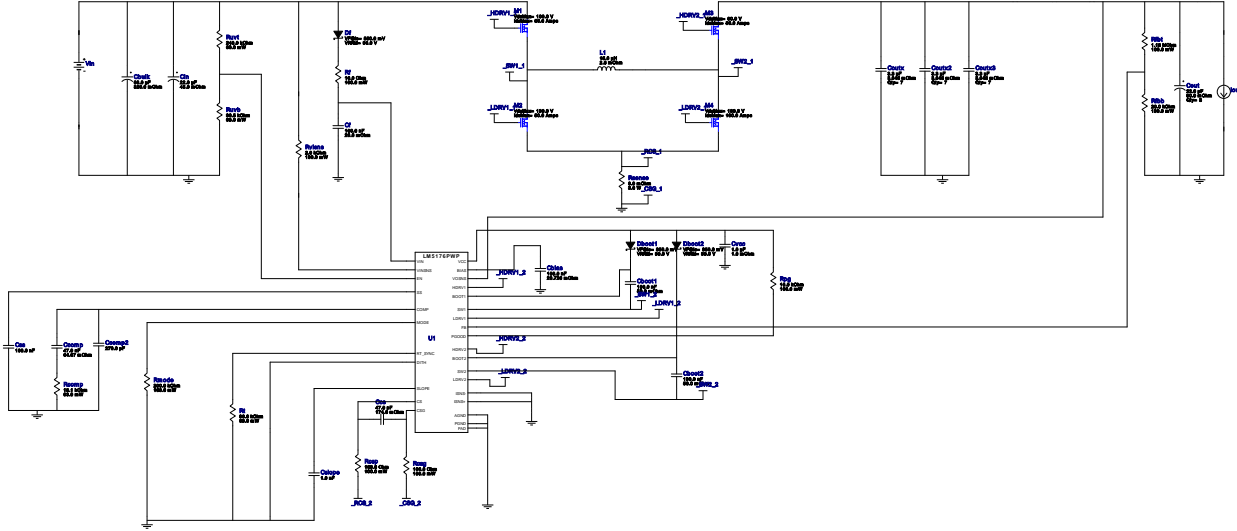
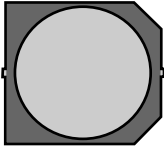


















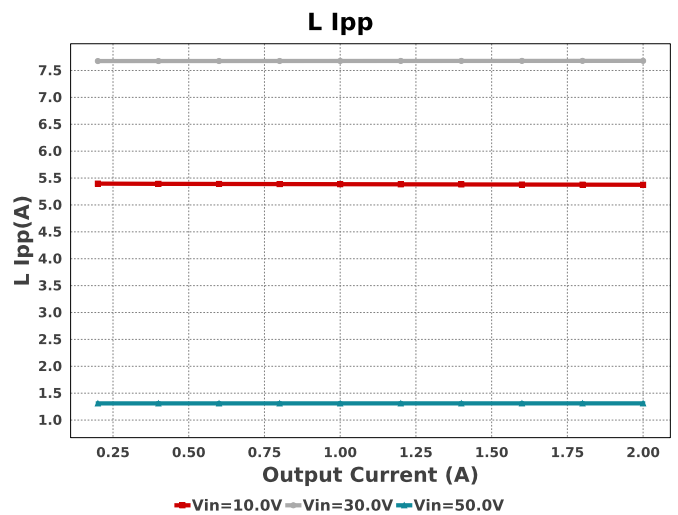
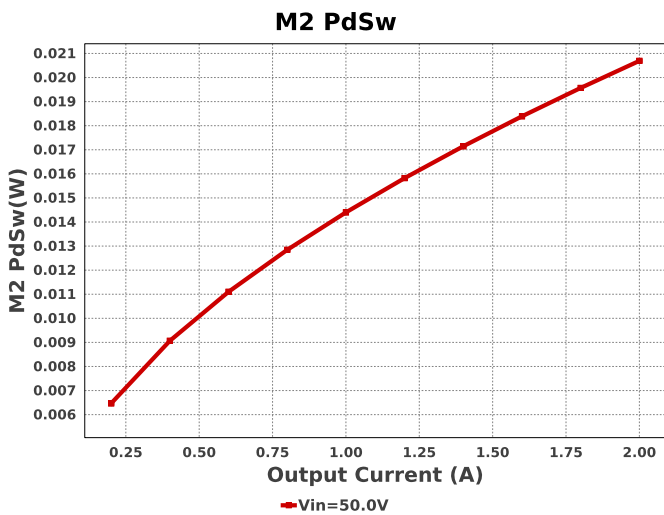
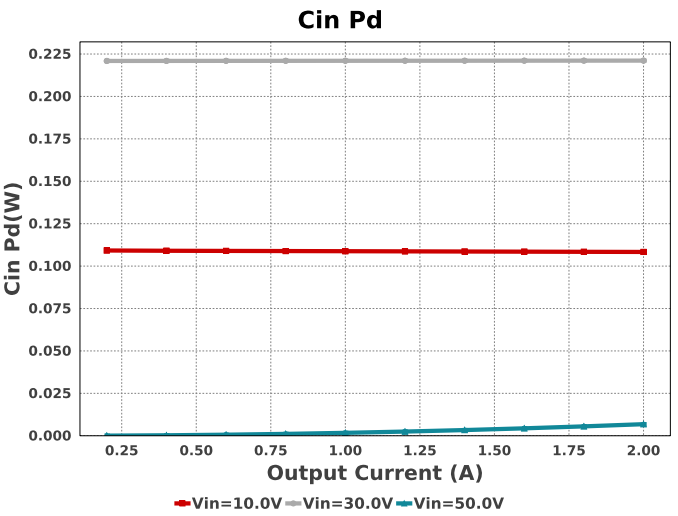
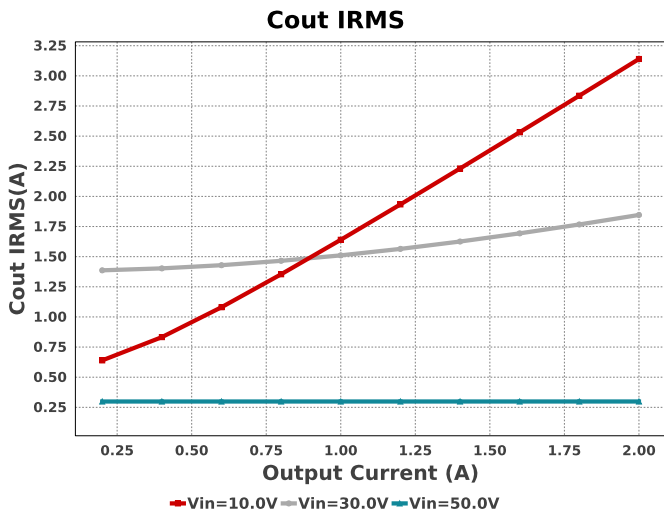
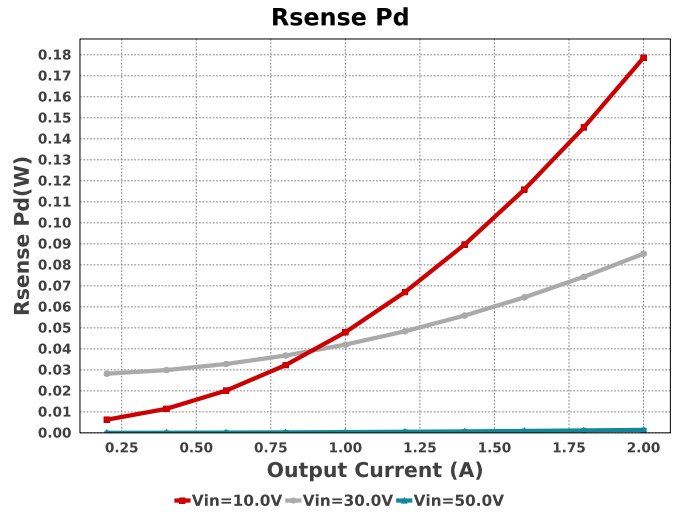
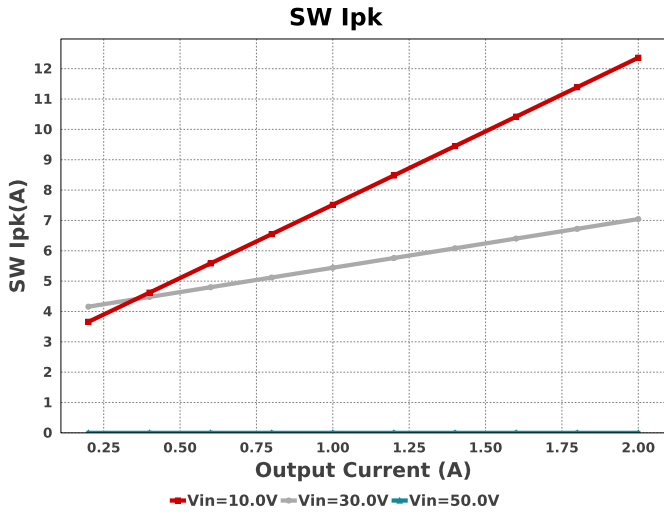
WEBENCH® Design Report

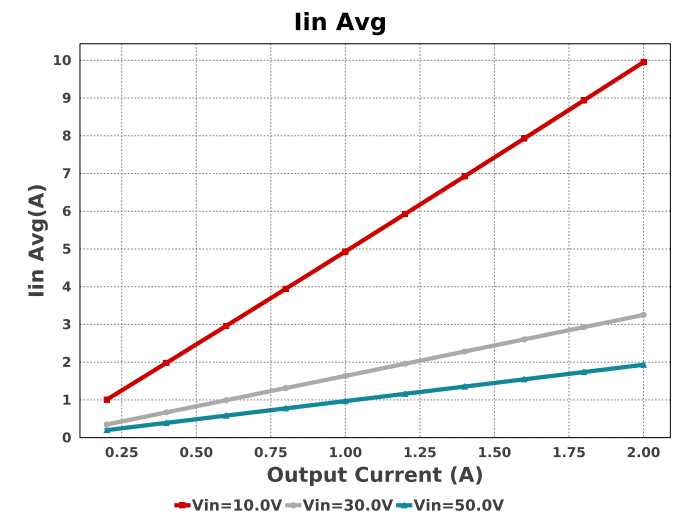
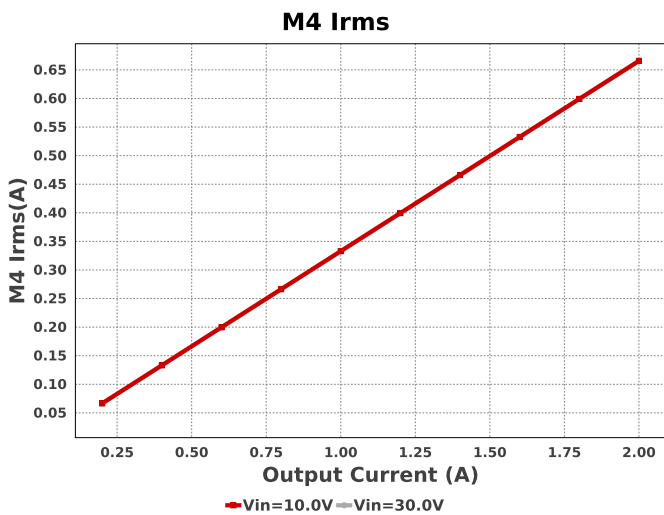
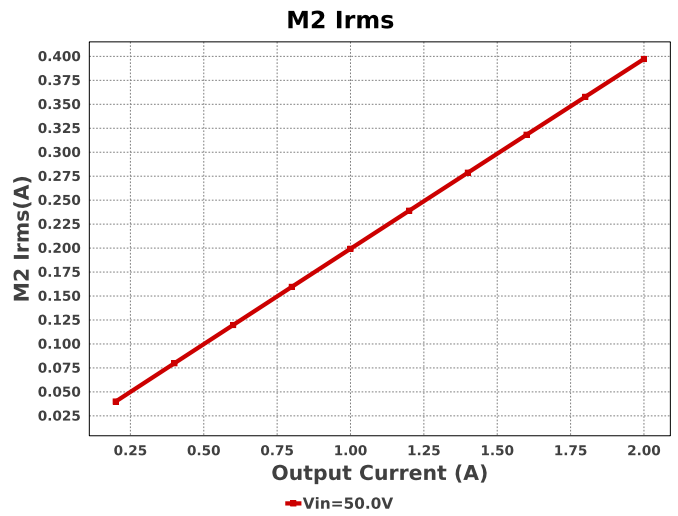
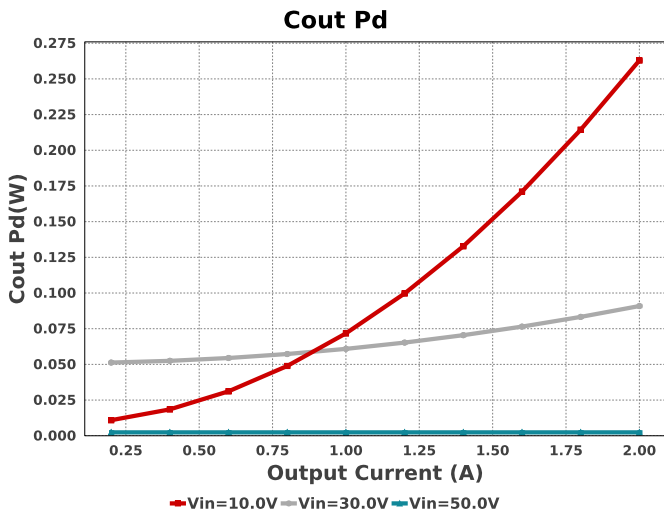
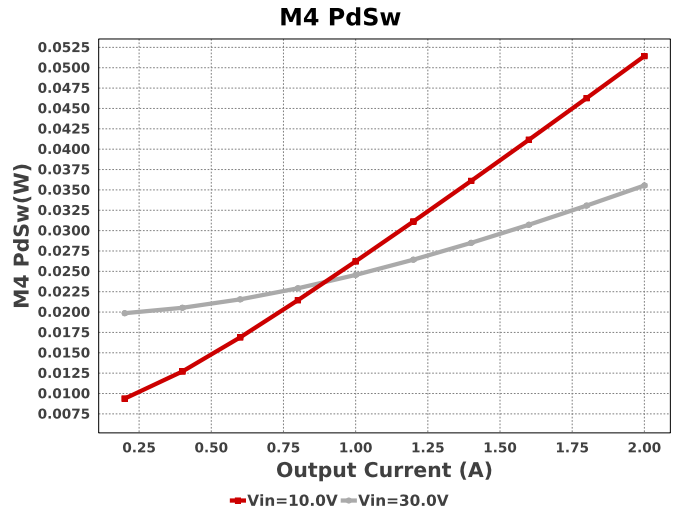
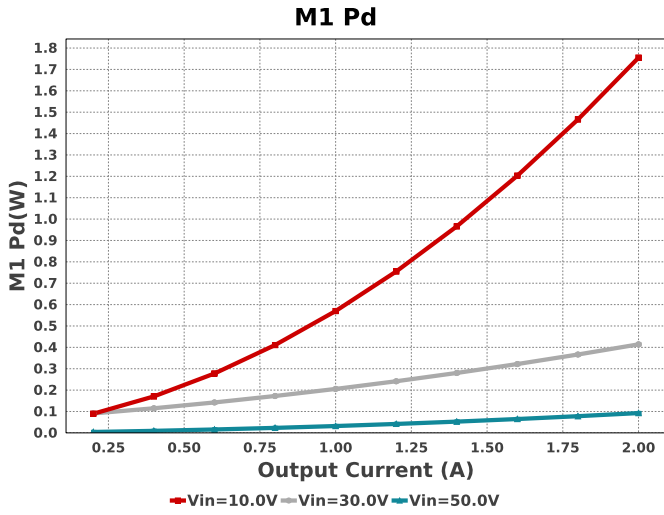
 Design : 30 LM5176PWPR
 LM5176PWPR 10V-50V to 48.00V @ 2A

Electrical BOM

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cbias	TDK	C2012X7R2A104K125AA Series= X7R	Cap= 100.0 nF ESR= 20.726 mOhm VDC= 100.0 V IRMS= 1.456 A	1	\$0.03	0805 7 mm ²
Cboot1	AVX	06033C104KAT2A Series= X7R	Cap= 100.0 nF ESR= 50.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	\$0.01	0603 5 mm ²
Cboot2	AVX	06033C104KAT2A Series= X7R	Cap= 100.0 nF ESR= 50.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	\$0.01	0603 5 mm ²
Cbulk	Panasonic	EEV-FK1K680Q Series= FK	Cap= 68.0 uF ESR= 320.0 mOhm VDC= 80.0 V IRMS= 500.0 mA	1	\$0.91	 SM_RADIAL_H13 264 mm ²
Ccomp	TDK	CGA2B3X7R1H473K050BB Series= X7R	Cap= 47.0 nF ESR= 64.07 mOhm VDC= 50.0 V IRMS= 646.12 mA	1	\$0.01	0402 3 mm ²
Ccomp2	Samsung Electro-Mechanics	CL21C271JBANNNC Series= C0G/NP0	Cap= 270.0 pF VDC= 50.0 V IRMS= 0.0 A	1	\$0.01	0805 7 mm ²
Ccs	AVX	06035A470JAT2A Series= C0G/NP0	Cap= 47.0 pF ESR= 174.0 mOhm VDC= 50.0 V IRMS= 0.0 A	1	\$0.01	0603 5 mm ²
Cf	TDK	CGA3E2X7R1H104K080AA Series= X7R	Cap= 100.0 nF ESR= 29.6 mOhm VDC= 50.0 V IRMS= 971.99 mA	1	\$0.01	0603 5 mm ²

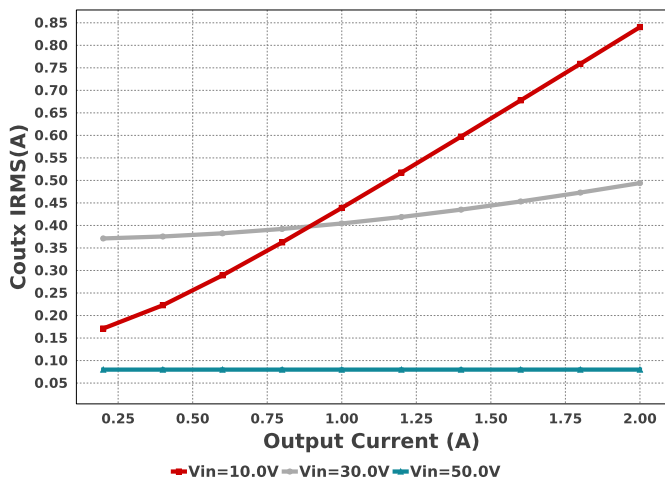
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cin	Panasonic	EEHZA1K220P Series= ZA	Cap= 22.0 uF ESR= 45.0 mOhm VDC= 80.0 V IRMS= 1.55 A	1	\$1.31	 SM_RADIAL_8MM 113 mm ²
Cout	Panasonic	EEHZA1J220XP Series= ZA	Cap= 22.0 uF ESR= 80.0 mOhm VDC= 63.0 V IRMS= 1.5 A	3	\$0.88	 SM_RADIAL_6.3BMM 80 mm ²
Coutx	TDK	C3216X7S2A335M160AB Series= X7S	Cap= 3.3 uF ESR= 3.048 mOhm VDC= 100.0 V IRMS= 4.157 A	7	\$0.38	 1206_190 11 mm ²
Coutx2	TDK	C3216X7S2A335M160AB Series= X7S	Cap= 3.3 uF ESR= 3.048 mOhm VDC= 100.0 V IRMS= 4.157 A	7	\$0.38	 1206_190 11 mm ²
Coutx3	TDK	C3216X7S2A335M160AB Series= X7S	Cap= 3.3 uF ESR= 3.048 mOhm VDC= 100.0 V IRMS= 4.157 A	7	\$0.38	 1206_190 11 mm ²
Cslope	MuRata	GRM1885C1H102JA01J Series= C0G/NP0	Cap= 1.0 nF VDC= 50.0 V IRMS= 0.0 A	1	\$0.01	 0603 5 mm ²
Css	AVX	08053C104JAZ2A Series= X7R	Cap= 100.0 nF VDC= 25.0 V IRMS= 0.0 A	1	\$0.07	 0805 7 mm ²
Cvcc	Taiyo Yuden	EMK107B7105KA-T Series= X7R	Cap= 1.0 uF ESR= 1.0 mOhm VDC= 16.0 V IRMS= 0.0 A	1	\$0.01	 0603 5 mm ²
Dboot1	SMC Diode Solutions	SK19TR	VF@Io= 850.0 mV VRRM= 90.0 V	1	\$0.06	 SMB 44 mm ²
Dboot2	SMC Diode Solutions	SK19TR	VF@Io= 850.0 mV VRRM= 90.0 V	1	\$0.06	 SMB 44 mm ²
Df	SMC Diode Solutions	SK19TR	VF@Io= 850.0 mV VRRM= 90.0 V	1	\$0.06	 SMB 44 mm ²
L1	Coilcraft	SER2918H-153KL	L= 15.0 uH 2.6 mOhm	1	\$2.65	 SER2918H 652 mm ²
M1	Texas Instruments	CSD19534Q5A	VdsMax= 100.0 V IdsMax= 50.0 Amps	1	\$0.28	 TRANS_NexFET_Q5A 55 mm ²
M2	Texas Instruments	CSD19534Q5A	VdsMax= 100.0 V IdsMax= 50.0 Amps	1	\$0.28	 TRANS_NexFET_Q5A 55 mm ²

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
M3	Texas Instruments	CSD18537NQ5A	VdsMax= 60.0 V IdsMax= 50.0 Amps	1	\$0.24	 TRANS_NexFET_Q5A 55 mm ²
M4	Texas Instruments	CSD19531Q5A	VdsMax= 100.0 V IdsMax= 100.0 Amps	1	\$0.52	 TRANS_NexFET_Q5A 55 mm ²
Rcomp	Vishay-Dale	CRCW040219K1FKED Series= CRCW..e3	Res= 19.1 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm ²
Rcsg	Vishay-Dale	CRCW0603100RFKEA Series= CRCW..e3	Res= 100.0 Ohm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
Rcsp	Vishay-Dale	CRCW0603100RFKEA Series= CRCW..e3	Res= 100.0 Ohm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
Rf	Yageo	RC0603FR-0710RL Series= ?	Res= 10.0 Ohm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
Rfbb	Yageo	RC0603FR-0720KL Series= ?	Res= 20.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
Rfbt	Vishay-Dale	CRCW06031M18FKEA Series= CRCW..e3	Res= 1.18 MOhm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
Rmode	Yageo	RC0603FR-07200KL Series= ?	Res= 200.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
Rpg	Yageo	RC0603FR-0710KL Series= ?	Res= 10.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
Rsense	Vishay-Dale	WSR39L000FEA Series= WSR	Res= 9.0 mOhm Power= 3.0 W Tolerance= 1.0%	1	\$0.72	 4527 122 mm ²
Rt	Yageo	AC0402FR-0786K6L Series= ?	Res= 86.6 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm ²
Ruvb	Yageo	AC0402FR-0736K5L Series= ?	Res= 36.5 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm ²
Ruvt	Vishay-Dale	CRCW0402249KFKED Series= CRCW..e3	Res= 249.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm ²
Rvisns	Vishay-Dale	CRCW06032K00FKEA Series= CRCW..e3	Res= 2.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm ²
U1	Texas Instruments	LM5176PWPR	Switcher	1	\$2.90	 PWP0028C_N 98 mm ²

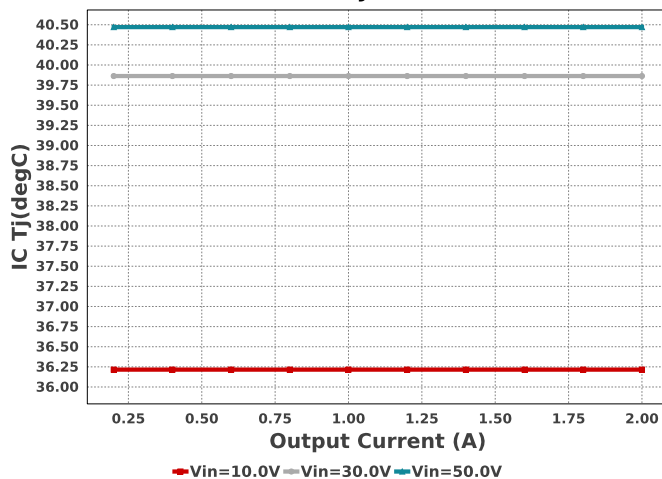




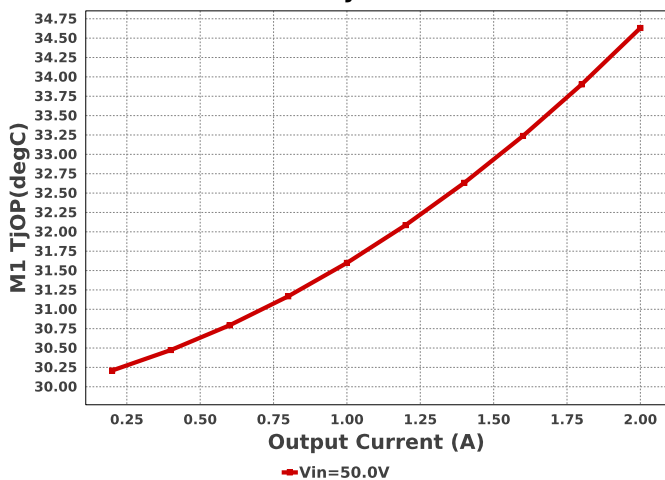
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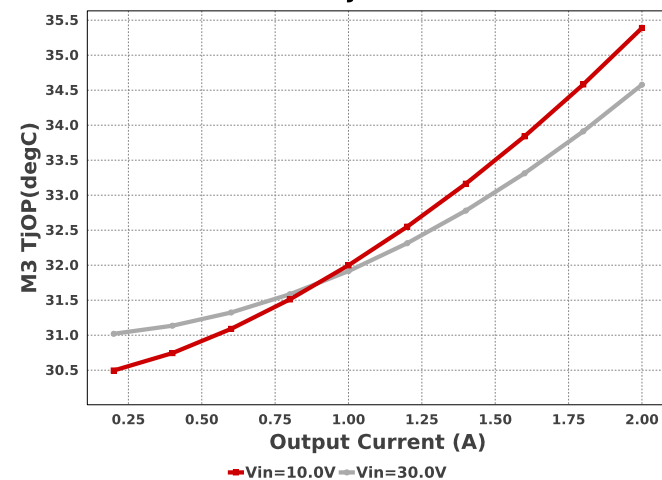
IC Tj



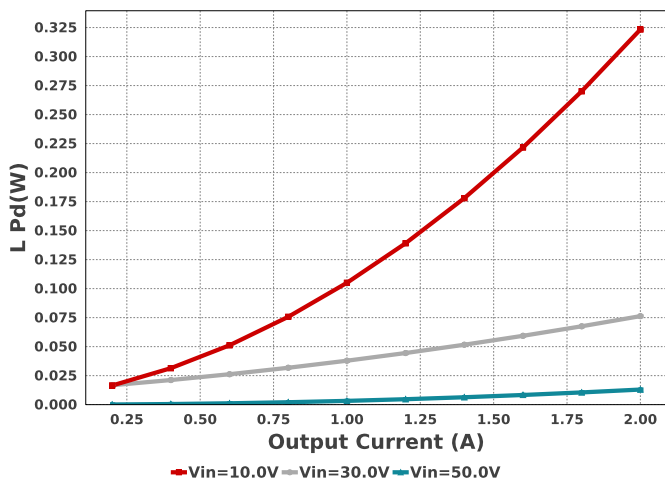
M1 TjOP



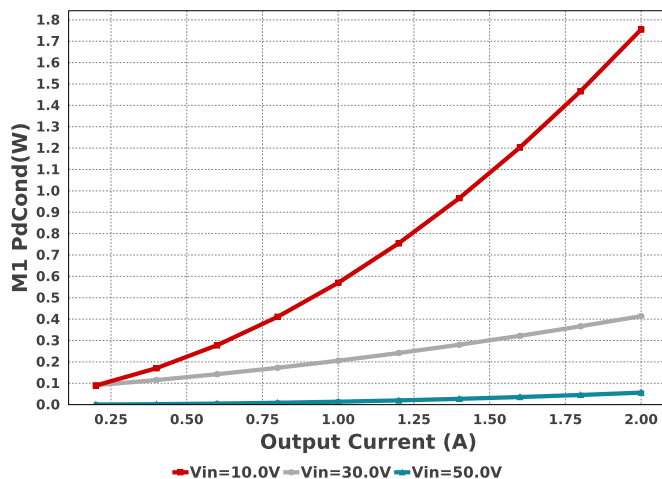
M3 TjOP

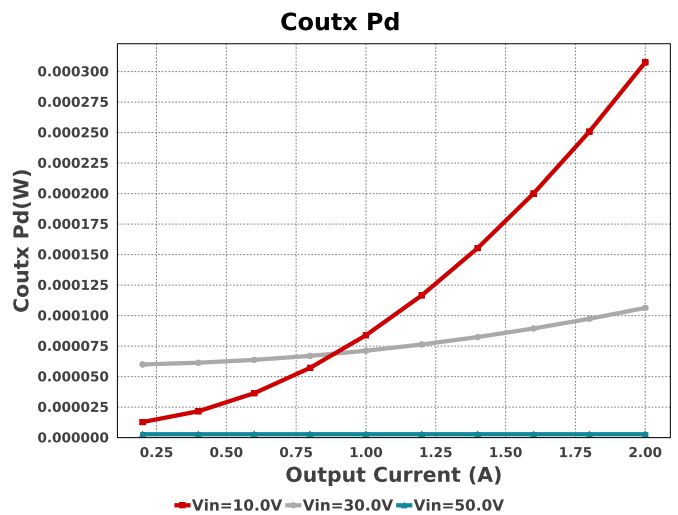
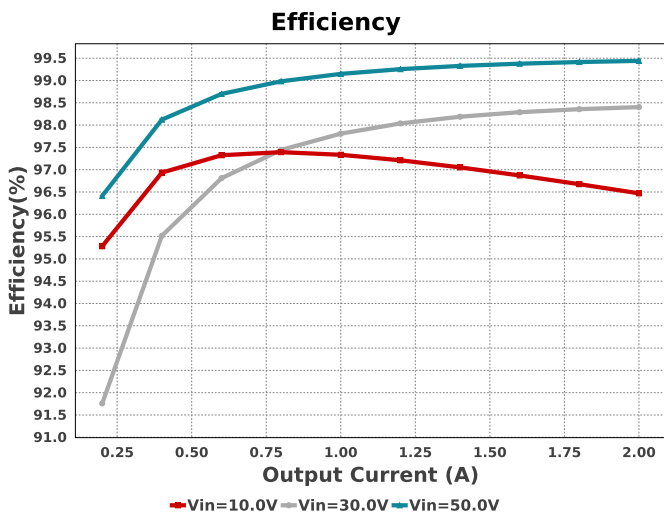
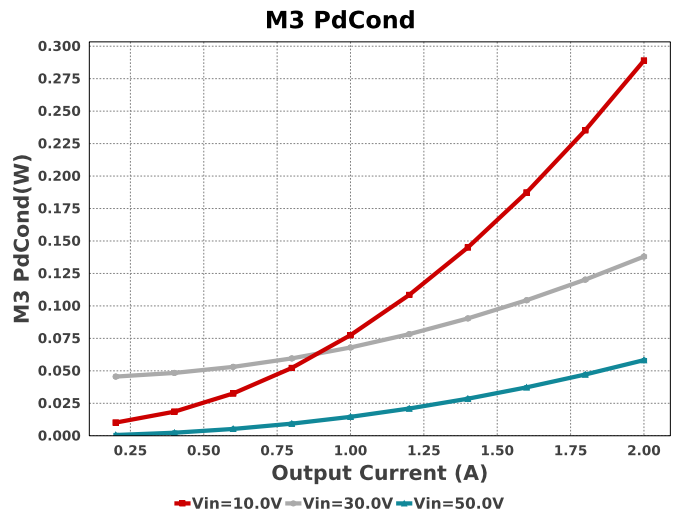
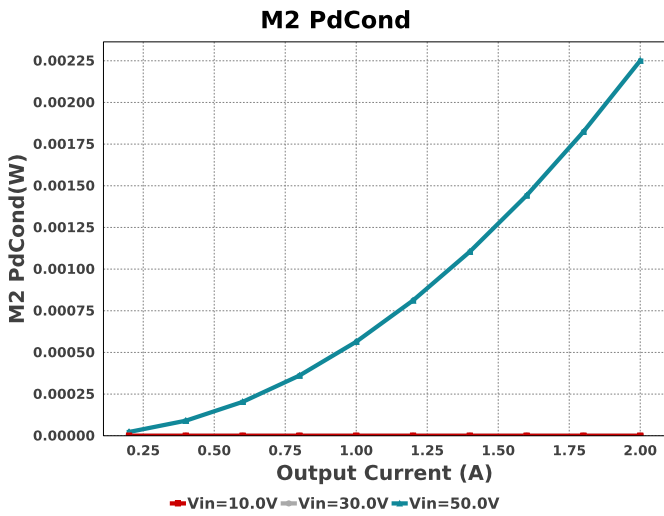
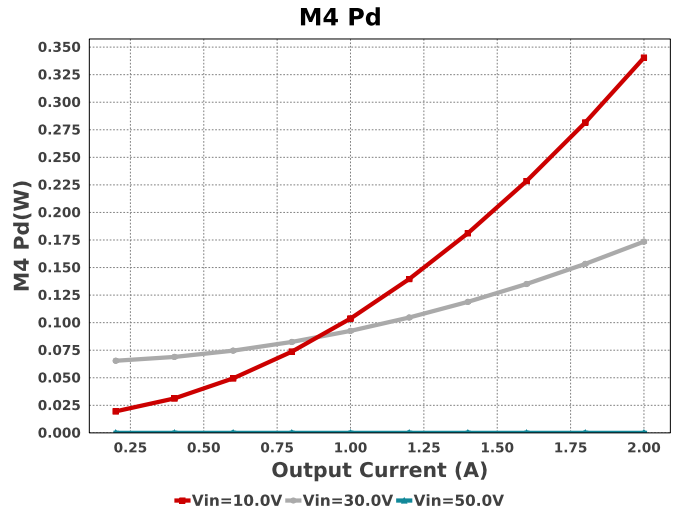
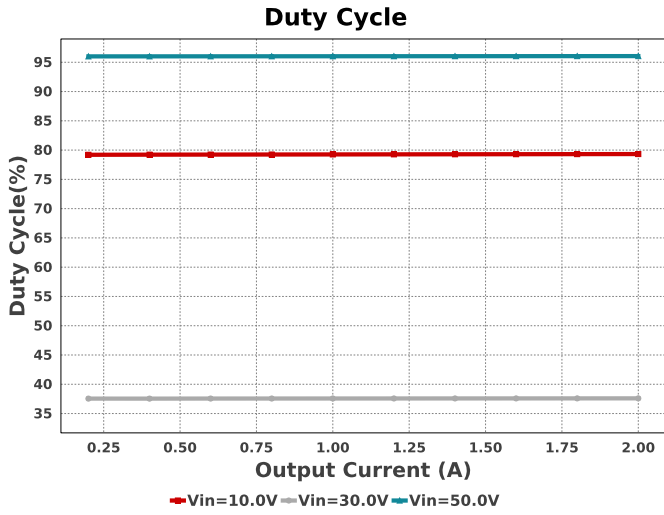


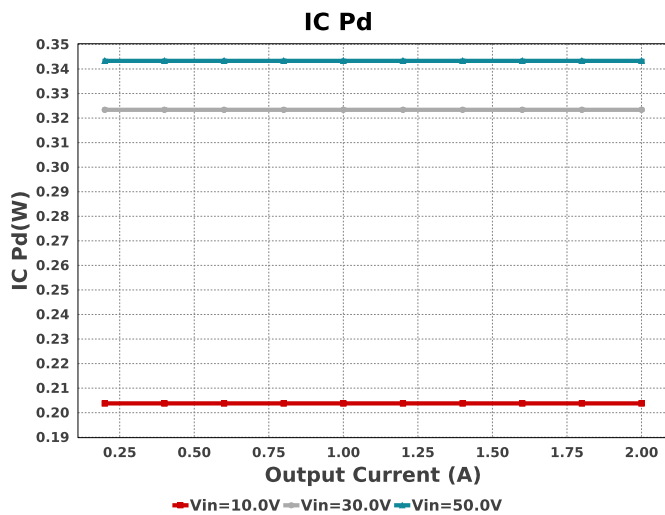
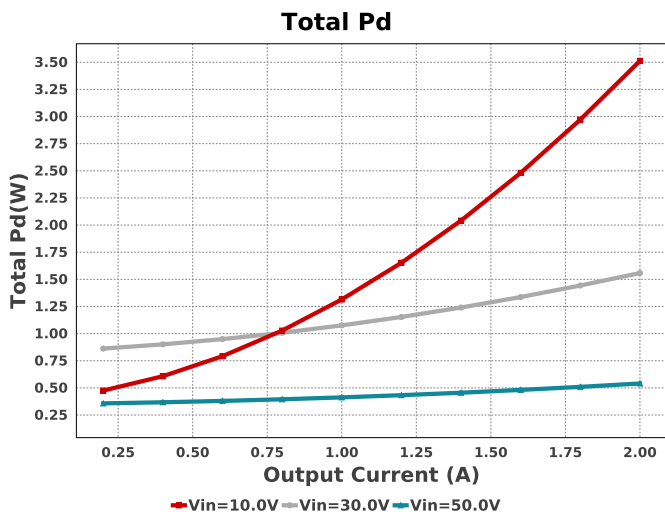
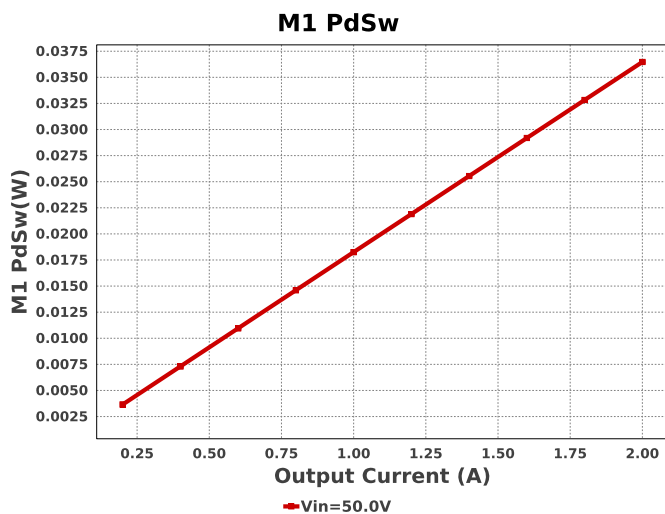
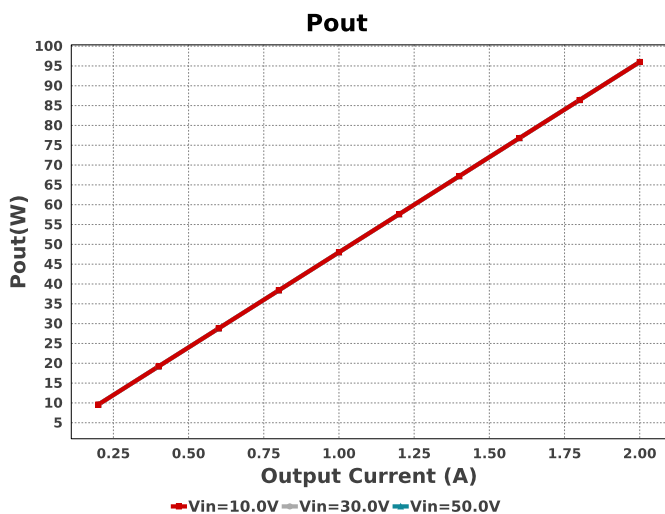
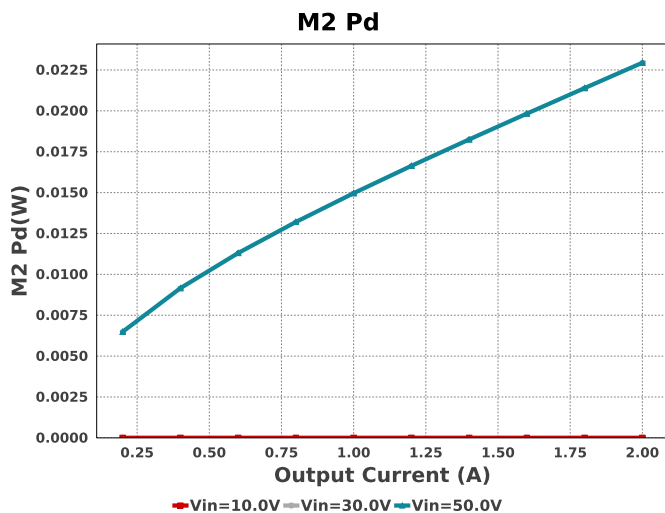
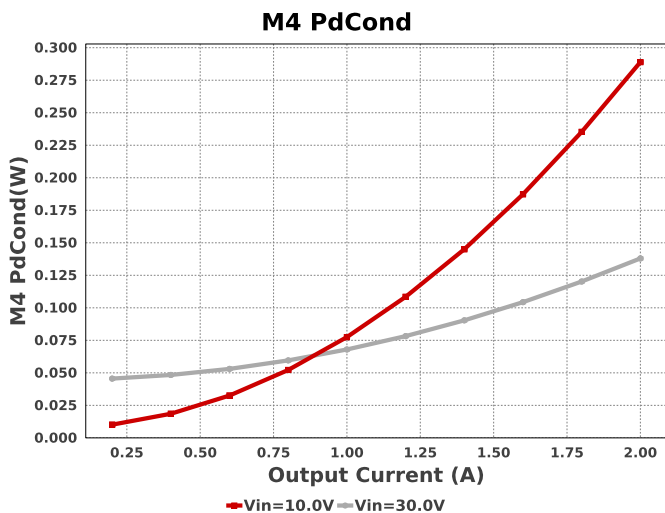
L Pd

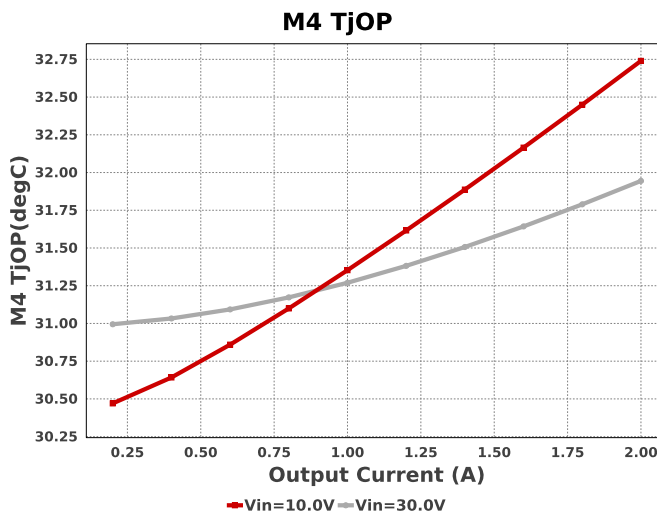
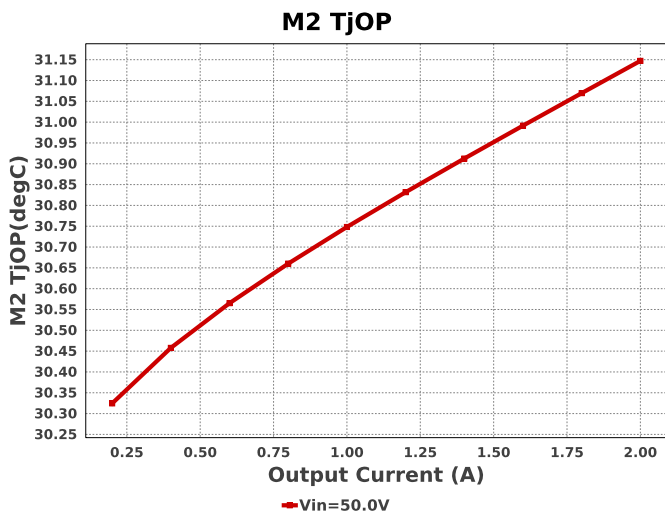
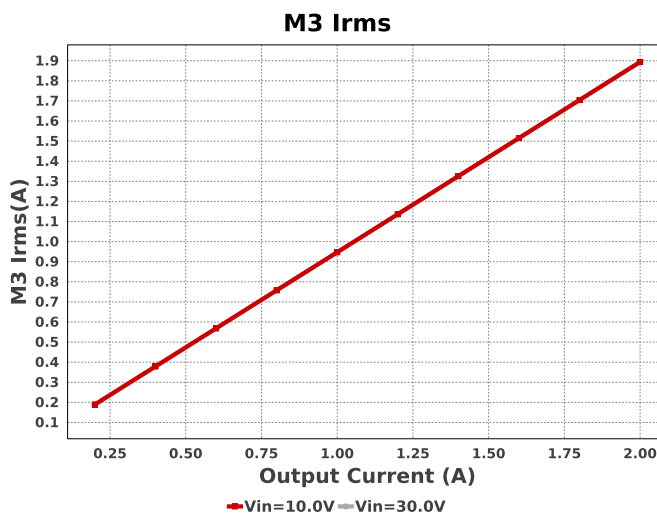
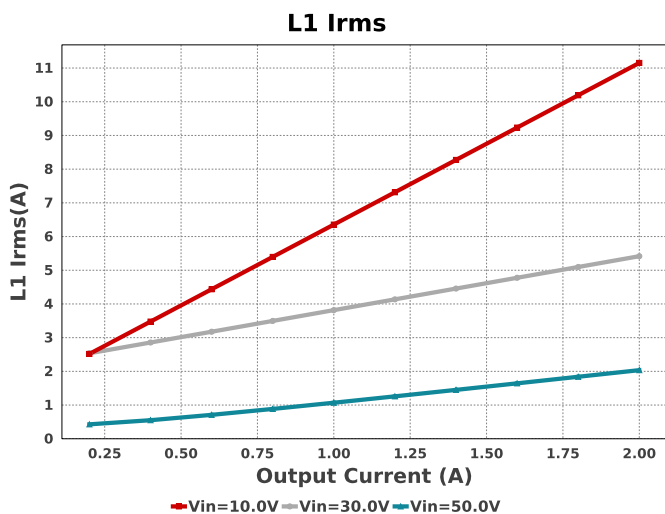
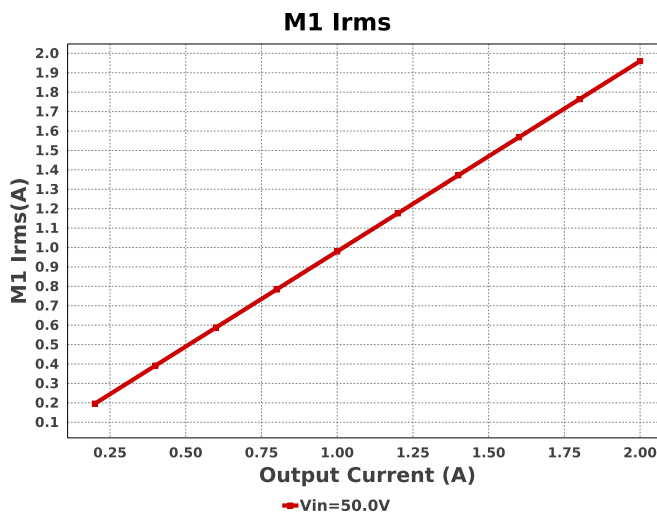
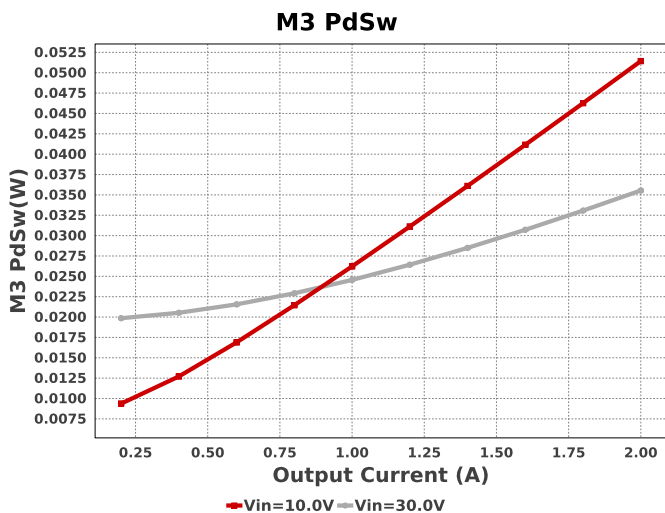


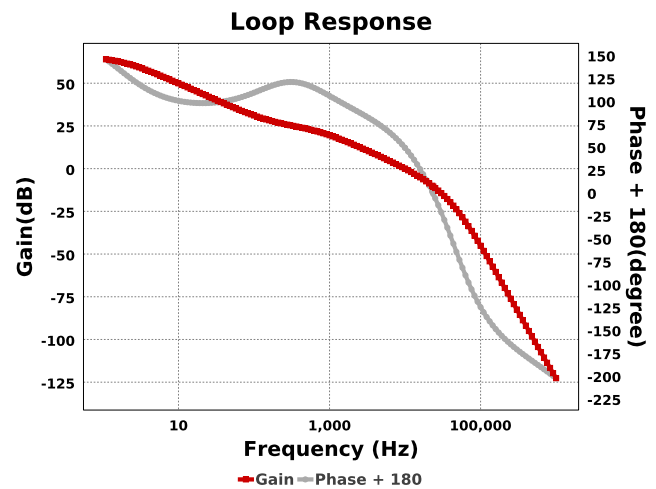
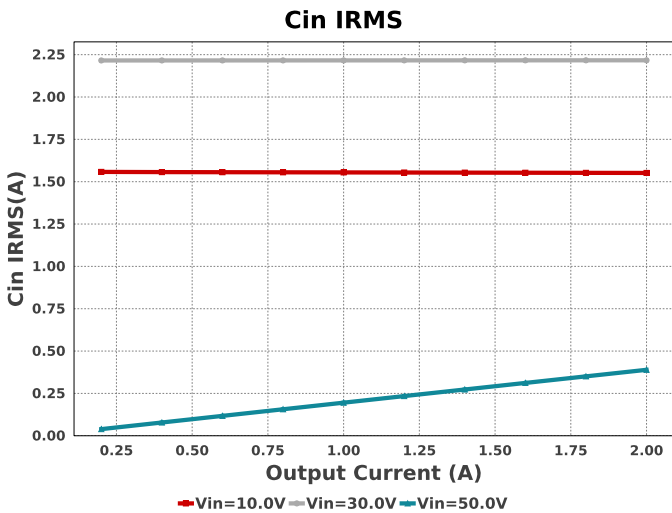
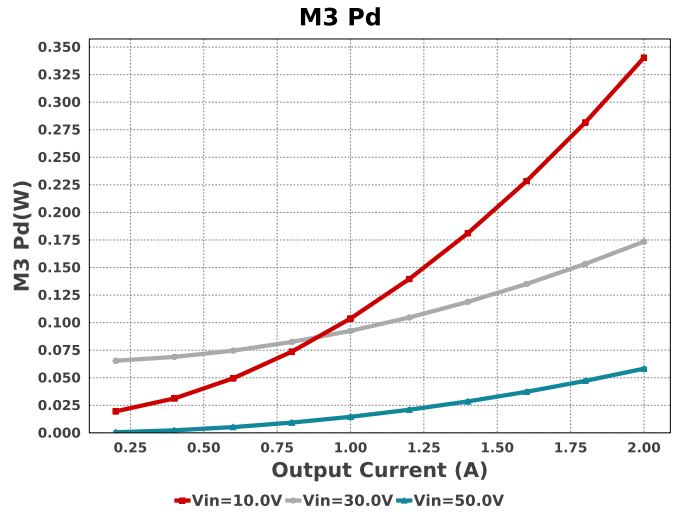
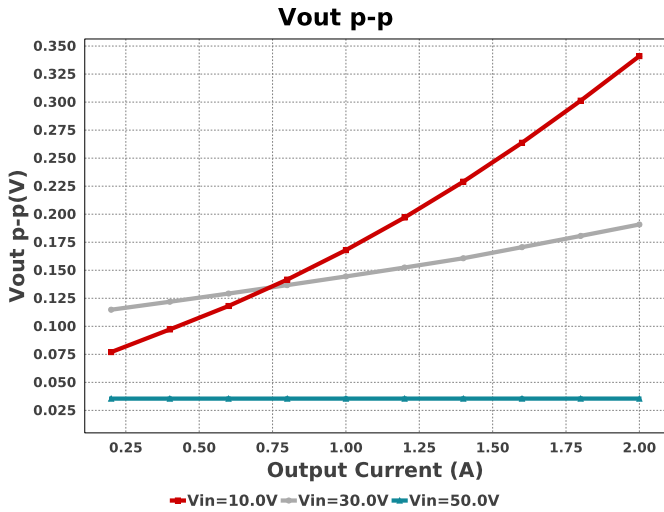
M1 PdCond











Operating Values

#	Name	Value	Category	Description
1.	Cin IRMS	389.353 mA	Capacitor	Input capacitor RMS ripple current
2.	Cin Pd	6.822 mW	Capacitor	Input capacitor power dissipation
3.	Cout IRMS	298.458 mA	Capacitor	Output capacitor RMS ripple current
4.	Cout Pd	2.375 mW	Capacitor	Output capacitor power dissipation
5.	Coutx IRMS	79.966 mA	Capacitor	Output capacitor_x RMS ripple current
6.	Coutx Pd	2.784 μW	Capacitor	Output capacitor_x power loss
7.	IC Pd	343.3 mW	IC	IC power dissipation
8.	IC Tj	40.471 degC	IC	IC junction temperature
9.	IC Tolerance	0.0 V	IC	IC Feedback Tolerance
10.	ICThetaJA	30.5 degC/W	IC	IC junction-to-ambient thermal resistance
11.	Iin Avg	1.931 A	IC	Average input current
12.	L Ipp	1.311 A	Inductor	Peak-to-peak inductor ripple current
13.	L Pd	13.0 mW	Inductor	Inductor power dissipation
14.	L1 Irms	2.035 A	Inductor	Inductor ripple current
15.	M1 Irms	1.96 A	Mosfet	MOSFET RMS ripple current
16.	M1 Pd	92.755 mW	Mosfet	MOSFET power dissipation
17.	M1 PdCond	56.285 mW	Mosfet	M1 MOSFET conduction losses
18.	M1 PdSw	36.47 mW	Mosfet	M1 MOSFET switching losses
19.	M1 Rdson	14.112 mOhm	Mosfet	Drain-Source On-resistance
20.	M1 ThetaJA	50.0 degC/W	Mosfet	MOSFET junction-to-ambient thermal resistance
21.	M1 TjOP	34.638 degC	Mosfet	MOSFET junction temperature
22.	M2 Irms	397.269 mA	Mosfet	MOSFET RMS ripple current
23.	M2 Pd	22.948 mW	Mosfet	MOSFET power dissipation
24.	M2 PdCond	2.256 mW	Mosfet	M2 MOSFET conduction losses
25.	M2 PdSw	20.692 mW	Mosfet	M2 MOSFET switching losses
26.	M2 Rdson	14.112 mOhm	Mosfet	Drain-Source On-resistance
27.	M2 ThetaJA	50.0 degC/W	Mosfet	MOSFET junction-to-ambient thermal resistance
28.	M2 TjOP	31.147 degC	Mosfet	MOSFET junction temperature
29.	M3 Pd	58.24 mW	Mosfet	M3 MOSFET total power dissipation
30.	M3 PdCond	58.24 mW	Mosfet	M3 MOSFET conduction losses
31.	M4 Pd	100.0 pW	Mosfet	M4 MOSFET total power dissipation
32.	Cin Pd	6.822 mW	Power	Input capacitor power dissipation

#	Name	Value	Category	Description
33.	Cout Pd	2.375 mW	Power	Output capacitor power dissipation
34.	Coutx Pd	2.784 μ W	Power	Output capacitor_x power loss
35.	IC Pd	343.3 mW	Power	IC power dissipation
36.	L Pd	13.0 mW	Power	Inductor power dissipation
37.	M1 Pd	92.755 mW	Power	MOSFET power dissipation
38.	M1 PdCond	56.285 mW	Power	M1 MOSFET conduction losses
39.	M1 PdSw	36.47 mW	Power	M1 MOSFET switching losses
40.	M2 Pd	22.948 mW	Power	MOSFET power dissipation
41.	M2 PdCond	2.256 mW	Power	M2 MOSFET conduction losses
42.	M2 PdSw	20.692 mW	Power	M2 MOSFET switching losses
43.	M3 Pd	58.24 mW	Power	M3 MOSFET total power dissipation
44.	M3 PdCond	58.24 mW	Power	M3 MOSFET conduction losses
45.	M4 Pd	100.0 μ W	Power	M4 MOSFET total power dissipation
46.	Rsense Pd	1.42 mW	Power	LED Current Rsns Power Dissipation
47.	Total Pd	540.624 mW	Power	Total Power Dissipation
48.	Rsense Pd	1.42 mW	Resistor	LED Current Rsns Power Dissipation
49.	BOM Count	58	System Information	Total Design BOM count
50.	Cross Freq	9.941 kHz	System Information	Bode plot crossover frequency
51.	Duty Cycle	96.054 %	System Information	Duty cycle
52.	Efficiency	99.44 %	System Information	Steady state efficiency
53.	FootPrint	2.172 k mm ²	System Information	Total Foot Print Area of BOM components
54.	Frequency	97.698 kHz	System Information	Switching frequency
55.	Gain Marg	-10.463 dB	System Information	Bode Plot Gain Margin
56.	Iout	2.0 A	System Information	Iout operating point
57.	Low Freq Gain	63.983 dB	System Information	Gain at 1Hz
58.	Mode	CCM	System Information	Conduction Mode
59.	Operating Topology	Buck	System Information	The current operating topology of the device
60.	Phase Marg	50.662 deg	System Information	Bode Plot Phase Margin
61.	Pout	96.0 W	System Information	Total output power
62.	SW Ipk	0.0 A	System Information	Peak switch current
63.	Total BOM	\$20.92	System Information	Total BOM Cost
64.	Vin	50.0 V	System Information	Vin operating point
65.	Vout	48.0 V	System Information	Operational Output Voltage
66.	Vout Actual	48.0 V	System Information	Vout Actual calculated based on selected voltage divider resistors
67.	Vout Tolerance	1.986 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
68.	Vout p-p	35.505 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	2.0	Maximum Output Current
SoftStart	15.0 ms	Soft Start Time (ms)
VinMax	50.0	Maximum input voltage
VinMin	10.0	Minimum input voltage
Vout	48.0	Output Voltage
base_pn	LM5176	Base Product Number
source	DC	Input Source Type
Ta	30.0	Ambient temperature
UserFsw	300.0 k	Customer Selected Frequency

WEBENCH® Assembly

Component Testing

Some published data on components in datasheets such as Capacitor ESR and Inductor DC resistance is based on conservative values that will guarantee that the components always exceed the specification. For design purposes it is usually better to work with typical values. Since this data is not always available it is a good practice to measure the Capacitance and ESR values of C_{in} and C_{out} , and the inductance and DC resistance of L1 before assembly of the board. Any large discrepancies in values should be electrically simulated in WEBENCH to check for instabilities and thermally simulated in WebTHERM to make sure critical temperatures are not exceeded.

Soldering Component to Board

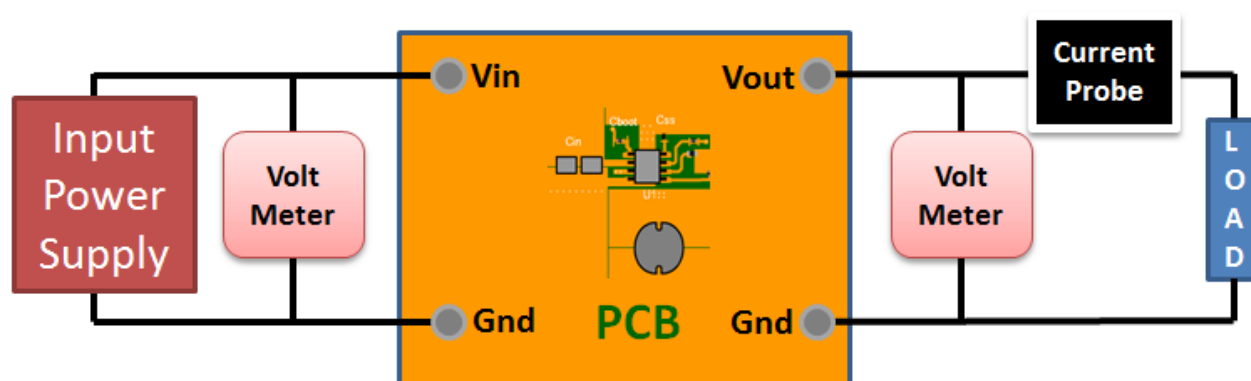
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. To solder the tab down to the board place the iron down on the board while resting against the tab, heating both surfaces simultaneously. Apply light pressure to the top of the plastic case until the solder flows around the part and the part is flush with the PCB. If the solder is not flowing around the board you may need a higher wattage iron (generally 25W to 30W is enough).

Initial Startup of Circuit

It is best to initially power up the board by setting the input supply voltage to the lowest operating input voltage 10.0V and set the input supply's current limit to zero. With the input supply off connect up the input supply to V_{in} and GND. Connect a digital volt meter and a load if needed to set the minimum load of the design from V_{out} and GND. Turn on the input supply and slowly turn up the current limit on the input supply. If the voltage starts to rise on the input supply continue increasing the input supply current limit while watching the output voltage. If the current increases on the input supply, but the voltage remains near zero, then there may be a short or a component misplaced on the board. Power down the board and visually inspect for solder bridges and recheck the diode and capacitor polarities. Once the power supply circuit is operational then more extensive testing may include full load testing, transient load and line tests to compare with simulation results.

Load Testing

The setup is the same as the initial startup, except that an additional digital voltmeter is connected between V_{in} and GND, a load is connected between V_{out} and GND and a current meter is connected in series between V_{out} and the load. The load must be able to handle at least rated output power + 50% (7.5 watts for this design). Ideally the load is supplied in the form of a variable load test unit. It can also be done in the form of suitably large power resistors. When using an oscilloscope to measure waveforms on the prototype board, the ground leads of the oscilloscope probes should be as short as possible and the area of the loop formed by the ground lead should be kept to a minimum. This will help reduce ground lead inductance and eliminate EMI noise that is not actually present in the circuit.



Design Assistance

1. Tip: Snubbers and/or gate resistors may be required to limit the SW1,2 node switching spikes below the IC and FET abs max ratings.
2. Tip: Slope Capacitor: smaller slope capacitors provide better transition region behavior.
3. Master key : 746703AA5E26DF6CF44920D6270A1979[v1]
4. **LM5176** Product Folder : <http://www.ti.com/product/LM5176> : contains the data sheet and other resources.

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