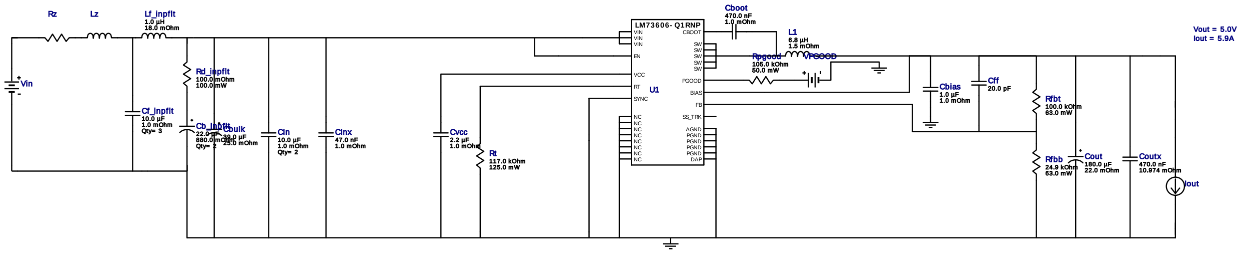
Device = LM73606QRNPRQ1
Topology = Buck
Created = 2020-12-01 00:35:44.200
BOM Cost = NA
BOM Count = 23
Total Pd = 2.6W

WEBENCH ® Design Report

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.

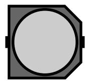
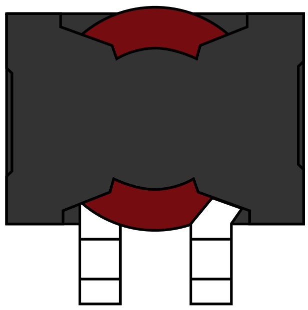
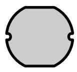
Design Alerts

Component Selection Information

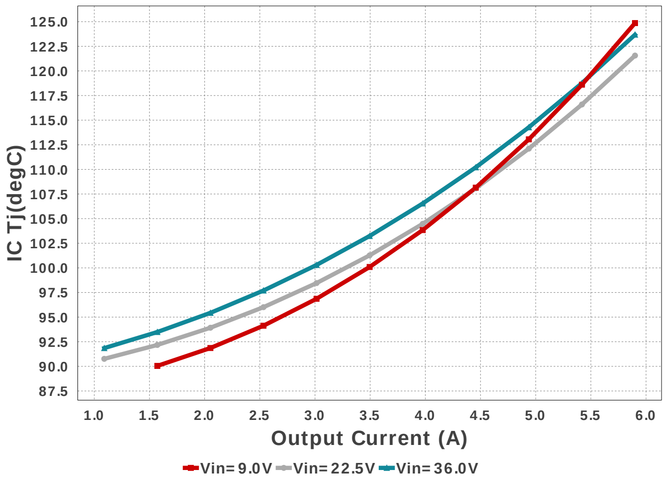
The LM73606-Q1 is qualified for Automotive applications. All passives and other components selected in this design may not be qualified for Automotive applications. The user is required to verify that all components in the design meet the qualification and safety requirements for their specific application.

Electrical BOM

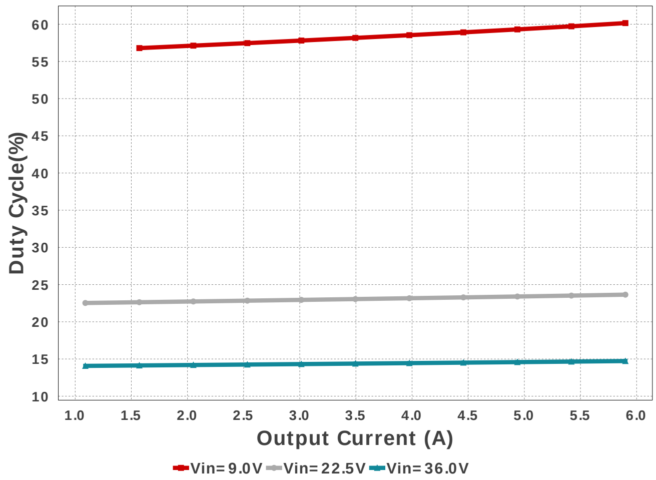
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cb_inpflt	Panasonic	EEE-FK1H220P Series= FK	Cap= 22.0 uF ESR= 880.0 mOhm VDC= 50.0 V IRMS= 165.0 mA	2	$0.11	SM_RADIAL_D 84 mm^2
Cbias	Kemet	C0603C105K8PACTU Series= X5R	Cap= 1.0 uF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.01	0603 5 mm^2
Cboot	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	Samsung Electro-Mechanics	CL21C200JBANNNC Series= C0G/NP0	Cap= 20.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
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
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 mm^2
Cout	Panasonic	16SVPF180M Series= SVPF	Cap= 180.0 uF ESR= 22.0 mOhm VDC= 16.0 V IRMS= 3.3 A	1	$0.44	 CAPSMT_62_F61 74 mm^2
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 mm^2
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 mm^2
L1	Coilcraft	SER2915L-682KL	L= 6.8 µH 1.5 mOhm	1	$1.88	 SER2915L 652 mm^2
Lf_inpflt	NIC Components	NPI54C1R0MTRF	L= 1.0 µH 18.0 mOhm	1	$0.12	 IND_NPI54C 61 mm^2
Rd_inpflt	Panasonic	ERJ-3RSFR10V Series= ERJ-3R	Res= 100.0 mOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.03	0603 5 mm^2
Rfbb	Vishay-Dale	CRCW040224K9FKED Series= CRCW..e3	Res= 24.9 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt	Vishay-Dale	CRCW0402100KFKED Series= CRCW..e3	Res= 100.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rpgood	Yageo	RC0201FR-07105KL Series= ?	Res= 105.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm^2
Rt	Yageo	RT0805BRD07117KL Series= RT0805	Res= 117.0 kOhm Power= 125.0 mW Tolerance= 0.1%	1	NA	0805 7 mm^2
U1	Texas Instruments	LM73606QRNPRQ1	Switcher	1	$2.70	 RNP0030A 48 mm^2

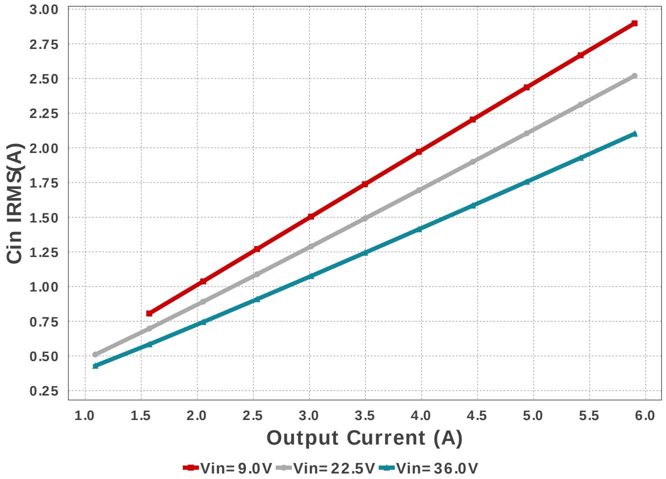
IC Tj



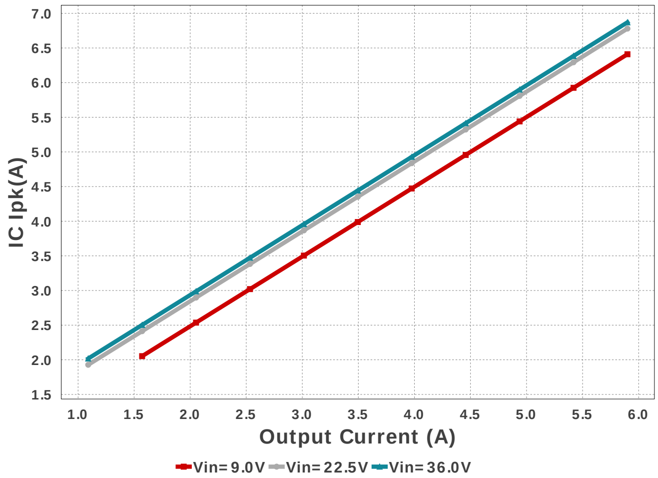
Duty Cycle



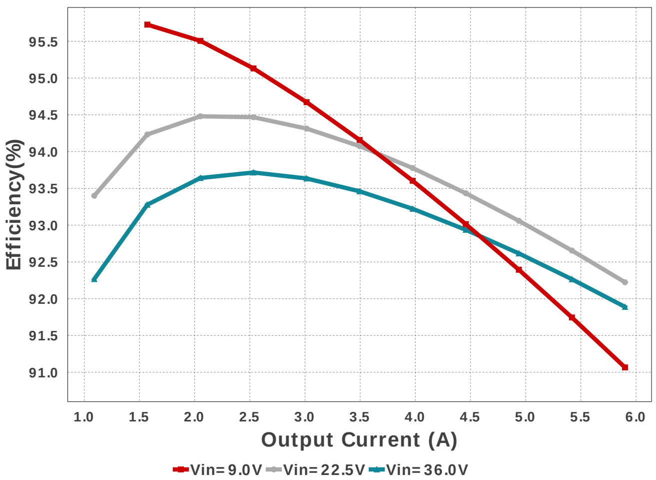
Cin IRMS



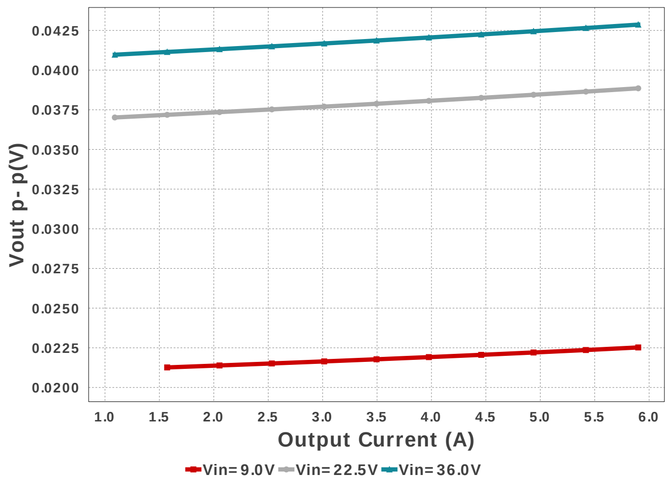
IC Ipk

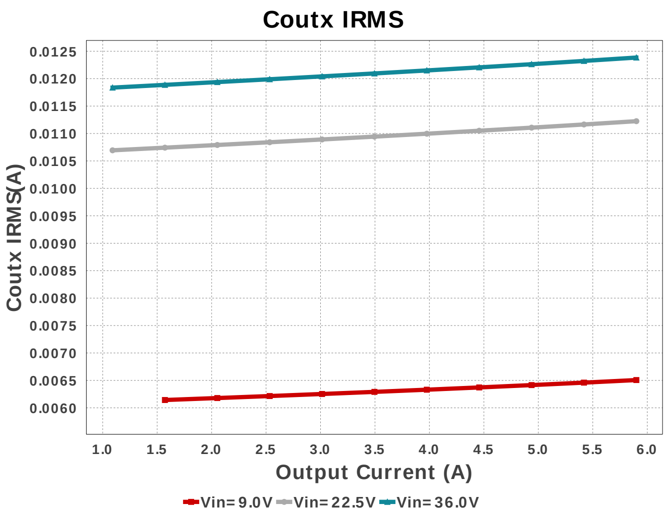


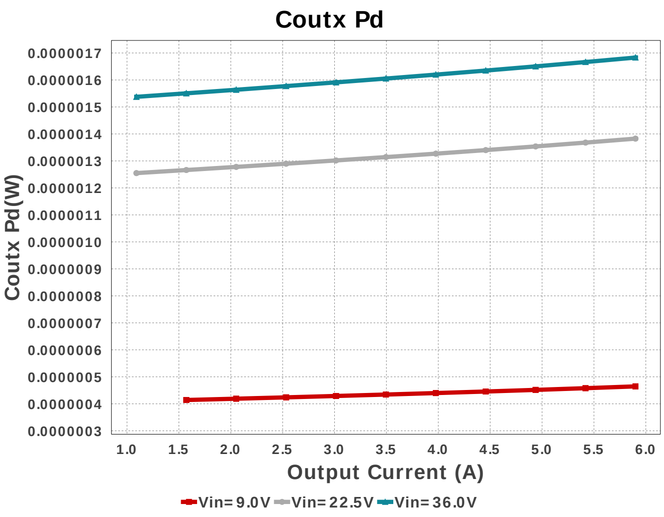
Efficiency

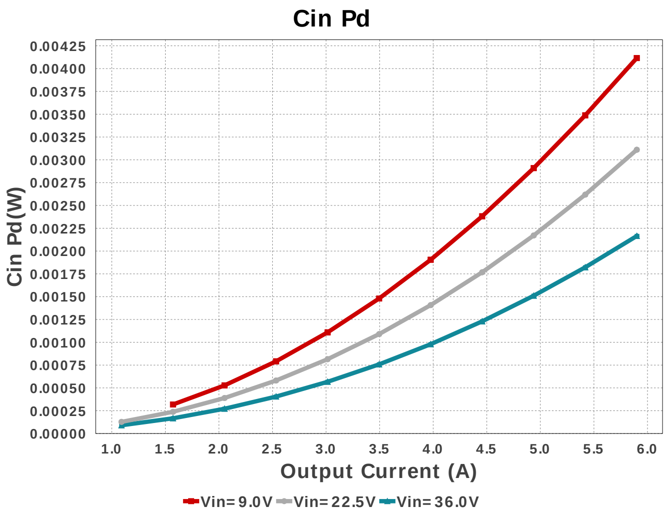


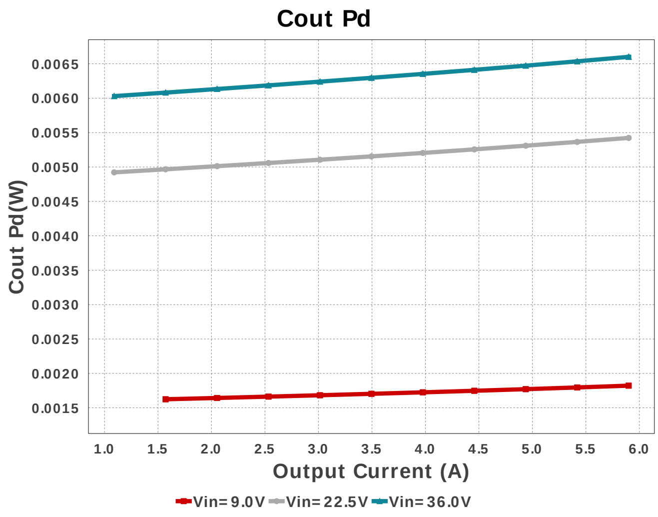
Vout p- p

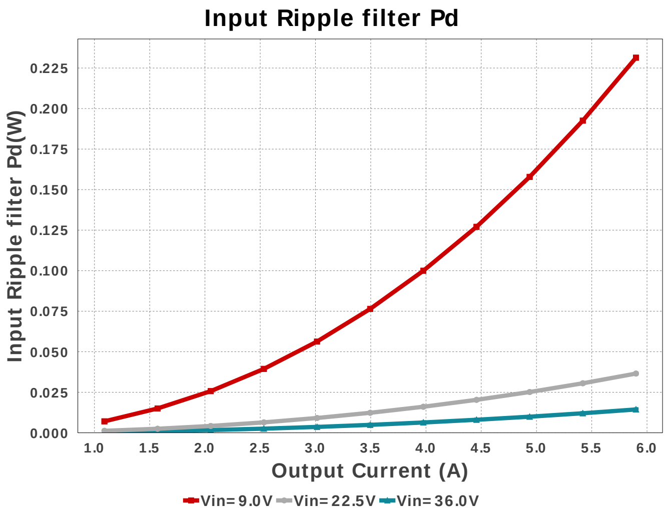


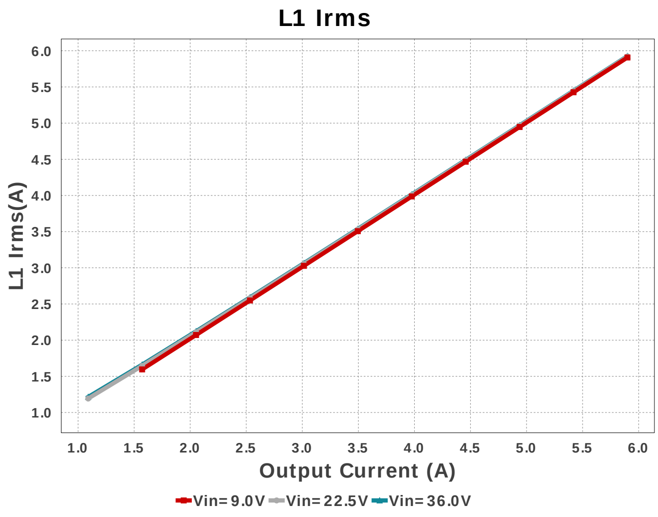

Coutx IRMS
Coutx IRMS(A)
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

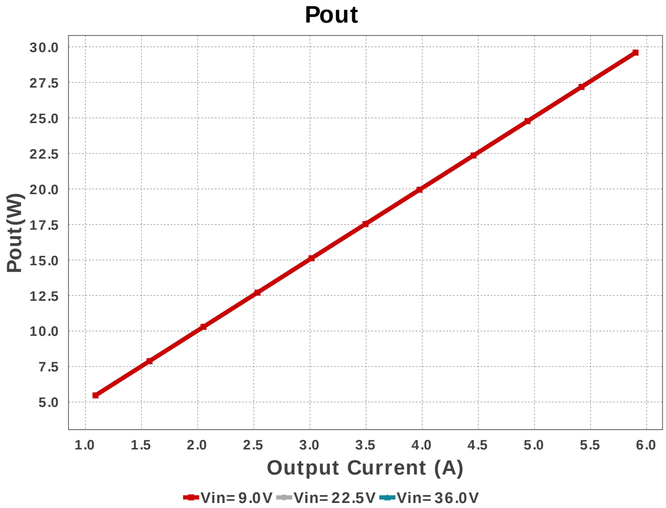

Coutx Pd
Coutx Pd(W)
0.0000017
0.0000016
0.0000015
0.0000014
0.0000013
0.0000012
0.0000011
0.0000010
0.0000009
0.0000008
0.0000007
0.0000006
0.0000005
0.0000004
0.0000003
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

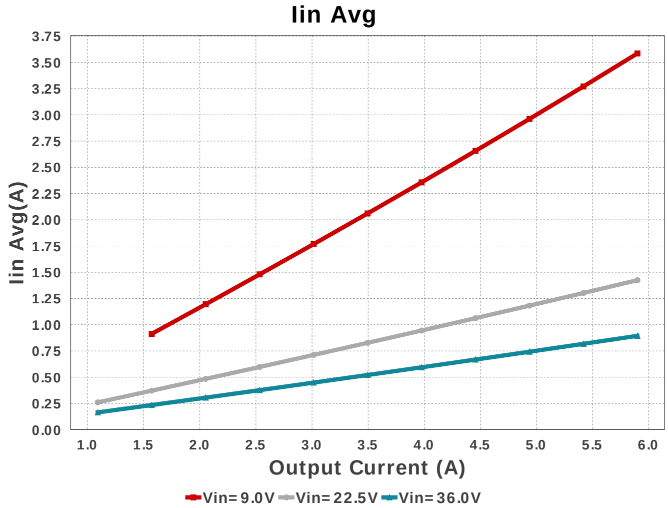

Cin Pd
Cin Pd(W)
0.00425
0.00400
0.00375
0.00350
0.00325
0.00300
0.00275
0.00250
0.00225
0.00200
0.00175
0.00150
0.00125
0.00100
0.00075
0.00050
0.00025
0.00000
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

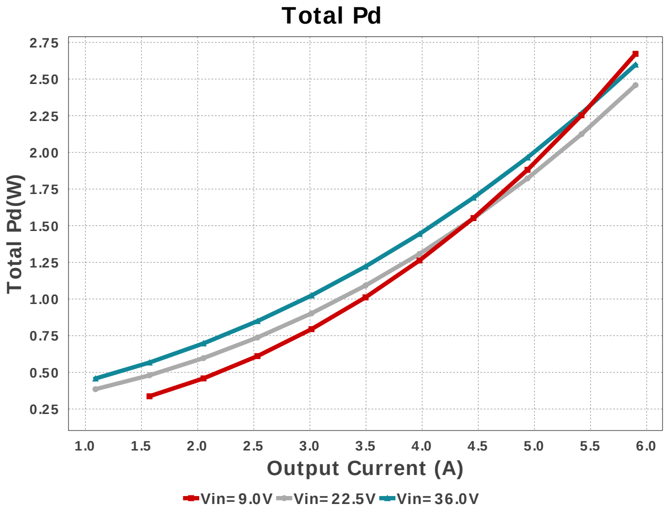

Cout Pd
Cout Pd(W)
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

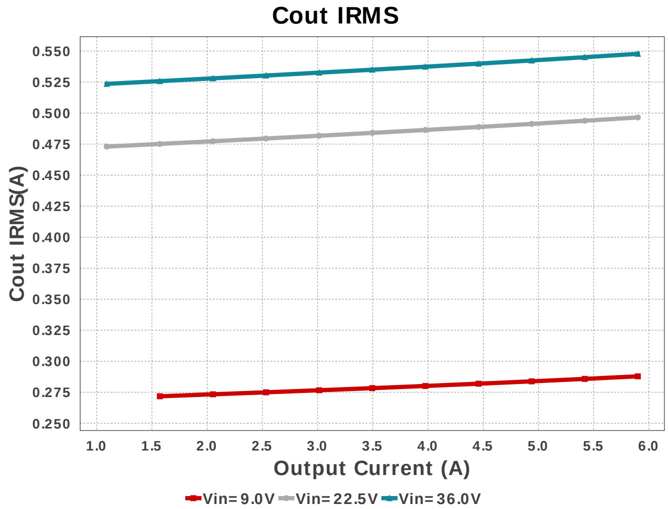

Input Ripple filter Pd
Input Ripple filter Pd(W)
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

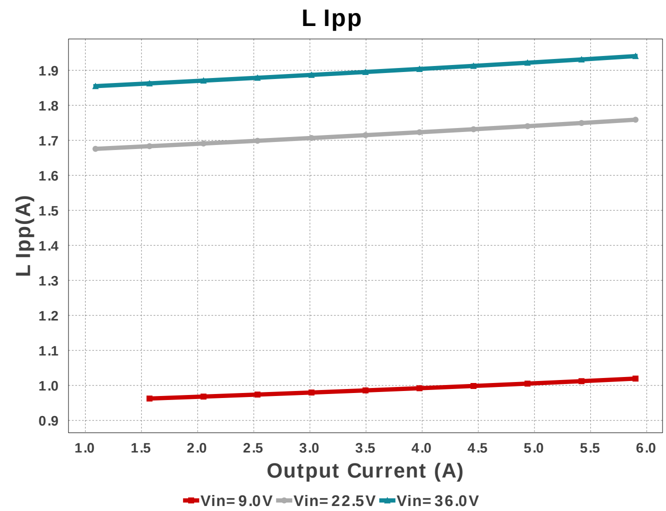

L1 Irms
L1 Irms(A)
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

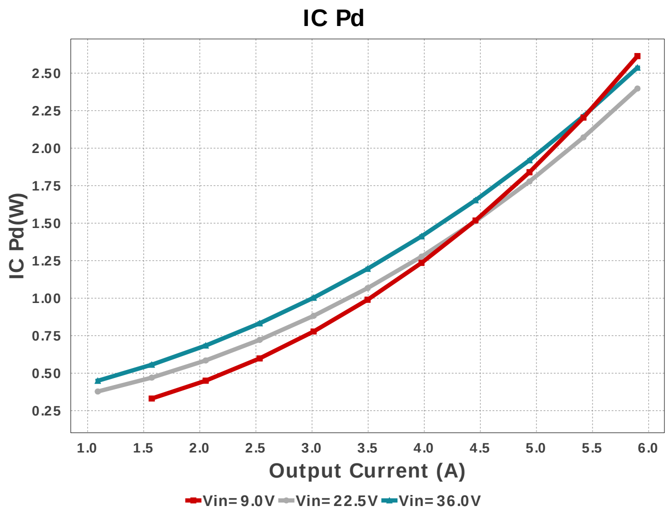

Pout
Pout(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

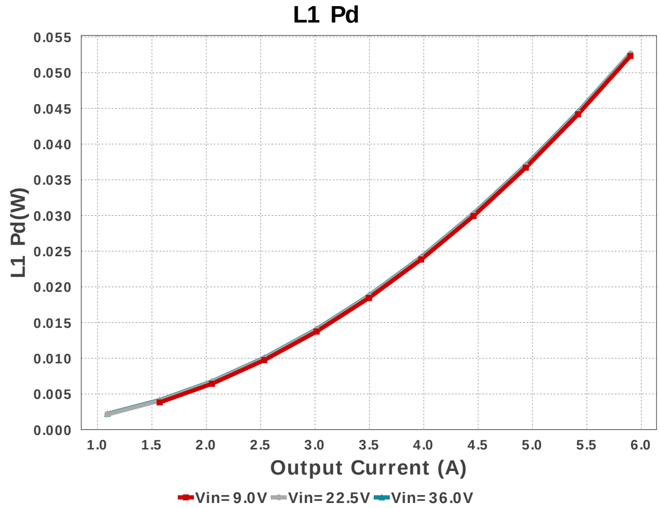

Iin Avg
Iin Avg(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

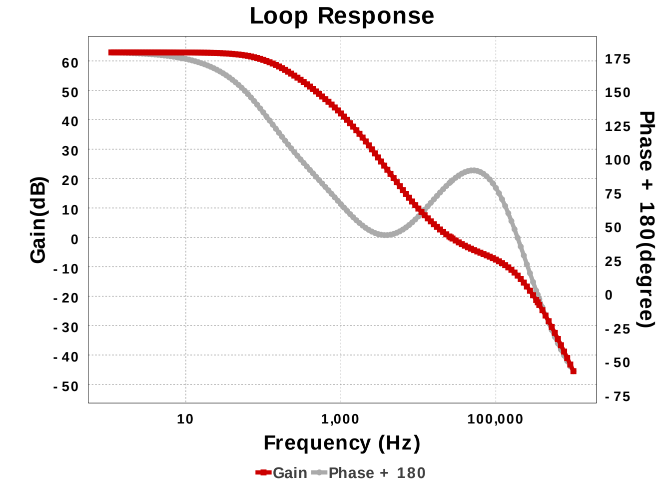

Total Pd
Total Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

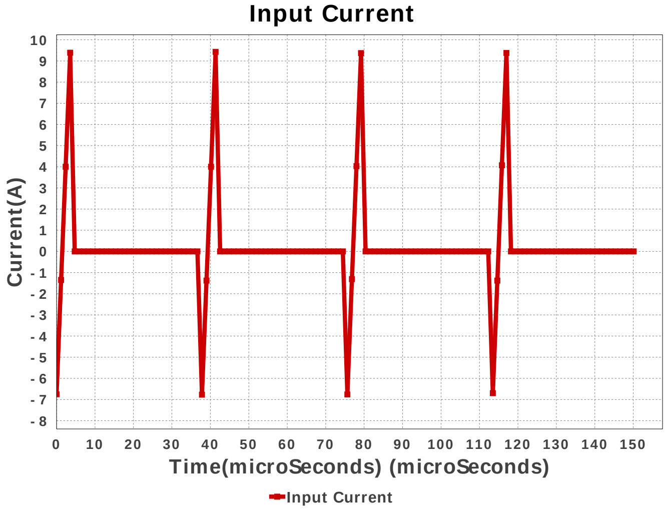

Cout IRMS
Cout IRMS(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

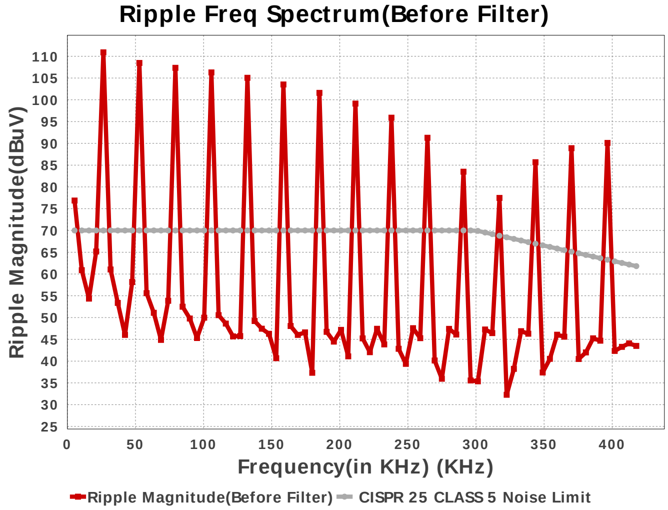

L Ipp
L Ipp(A)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

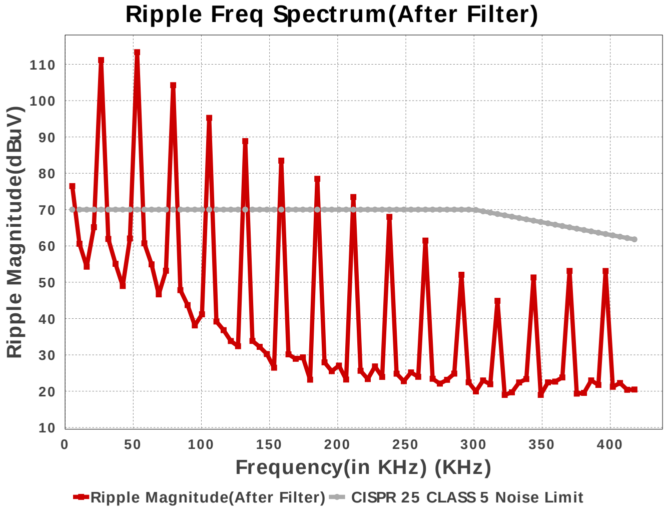

IC Pd
IC Pd(W)
Output Current (A)
Vin=9.0V Vin=22.5V Vin=36.0V

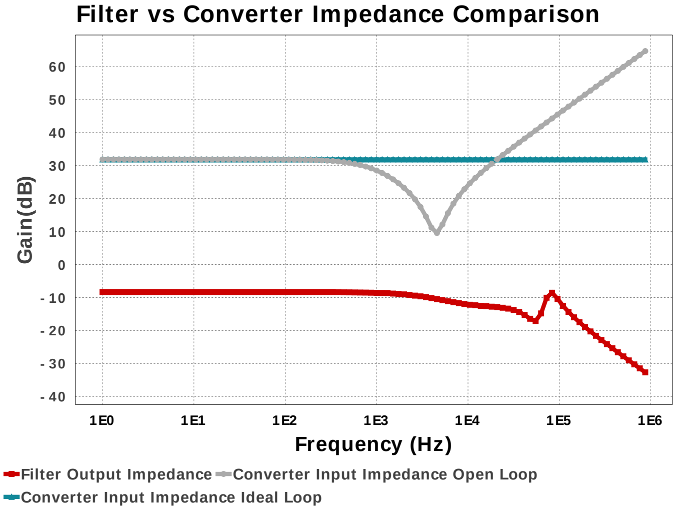

L1 Pd
L1 Pd(W)
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin= 9.0V Vin= 22.5V Vin= 36.0V


Loop Response
Gain(dB)
60 50 40 30 20 10 0 -10 -20 -30 -40 -50
Phase + 180(degree)
175 150 125 100 75 50 25 0 -25 -50 -75
10 1,000 100,000
Frequency (Hz)
Gain Phase + 180

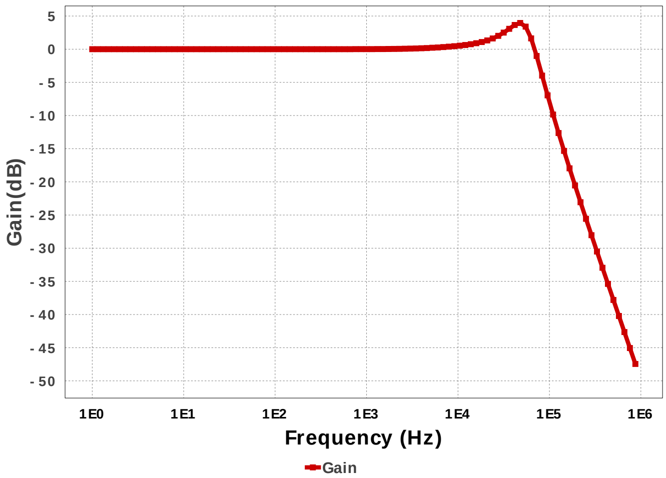

Input Current
Current(A)
10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Time(microSeconds) (microSeconds)
Input Current


Ripple Freq Spectrum(Before Filter)
Ripple Magnitude(dBuV)
110 105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25
0 50 100 150 200 250 300 350 400
Frequency(in KHz) (KHz)
Ripple Magnitude(Before Filter) CISPR 25 CLASS 5 Noise Limit

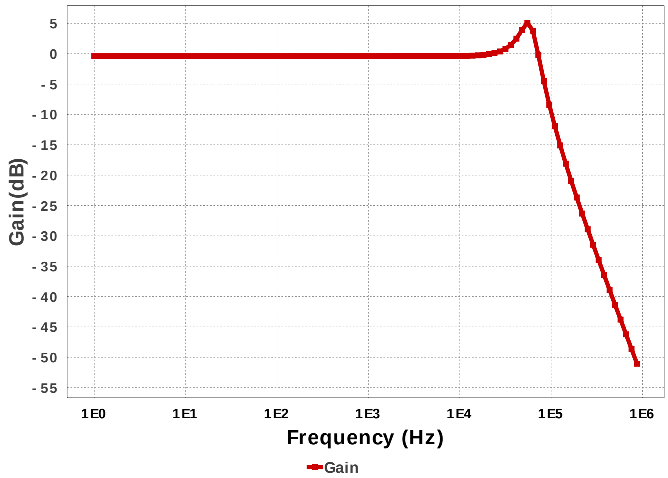

Ripple Freq Spectrum(After Filter)
Ripple Magnitude(dBuV)
110 100 90 80 70 60 50 40 30 20 10
0 50 100 150 200 250 300 350 400
Frequency(in KHz) (KHz)
Ripple Magnitude(After Filter) CISPR 25 CLASS 5 Noise Limit


Filter vs Converter Impedance Comparison
Gain(dB)
60 50 40 30 20 10 0 -10 -20 -30 -40
1E0 1E1 1E2 1E3 1E4 1E5 1E6
Frequency (Hz)
Filter Output Impedance Converter Input Impedance Open Loop
Converter Input Impedance Ideal Loop

Filter Forward Transfer Function



Input Ripple Attenuation Transfer Function



Operating Values

#	Name	Value	Category	Description
1.	BOM Count	23		Total Design BOM count
2.	Total BOM	NA		Total BOM Cost
3.	Cin IRMS	2.102 A	Capacitor	Input capacitor RMS ripple current
4.	Cin Pd	2.165 mW	Capacitor	Input capacitor power dissipation
5.	Cout IRMS	547.771 mA	Capacitor	Output capacitor RMS ripple current
6.	Cout Pd	6.601 mW	Capacitor	Output capacitor power dissipation
7.	Coutx IRMS	12.384 mA	Capacitor	Output capacitor_x RMS ripple current
8.	Coutx Pd	1.683 µW	Capacitor	Output capacitor_x power loss
9.	Input Ripple Noise After input filter	63.24 dBuV	EMI Noise	Input Ripple Noise after filter at switching frequency
10.	Input Ripple Noise before input filter	97.94 dBuV	EMI Noise	Input Ripple Noise before filter at switching frequency
11.	Input Ripple filter Pd	14.394 mW	EMI Noise	Input Ripple Filter Power Dissipation
12.	Noise limits defined by CISPR Standards	66.82 dBuV	EMI Noise	Noise limits for CLASS 5 of CISPR 25 standard
13.	IC Ipk	6.87 A	IC	Peak switch current in IC
14.	IC Pd	2.536 W	IC	IC power dissipation
15.	IC Tj	123.68 degC	IC	IC junction temperature
16.	ICThetaJA	15.25 degC/W	IC	IC junction-to-ambient thermal resistance
17.	Iin Avg	894.24 mA	IC	Average input current
18.	L Ipp	1.94 A	Inductor	Peak-to-peak inductor ripple current
19.	L1 Irms	5.927 A	Inductor	Inductor ripple current
20.	L1 Pd	52.686 mW	Inductor	Power Dissipation in the Inductor
21.	Cin Pd	2.165 mW	Power	Input capacitor power dissipation
22.	Cout Pd	6.601 mW	Power	Output capacitor power dissipation
23.	Coutx Pd	1.683 µW	Power	Output capacitor_x power loss
24.	IC Pd	2.536 W	Power	IC power dissipation
25.	Input Ripple filter Pd	14.394 mW	Power	Input Ripple Filter Power Dissipation
26.	L1 Pd	52.686 mW	Power	Power Dissipation in the Inductor
27.	Total Pd	2.598 W	Power	Total Power Dissipation
28.	Cross Freq	26.17 kHz	System Information	Bode plot crossover frequency
29.	Duty Cycle	14.721 %	System Information	Duty cycle
30.	Efficiency	91.889 %	System Information	Steady state efficiency
31.	FootPrint	1.235 k mm^2	System Information	Total Foot Print Area of BOM components
32.	Frequency	345.683 kHz	System Information	Switching frequency
33.	Gain Marg	-22.076 dB	System Information	Bode Plot Gain Margin
34.	Iout	5.9 A	System Information	Iout operating point
35.	Low Freq Gain	62.901 dB	System Information	Gain at 1Hz
36.	Mode	PWM	System Information	Conduction Mode
37.	Phase Marg	83.566 deg	System Information	Bode Plot Phase Margin
38.	Pout	29.595 W	System Information	Total output power

#	Name	Value	Category	Description
39.	Vin	36.0 V	System Information	Vin operating point
40.	Vout	5.0 V	System Information	Operational Output Voltage
41.	Vout Actual	5.016 V	System Information	Vout Actual calculated based on selected voltage divider resistors
42.	Vout Tolerance	3.548 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
43.	Vout p-p	42.867 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	5.9	Maximum Output Current
VinMax	36.0	Maximum input voltage
VinMin	9.0	Minimum input voltage
Vout	5.0	Output Voltage
base_pn	LM73606-Q1	Base Product Number
source	DC	Input Source Type
Ta	85.0	Ambient temperature
UserFsw	350.0 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 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

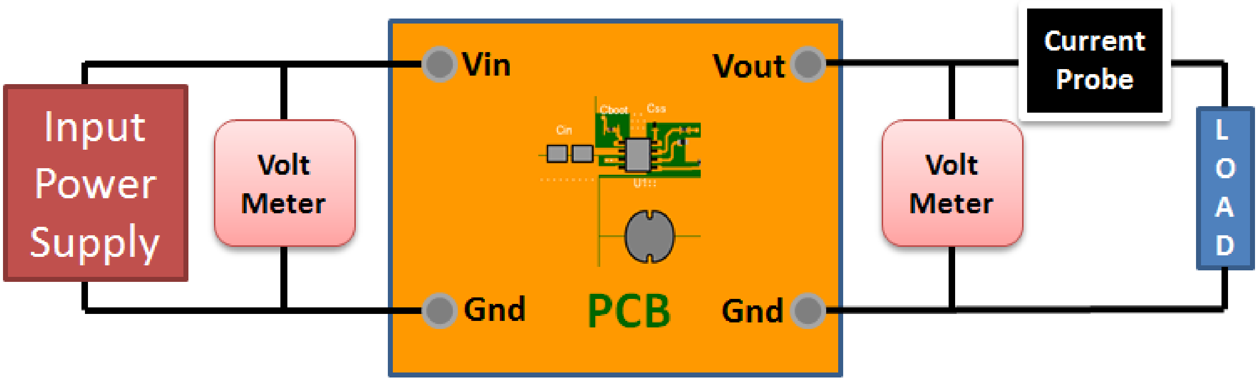
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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.

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