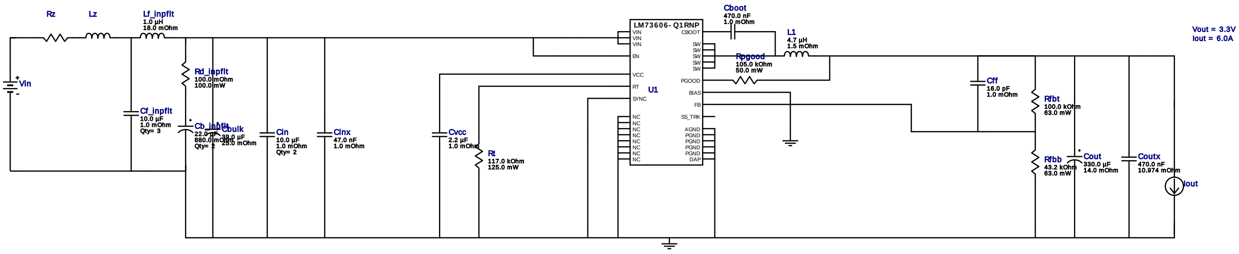
TEXAS INSTRUMENTS

WEBENCH ® Design Report

VinMin = 9.0V
VinMax = 36.0V
Vout = 3.3V
Iout = 6.0A

Device = LM73606QRNPRQ1
Topology = Buck
Created = 2020-12-01 00:35:44.200
BOM Cost = NA
BOM Count = 22
Total Pd = 2.54W

Design : 67 LM73606QRNPRQ1
LM73606QRNPRQ1 9V-36V to 3.30V @ 6A



1. The input capacitor included in the BOM only contains a small filter capacitor that should be placed near the IC. Depending on where the power supply is laid out in the system additional bulk capacitance may need to be added to filter the line ripple.

2. If there is no VinTyp specified, WEBENCH will use the VinMax value. To change the VinTyp value, click on the "Change Design Inputs" button under the Optimization Tuning knob. In some applications, while the design requires the input voltage to be a wide range, for a majority of the time, it is operating at a much lower voltage than the maximum input voltage. Sizing the inductor based on the maximum input voltage may yield an inductance much larger than typically needed, causing a larger footprint for the overall design. At the same time, components such as the input capacitor must be rated based on the maximum input voltage. WEBENCH now supports the use of this additional input voltage specification.

3. This regulator device is qualified for Automotive applications. All passives and other components selected in this design may not be qualified for Automotive applications. The user is required to verify that all components in the design meet the qualification and safety requirements for their specific application.View WEBENCH(R) Disclaimer.

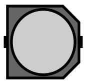
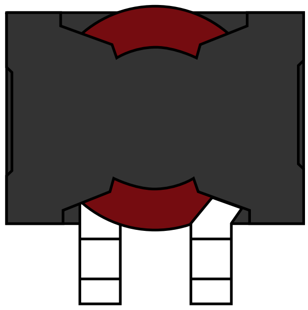
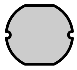
Design Alerts

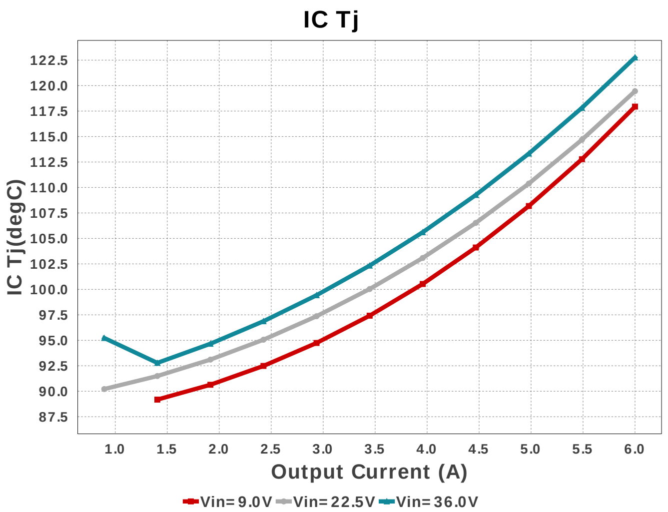
Component Selection Information

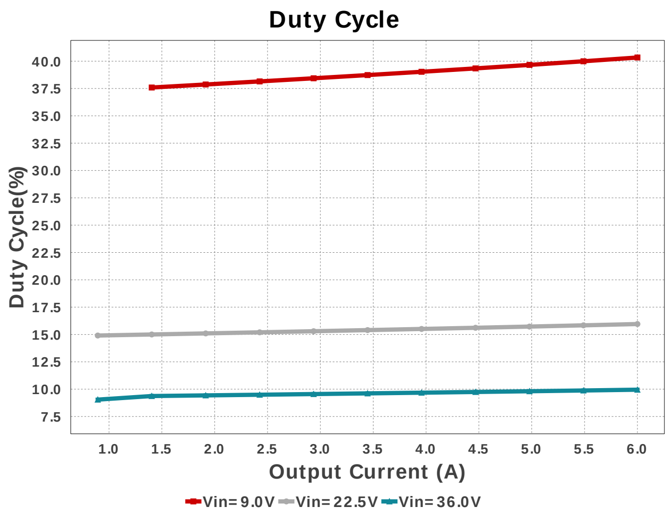
The LM73606-Q1 is qualified for Automotive applications. All passives and other components selected in this design may not be qualified for Automotive applications. The user is required to verify that all components in the design meet the qualification and safety requirements for their specific application.

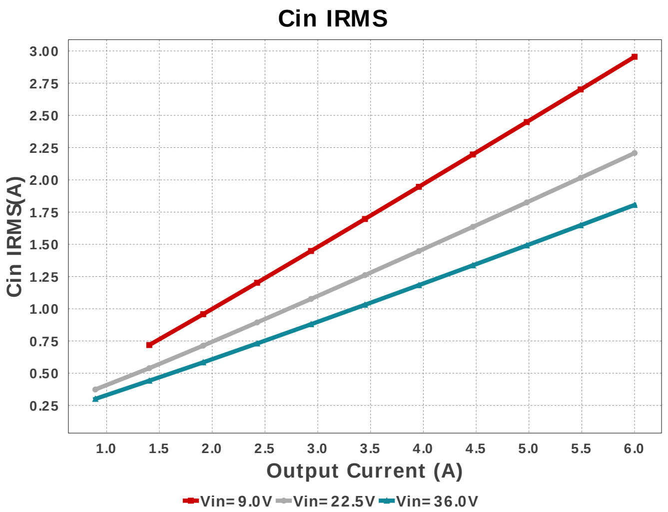
Electrical BOM

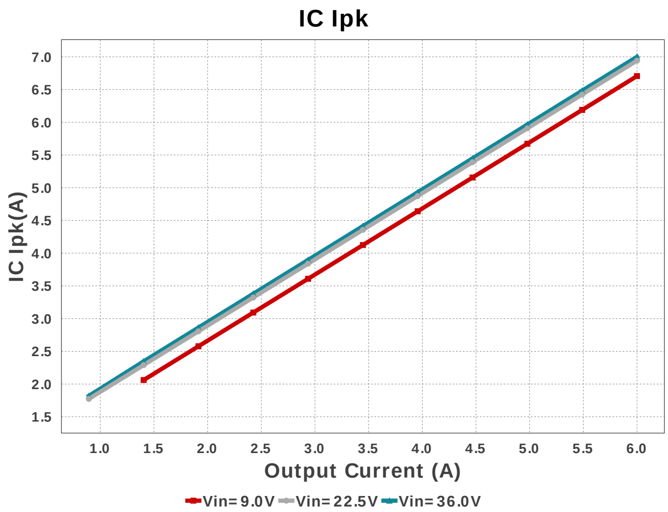
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cb_inpflt	Panasonic	EEE-FK1H220P Series= FK	Cap= 22.0 uF ESR= 880.0 mOhm VDC= 50.0 V IRMS= 165.0 mA	2	$0.11	SM_RADIAL_D 84 mm^2
Cboot	MuRata	GRM155R60J474KE19D Series= X5R	Cap= 470.0 nF ESR= 1.0 mOhm VDC= 6.3 V IRMS= 0.0 A	1	$0.02	0402 3 mm^2
Cbulk	Panasonic	50SVPF39M Series= SVPF	Cap= 39.0 uF ESR= 25.0 mOhm VDC= 50.0 V IRMS= 3.8 A	1	$0.74	CAPSMT_62_E12 106 mm^2
Cf_inpflt	TDK	C3225X7R1H106M250AC Series= X7R	Cap= 10.0 uF ESR= 1.0 mOhm VDC= 50.0 V IRMS= 5.0 A	3	$0.28	1210 15 mm^2
Cff	MuRata	GRM1555C1H160JA01D Series= C0G/NP0	Cap= 16.0 pF ESR= 1.0 mOhm VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cin	MuRata	GRM32ER71J106MA12L Series= X7R	Cap= 10.0 uF ESR= 1.0 mOhm VDC= 63.0 V IRMS= 0.0 A	2	$0.31	1210_270 15 mm^2

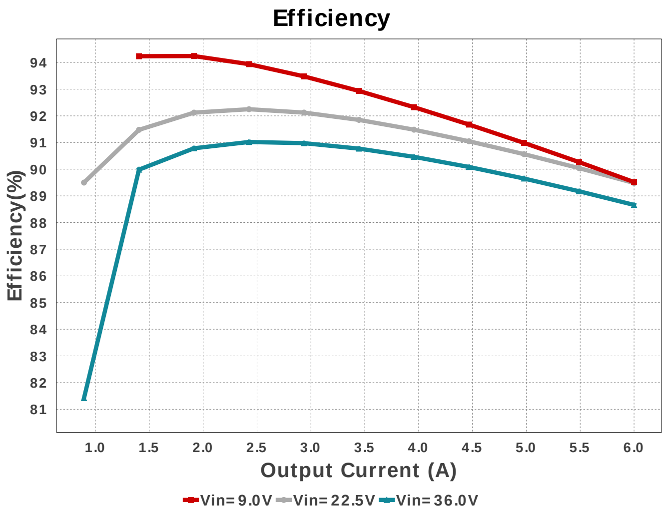
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cinx	MuRata	GRM21BR72A473KA01L Series= X7R	Cap= 47.0 nF ESR= 1.0 mOhm VDC= 100.0 V IRMS= 0.0 A	1	$0.05	0805 7 mm²
Cout	Chemi-Con	APXE6R3ARA331MF80G Series= PXE	Cap= 330.0 uF ESR= 14.0 mOhm VDC= 6.3 V IRMS= 3.47 A	1	$0.53	 CAPSMT_62_F80 74 mm²
Coutx	TDK	C1608X7R1H474K080AC Series= X7R	Cap= 470.0 nF ESR= 10.974 mOhm VDC= 50.0 V IRMS= 1.57483 A	1	$0.05	0603 5 mm²
Cvcc	Taiyo Yuden	EMK212BJ225KG-T Series= X5R	Cap= 2.2 uF ESR= 1.0 mOhm VDC= 16.0 V IRMS= 0.0 A	1	$0.02	0805 7 mm²
L1	Coilcraft	SER2915L-472KL	L= 4.7 µH 1.5 mOhm	1	$1.88	 SER2915L 652 mm²
Lf_inpflt	NIC Components	NPI54C1R0MTRF	L= 1.0 µH 18.0 mOhm	1	$0.12	 IND_NPI54C 61 mm²
Rd_inpflt	Panasonic	ERJ-3RSFR10V Series= ERJ-3R	Res= 100.0 mOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.03	0603 5 mm²
Rfbb	Vishay-Dale	CRCW040243K2FKED Series= CRCW..e3	Res= 43.2 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rfbt	Vishay-Dale	CRCW0402100KFKED Series= CRCW..e3	Res= 100.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rpgood	Yageo	RC0201FR-07105KL Series= ?	Res= 105.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
Rt	Yageo	RT0805BRD07117KL Series= RT0805	Res= 117.0 kOhm Power= 125.0 mW Tolerance= 0.1%	1	NA	0805 7 mm²
U1	Texas Instruments	LM73606QRNPRQ1	Switcher	1	$2.70	 RNP0030A 48 mm²

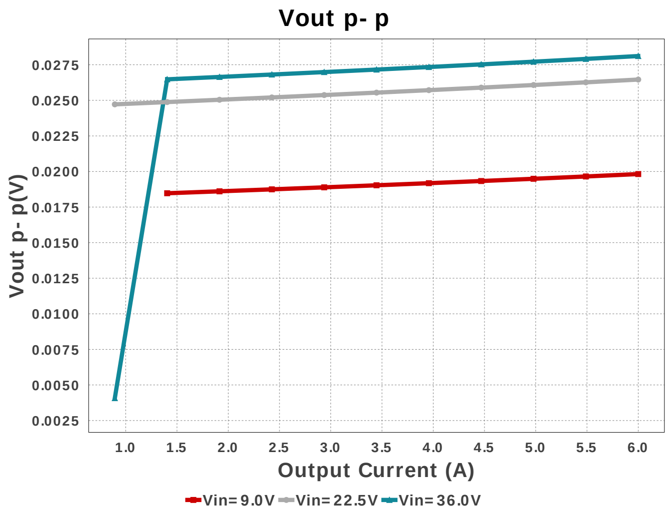

IC Tj
IC Tj(degC)
Output Current (A)
Vin= 9.0V Vin= 22.5V Vin= 36.0V

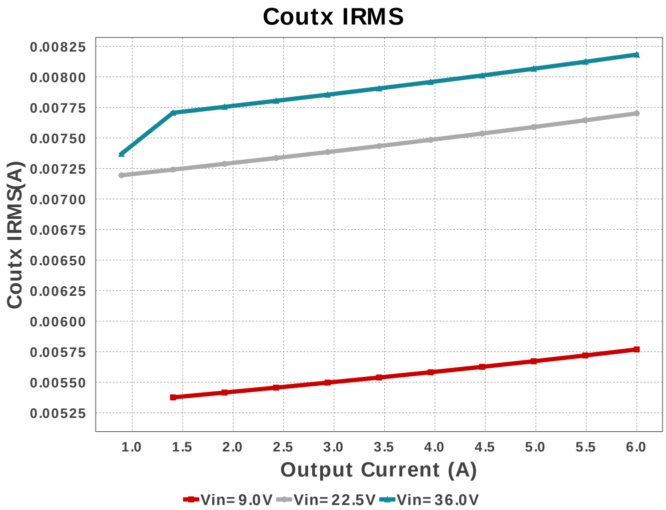

Duty Cycle
Duty Cycle(%)
Output Current (A)
Vin= 9.0V Vin= 22.5V Vin= 36.0V

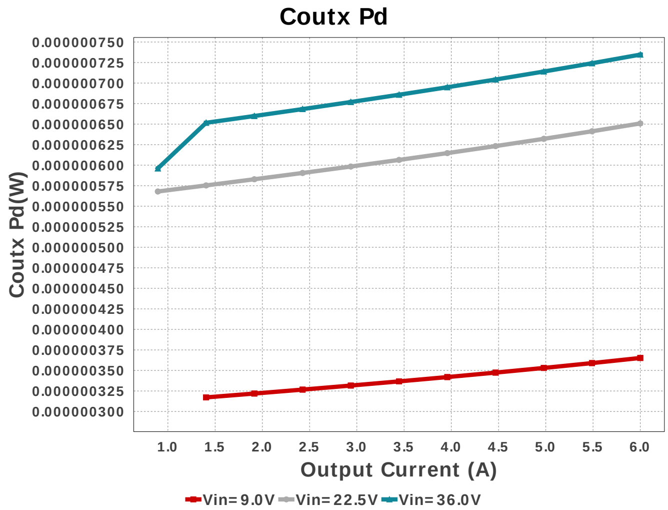

Cin IRMS
Cin IRMS(A)
Output Current (A)
Vin= 9.0V Vin= 22.5V Vin= 36.0V

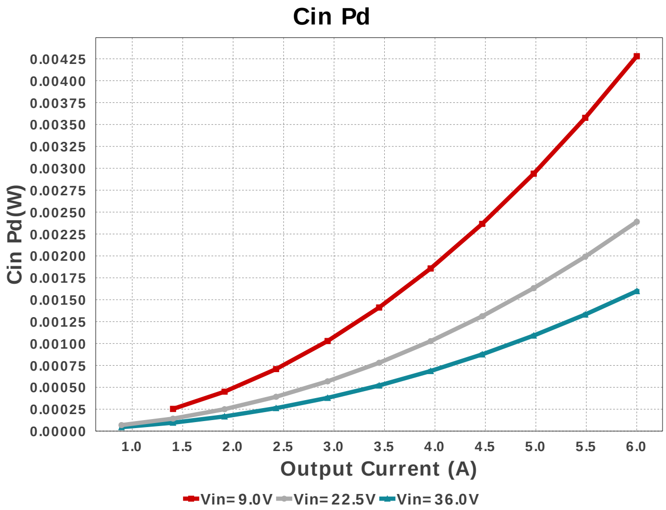

IC Ipk
IC Ipk(A)
Output Current (A)
Vin= 9.0V Vin= 22.5V Vin= 36.0V

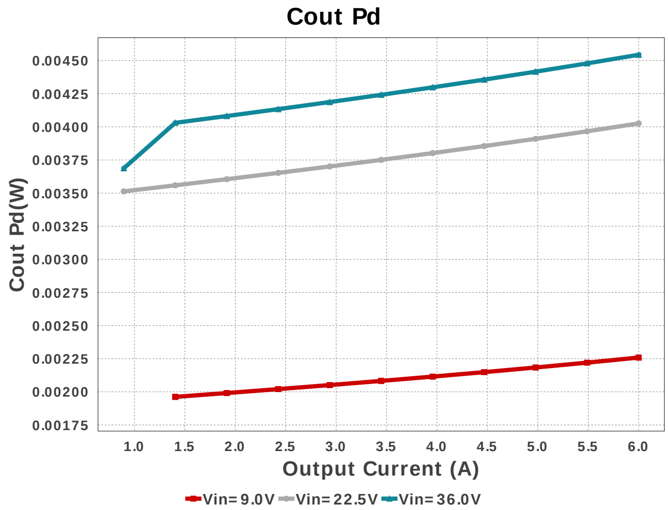

Efficiency
Efficiency(%)
Output Current (A)
Vin= 9.0V Vin= 22.5V Vin= 36.0V

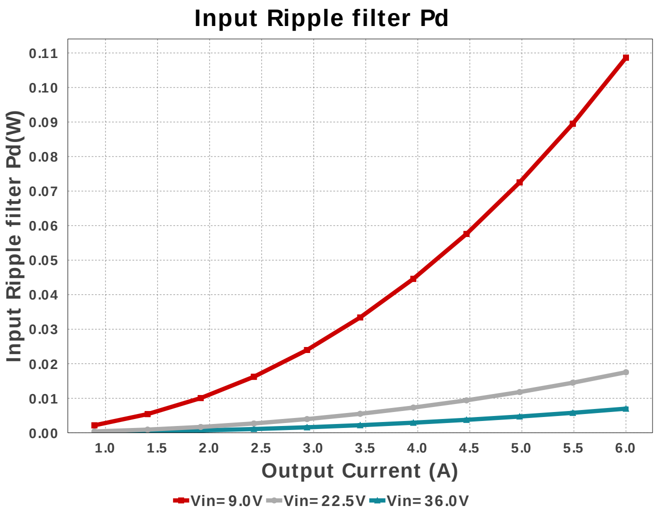

Vout p- p
Vout p- p(V)
Output Current (A)
Vin= 9.0V Vin= 22.5V Vin= 36.0V

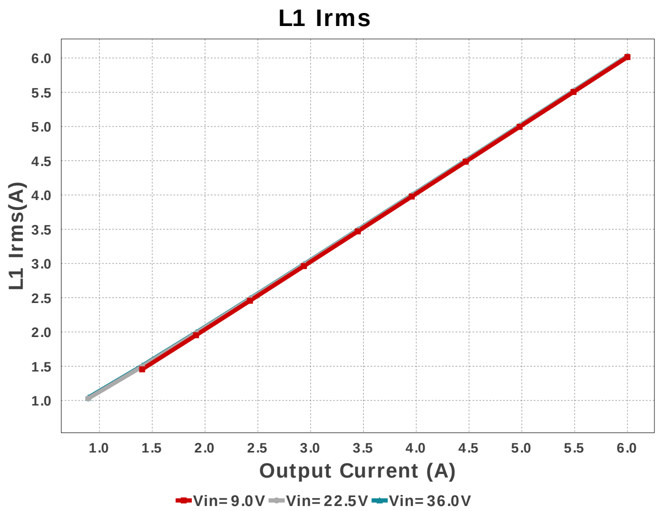

Coutx IRMS
Coutx IRMS(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

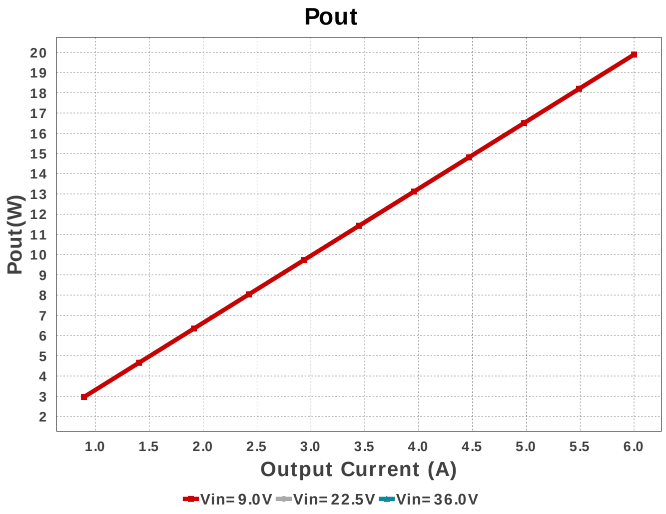

Coutx Pd
Coutx Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

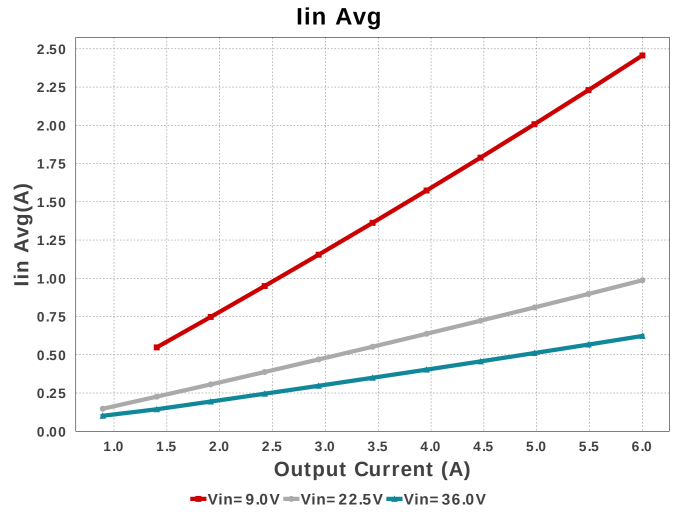

Cin Pd
Cin Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

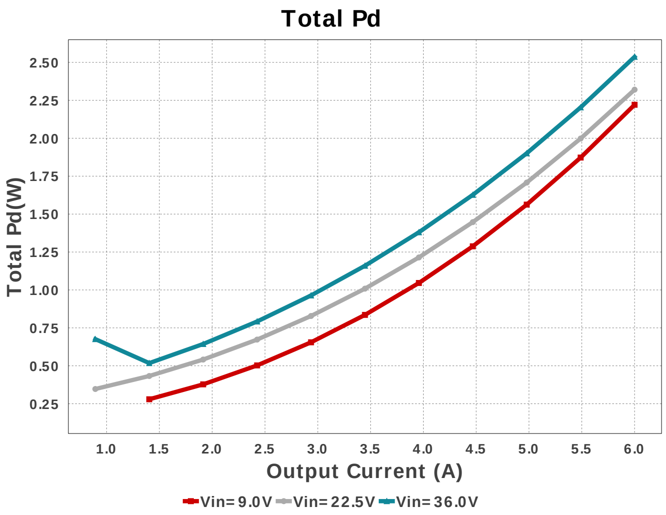

Cout Pd
Cout Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

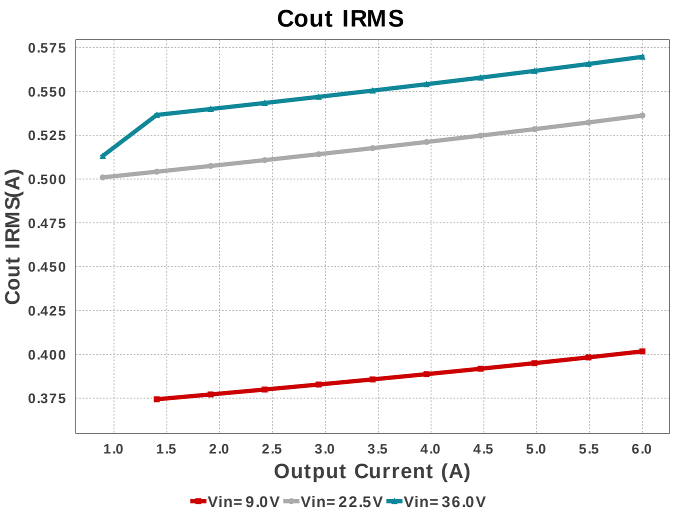

Input Ripple filter Pd
Input Ripple filter Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

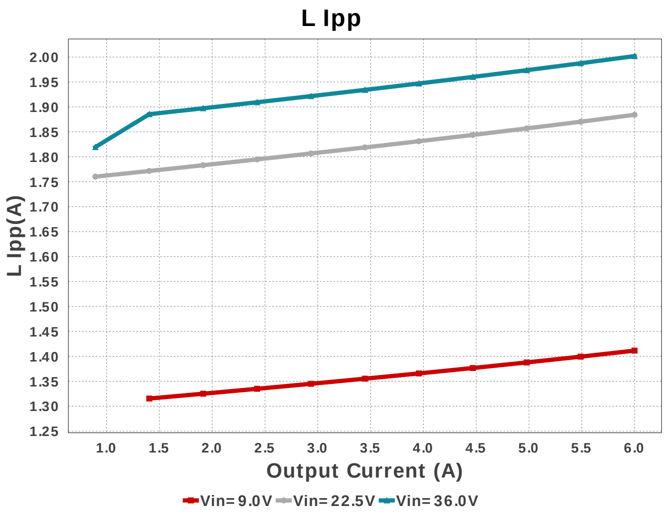

L1 Irms
L1 Irms(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

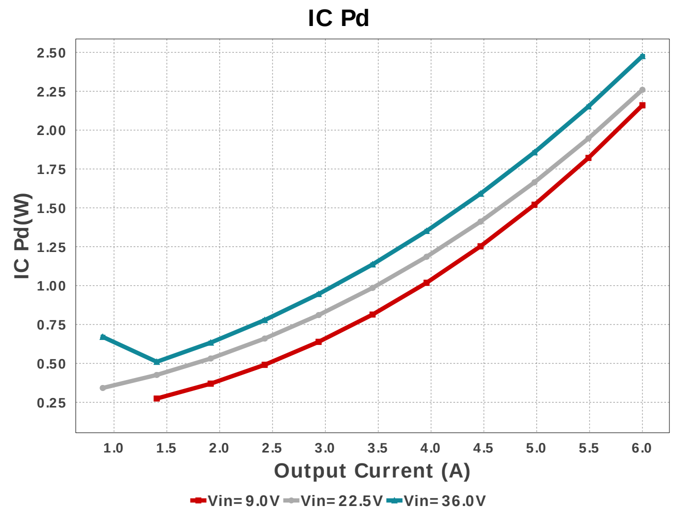

Pout
Pout(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V


Iin Avg
Iin Avg(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

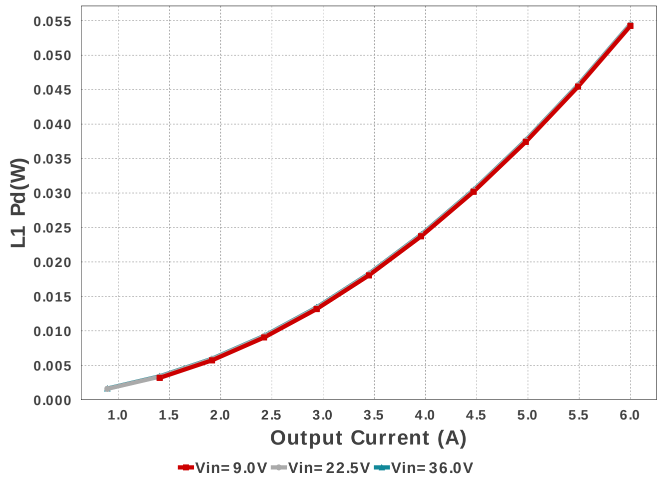

Total Pd
Total Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V


Cout IRMS
Cout IRMS(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

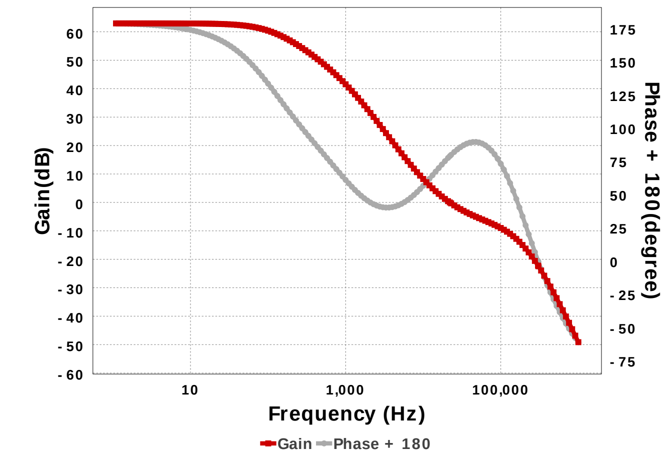

L Ipp
L Ipp(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V


IC Pd
IC Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

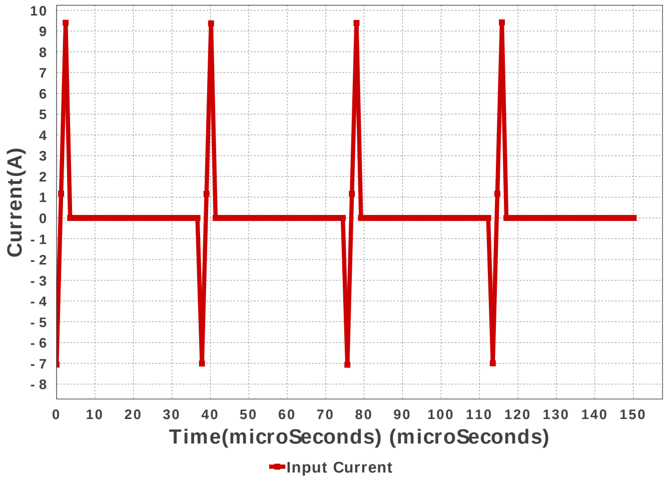
L1 Pd



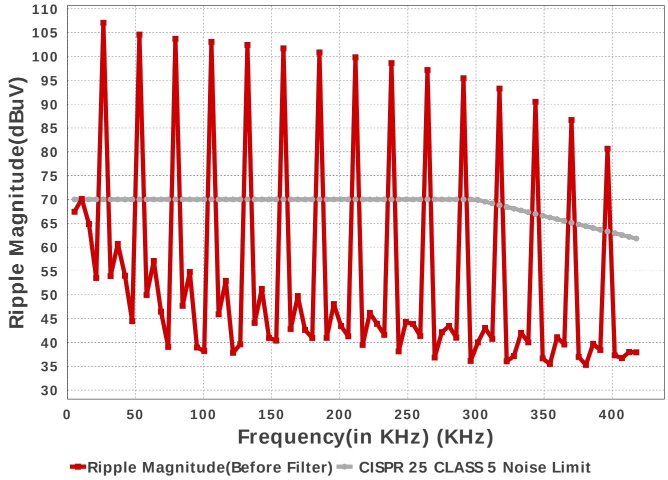
Loop Response



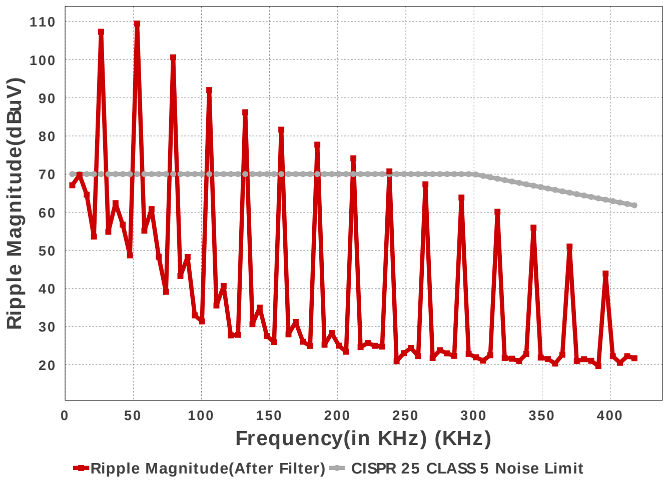
Input Current



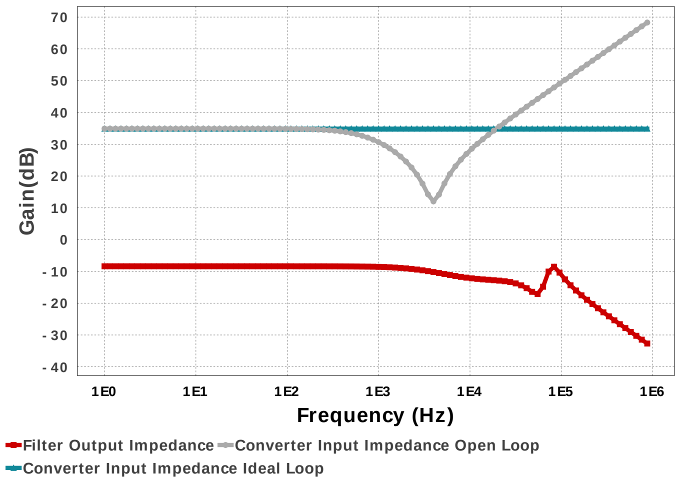
Ripple Freq Spectrum(Before Filter)

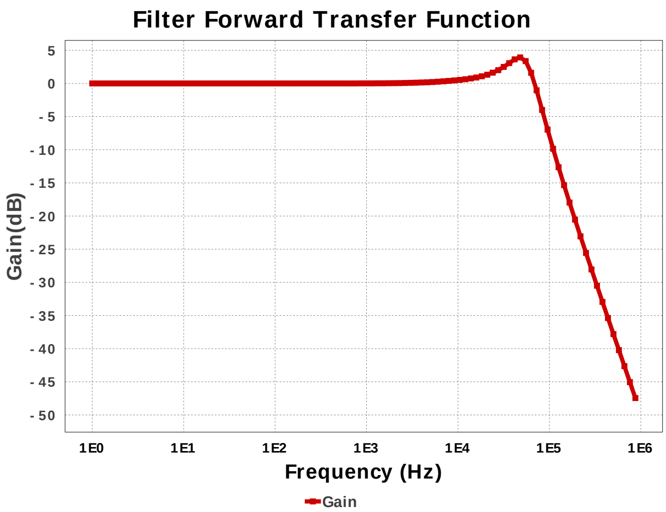


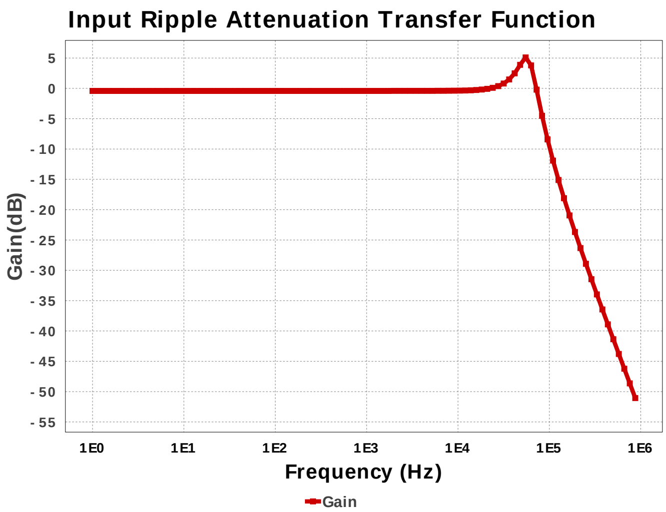
Ripple Freq Spectrum(After Filter)



Filter vs Converter Impedance Comparison







Operating Values

#	Name	Value	Category	Description
1.	Cin IRMS	1.805 A	Capacitor	Input capacitor RMS ripple current
2.	Cin Pd	1.598 mW	Capacitor	Input capacitor power dissipation
3.	Cout IRMS	569.716 mA	Capacitor	Output capacitor RMS ripple current
4.	Cout Pd	4.544 mW	Capacitor	Output capacitor power dissipation
5.	Coutx IRMS	8.182 mA	Capacitor	Output capacitor_x RMS ripple current
6.	Coutx Pd	734.66 nW	Capacitor	Output capacitor_x power loss
7.	Input Ripple Noise After input filter	61.19 dBuV	EMI Noise	Input Ripple Noise after filter at switching frequency
8.	Input Ripple Noise before input filter	95.63 dBuV	EMI Noise	Input Ripple Noise before filter at switching frequency
9.	Input Ripple filter Pd	6.985 mW	EMI Noise	Input Ripple Filter Power Dissipation
10.	Noise limits defined by CISPR Standards	66.82 dBuV	EMI Noise	Noise limits for CLASS 5 of CISPR 25 standard
11.	IC Ipk	7.001 A	IC	Peak switch current in IC
12.	IC Pd	2.476 W	IC	IC power dissipation
13.	IC Tj	122.757 degC	IC	IC junction temperature
14.	ICThetaJA	15.25 degC/W	IC	IC junction-to-ambient thermal resistance
15.	Iin Avg	622.93 mA	IC	Average input current
16.	L Ipp	2.002 A	Inductor	Peak-to-peak inductor ripple current
17.	L1 Irms	6.028 A	Inductor	Inductor ripple current
18.	L1 Pd	54.501 mW	Inductor	Power Dissipation in the Inductor
19.	Cin Pd	1.598 mW	Power	Input capacitor power dissipation
20.	Cout Pd	4.544 mW	Power	Output capacitor power dissipation
21.	Coutx Pd	734.66 nW	Power	Output capacitor_x power loss
22.	IC Pd	2.476 W	Power	IC power dissipation
23.	Input Ripple filter Pd	6.985 mW	Power	Input Ripple Filter Power Dissipation
24.	L1 Pd	54.501 mW	Power	Power Dissipation in the Inductor
25.	Total Pd	2.537 W	Power	Total Power Dissipation
26.	BOM Count	22	System Information	Total Design BOM count
27.	Cross Freq	22.056 kHz	System Information	Bode plot crossover frequency
28.	Duty Cycle	9.951 %	System Information	Duty cycle
29.	Efficiency	88.661 %	System Information	Steady state efficiency
30.	FootPrint	1.226 k mm^2	System Information	Total Foot Print Area of BOM components
31.	Frequency	345.683 kHz	System Information	Switching frequency
32.	Gain Marg	-22.445 dB	System Information	Bode Plot Gain Margin
33.	Iout	6.0 A	System Information	Iout operating point
34.	Low Freq Gain	62.953 dB	System Information	Gain at 1Hz
35.	Mode	PWM	System Information	Conduction Mode
36.	Phase Marg	79.579 deg	System Information	Bode Plot Phase Margin
37.	Pout	19.889 W	System Information	Total output power

#	Name	Value	Category	Description
38.	Total BOM	NA	System Information	Total BOM Cost
39.	Vin	36.0 V	System Information	Vin operating point
40.	Vout	3.3 V	System Information	Operational Output Voltage
41.	Vout Actual	3.315 V	System Information	Vout Actual calculated based on selected voltage divider resistors
42.	Vout Tolerance	3.338 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
43.	Vout p-p	28.112 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	6.0	Maximum Output Current
VinMax	36.0	Maximum input voltage
VinMin	9.0	Minimum input voltage
Vout	3.3	Output Voltage
base_pn	LM73606-Q1	Base Product Number
source	DC	Input Source Type
Ta	85.0	Ambient temperature

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 Cin and Cout, 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

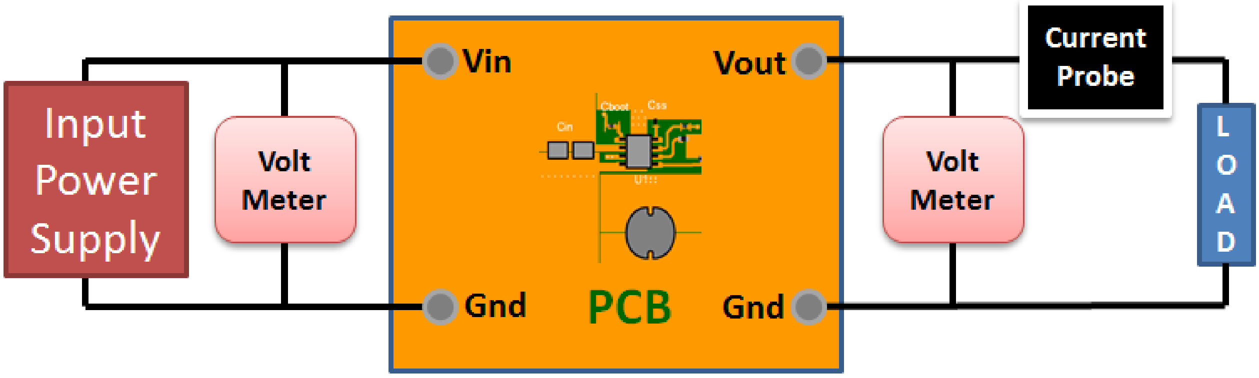
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. To solder the tab town 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 9.0V and set the input supply's current limit to zero. With the input supply off connect up the input supply to Vin and GND. Connect a digital volt meter and a load if needed to set the minimum Iout of the design from Vout 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 Vin and GND, a load is connected between Vout and GND and a current meter is connected in series between Vout 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. The LM73606-Q1 is qualified for Automotive applications. All passives and other components selected in this design may not be qualified for Automotive applications. The user is required to verify that all components in the design meet the qualification and safety requirements for their specific application.

2. Master key : BB4FF38B303A806B[v1]

3. **LM73606-Q1** Product Folder : http://www.ti.com/product/LM73606-Q1 : contains the data sheet and other resources.

Important Notice and Disclaimer