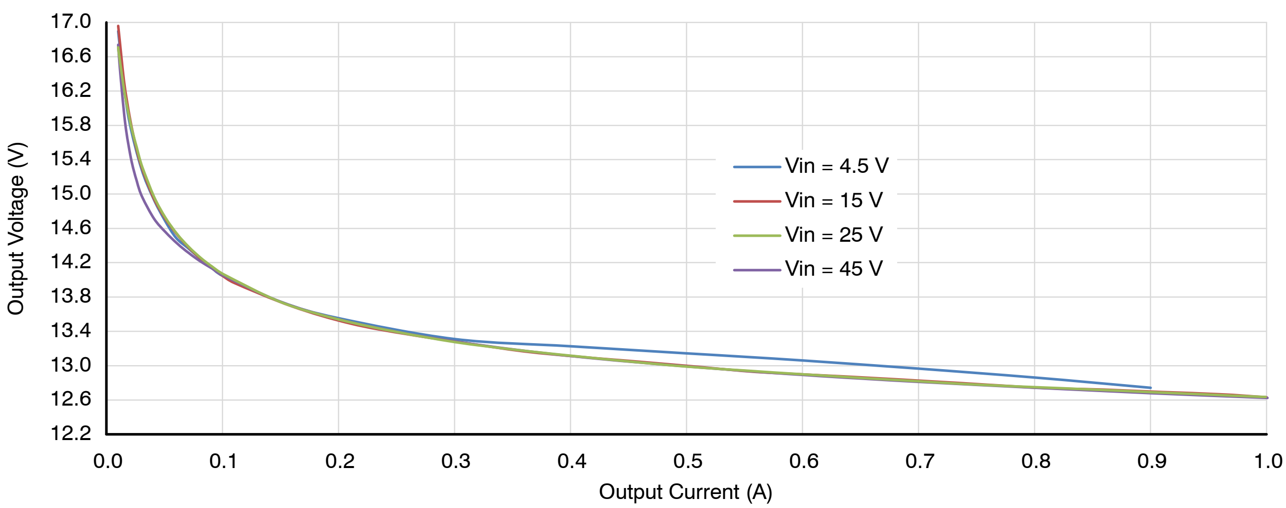

Figure 34. Output Voltage Variation with Load Current when VCC Pin is Connected to AUX Winding

Efficiency Data

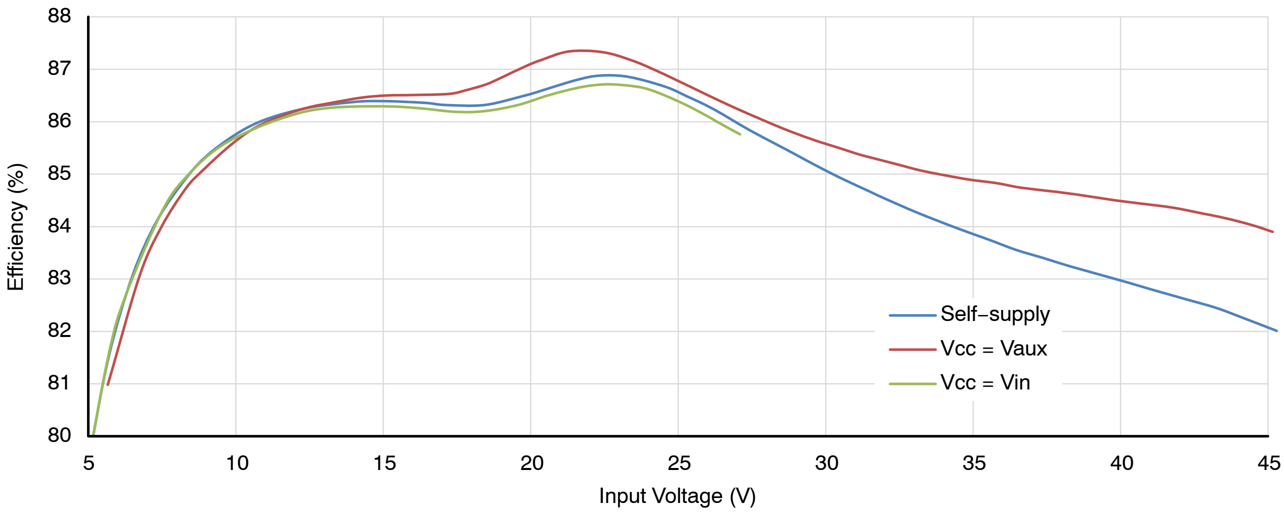

Figure 35. Efficiency vs. Input Voltage for Load Current 1 A

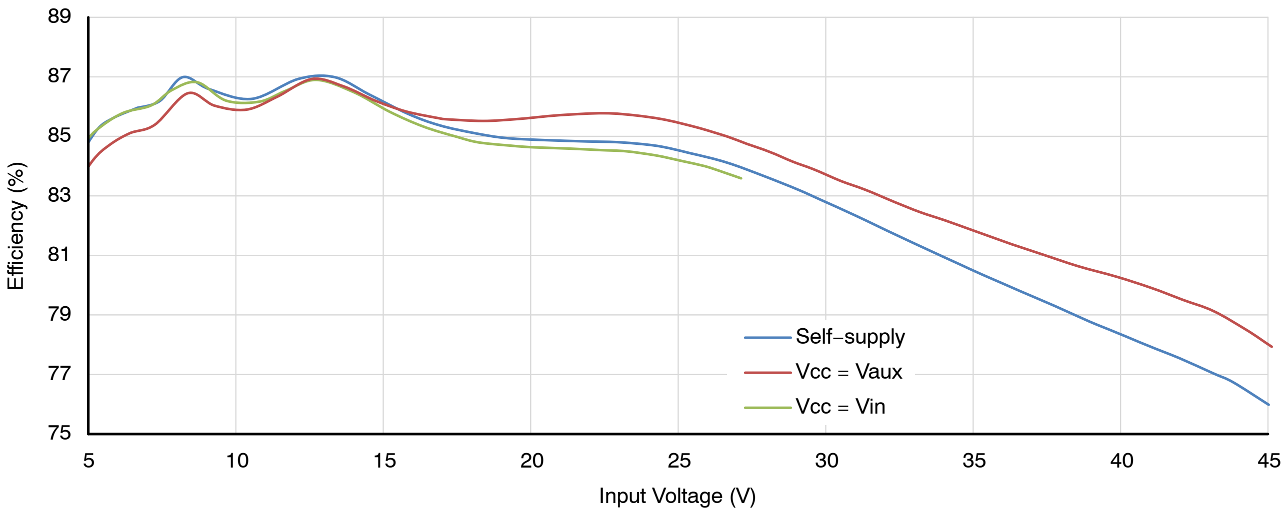

Figure 36. Efficiency vs. Input Voltage for Load Current 0.5 A

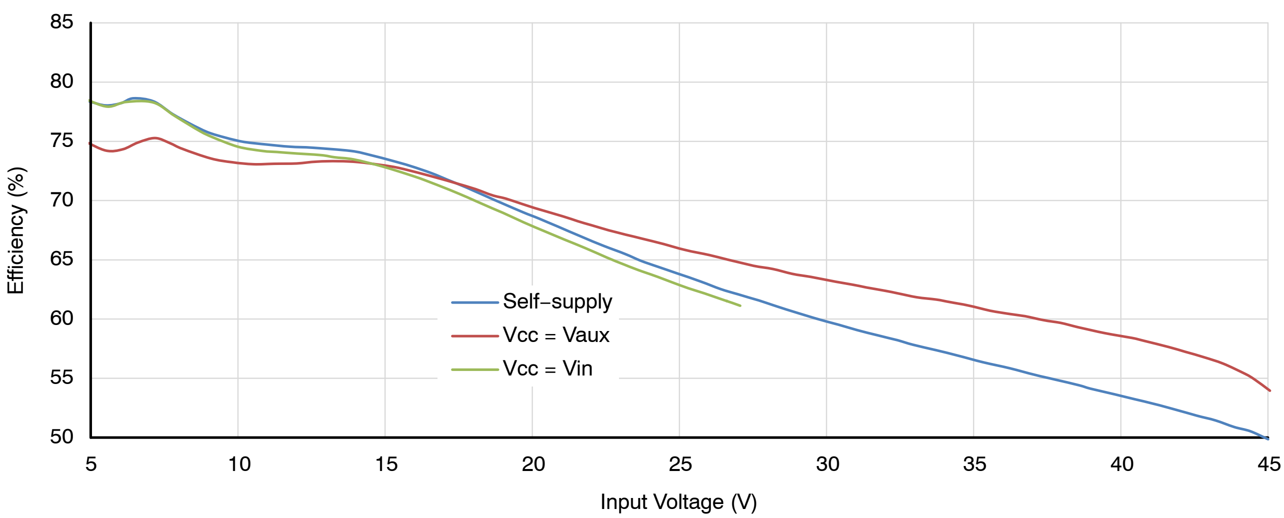

Figure 37. Efficiency vs. Input Voltage for Load Current 0.1 A

Standby Data

For all standby measurements, the dummy load 1 kΩ (R19) and Zener diode D5 were removed.

Table 1. STANDBY INPUT POWER FOR Iout = 1 mA WHEN THE IC IS SELF−SUPPLIED VIA LDO

V_{IN} (V)	I_{IN} (mA)	P_{IN} (mW)	V_{OUT} (V)
4.5	14.7	66.5	13.1
15	6.8	102.6	13.4
25	4.6	114.5	14.1
45	4.0	179.0	15.4

Table 2. STANDBY INPUT POWER FOR Iout = 1 mA WHEN THE VCC PIN IS CONNECTED TO VIN PIN

V_{IN} (V)	I_{IN} (mA)	P_{IN} (mW)	V_{OUT} (V)
4.5	14.9	67.3	13.0
15	7.0	104.3	13.4
25	4.6	115.0	15.4

Table 3. STANDBY INPUT POWER FOR Iout = 1 mA WHEN THE IC IS SELF−SUPPLIED VIA LDO

V_{IN} (V)	I_{IN} (mA)	P_{IN} (mW)	V_{OUT} (V)
4.5	107.9	485.4	15.8
15	38.9	585.3	15.9
25	28.3	708.5	15.9
45	20.3	914.4	15.5

Table 4. BILL OF MATERIALS

Designator (Main Board)	Qty	Description	Value	Toler-ance	Footprint	Manufac-turer	Manufacturer Part Number
C1	1	Ceramic capacitor	10 nF / 100 V	20%	0805	Generic	
C2	1	Ceramic capacitor	22 pF / 10 V	10%	0805	Generic	
C3	1	Ceramic capacitor	4.7 µF / 50 V	10%	1206	TDK	CGA5L3X7R1H475K160AB
C4	1	Ceramic capacitor	10 nF / 10 V	10%	0805	Generic	
C5, C13, C14	3	Electrolytic Capacitor	330 µF / 16 V	20%	TH	Rubycon	16ZLG330MEFC8X11.5
C6	1	Ceramic capacitor	22 nF / 10 V	10%	0805	Generic	
C7, C8	2	Ceramic capacitor	0.1 µF / 50 V	20%	0805	Generic	
C9	1	Electrolytic Capacitor	100 µF / 50 V	20%	TH	Rubycon	50ZL100MEFC8X11.5
C10, C11	2	Ceramic capacitor	2.2 µF / 100 V	20%	1210	Kemet	C1210C225M1RACTU
C12	1	Ceramic capacitor	0.47 µF / 50 V	20%	0805	Generic	
C15	1	Ceramic capacitor	4.7 nF / 16 V	10%	0805	Generic	
C16	1	Ceramic capacitor	330 pF / 16 V	10%	0805	Generic	
C17	1	Ceramic capacitor	470 pF / 100 V	10%	0805	Generic	
C18	1	Ceramic capacitor	3.3 nF / 630 V	10%	1206	Kemet	C1206C332KBRACTU
C19	1	Ceramic capacitor	470 pF / 50V	20%	0805	Generic	
D1	1	HV diode	1N4937	–	DO−41	**onsemi**	1N4937G
D2	1	power diode	FSV10120V	–	TO−277	**onsemi**	FSV10120V
D3	1	signal diode	MMSD914	–	SOD−123	**onsemi**	SMMSD914
D4	1	signal diode	BAV21	–	SOD−123	**onsemi**	
D5	1	Zener diode 15 V/3 W	1SMB5929BT3G	5%	SMB−2	**onsemi**	1SMB5929BT3G
J1a, J2a	2	Banana plug	–	–	–	multicomp	24.243.1
J1b, J2b	2	Banana plug	–	–	–	multicomp	24.243.2
L3	1	Inductor	1.5 µH	30%	–	Coilcraft	MSS1038−152NL
R1	1	Resistor	18 kΩ	1%	2512	Generic	
R2, R13	2	Resistor	40 mΩ	1%	2512	Vishay	WSL2512R0400FEA
R3	1	Resistor	845 Ω	1%	0805	Generic	
R4	1	Resistor	1.5 kΩ	1%	0805	Generic	
R5	1	Resistor	68 kΩ	1%	0805	Generic	
R6, R8, R17	3	Resistor	10 kΩ	1%	0805	Generic	
R7, R11	2	Resistor	133 kΩ	1%	0805	Generic	
R9	1	Resistor	38.3 kΩ	1%	0805	Generic	
R10, R16	2	Resistor	10 Ω	1%	0805	Generic	
R12, R14	2	Resistor	100 Ω / 0.5 W	1%	0805	Generic	
R15	1	Resistor	0 Ω	1%	0805	Generic	
R18, R21	2	Resistor	47 Ω	1%	0805	Generic	
R19	1	Resistor	1 kΩ	1%	2512	Generic	
R20	1	Resistor	2.2 Ω	1%	0805	Generic	
SW1	1	PCB Switch	–	–	–	multicomp	MCNDS−02V
T1	1	Transformer	ZA9654−AE	–	–	Coilcraft	ZA9654−AE
Q1	1	N−channel MOSFET	FDMS86103L	–	PQFN−8	**onsemi**	FDMS86103L
U1	1	PWM Controller	NCV12711	–	MSOP−10	**onsemi**	NCV12711A

NOTE: Ceramic capacitor are X7R type unless stated otherwise.
NOTE: TH = through hole part.
NOTE: All parts are lead free.

ADDITIONAL INFORMATION

TECHNICAL PUBLICATIONS:
Technical Library: www.onsemi.com/design/resources/technical−documentation
onsemi Website: www.onsemi.com

ONLINE SUPPORT: www.onsemi.com/support
For additional information, please contact your local Sales Representative at www.onsemi.com/support/sales