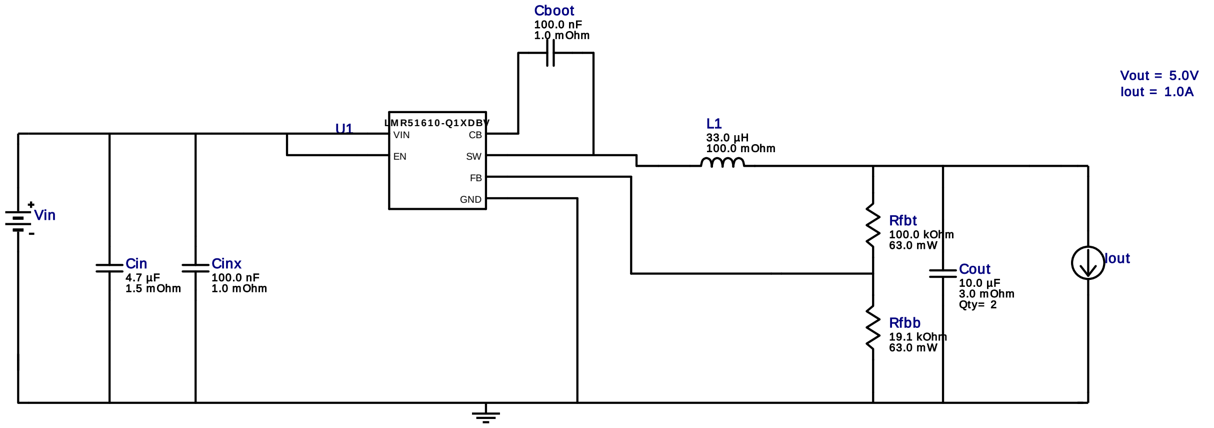
WEBENCH® Design Report

VinMin = 6.0V
VinMax = 60.0V
Vout = 5.0V
Iout = 1.0A

Device = LMR51610XQDBVRQ1
Topology = Buck
Created = 2024-09-24 06:21:52.738
BOM Cost = $1.78
BOM Count = 9
Total Pd = 1.15W

Design : 58 LMR51610XQDBVRQ1
LMR51610XQDBVRQ1 6V-60V to 5.00V @ 1A

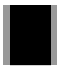
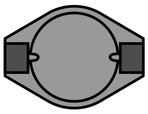



## Design Alerts

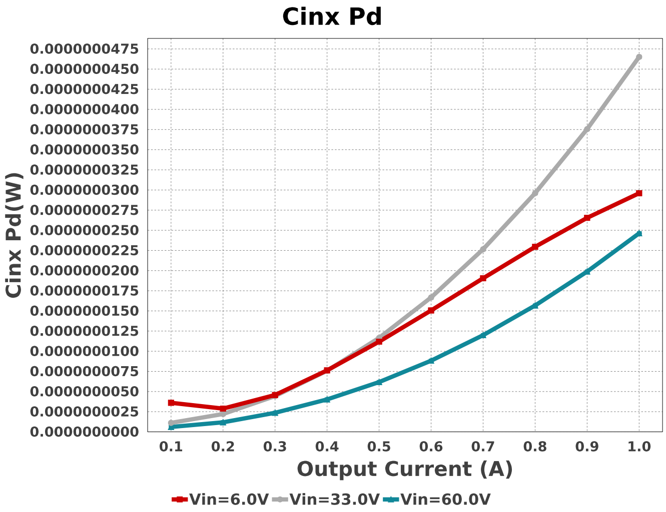
### Component Selection Information

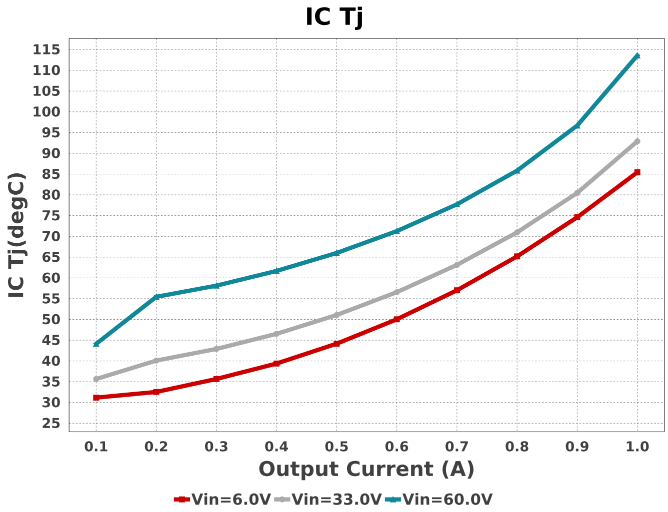
The LMR51610-Q1 is qualified for Automotive applications. All passives and other components selected in this design may not be qualified for Automotive applications. The user is required to verify that all components in the design meet the qualification and safety requirements for their specific application

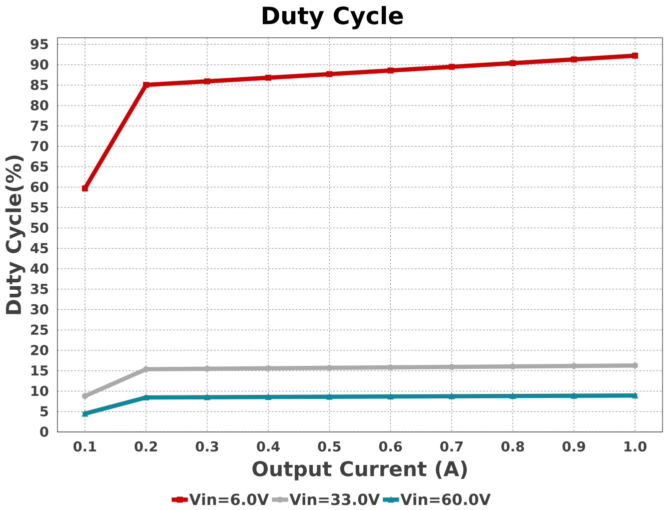
## Electrical BOM

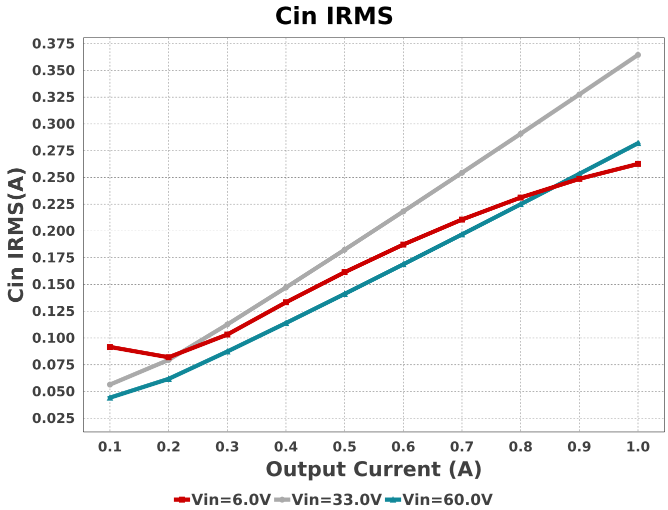
| Name | Manufacturer | Part Number | Properties | Qty | Price | Footprint |
|---|---|---|---|---|---|---|
| Cboot | MuRata | GRM155R71C104KA88D<br>Series= X7R | Cap= 100.0 nF<br>ESR= 1.0 mOhm<br>VDC= 16.0 V<br>IRMS= 0.0 A | 1 | $0.01 | 0402 3 mm² |
| Cin | TDK | C5750X7R2A475M230KA<br>Series= X7R | Cap= 4.7 uF<br>ESR= 1.5 mOhm<br>VDC= 100.0 V<br>IRMS= 5.5 A | 1 | $0.86 | <br>2220_280 54 mm² |
| Cinx | MuRata | GRM188R72A104KA35D<br>Series= X7R | Cap= 100.0 nF<br>ESR= 1.0 mOhm<br>VDC= 100.0 V<br>IRMS= 3.85 A | 1 | $0.04 | 0603 5 mm² |
| Cout | Kemet | C0805C106K8PACTU<br>Series= X5R | Cap= 10.0 uF<br>ESR= 3.0 mOhm<br>VDC= 10.0 V<br>IRMS= 11.43 A | 2 | $0.03 | 0805 7 mm² |
| L1 | NIC Components | NPI31W330MTRF | L= 33.0 µH<br>100.0 mOhm | 1 | $0.26 | <br>IND_NPI31W 172 mm² |
| Rfbb | Vishay-Dale | CRCW040219K1FKED<br>Series= CRCW..e3 | Res= 19.1 kOhm<br>Power= 63.0 mW<br>Tolerance= 1.0% | 1 | $0.01 | 0402 3 mm² |
| Rfbt | Vishay-Dale | CRCW0402100KFKED<br>Series= CRCW..e3 | Res= 100.0 kOhm<br>Power= 63.0 mW<br>Tolerance= 1.0% | 1 | $0.01 | 0402 3 mm² |

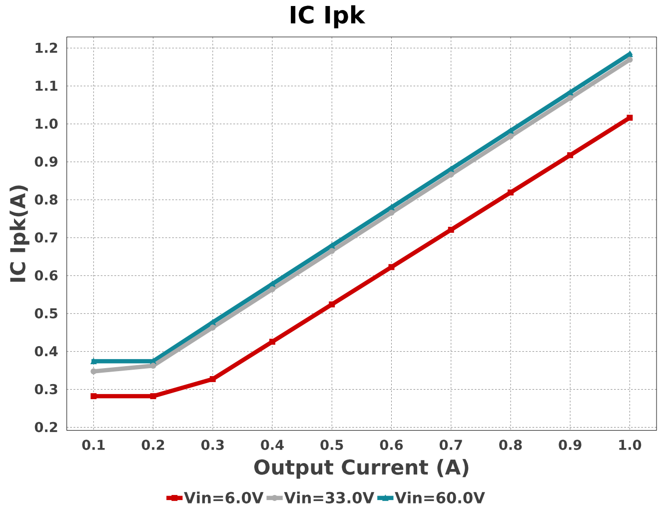
| Name | Manufacturer | Part Number | Properties | Qty | Price | Footprint |
|---|---|---|---|---|---|---|
| U1 | Texas Instruments | LMR51610XQDBVRQ1 | Switcher | 1 | $0.53 | DBV0006A 15 mm² |

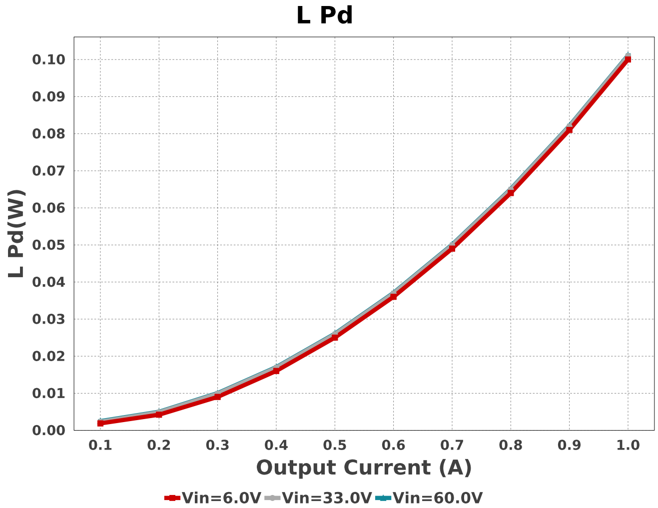


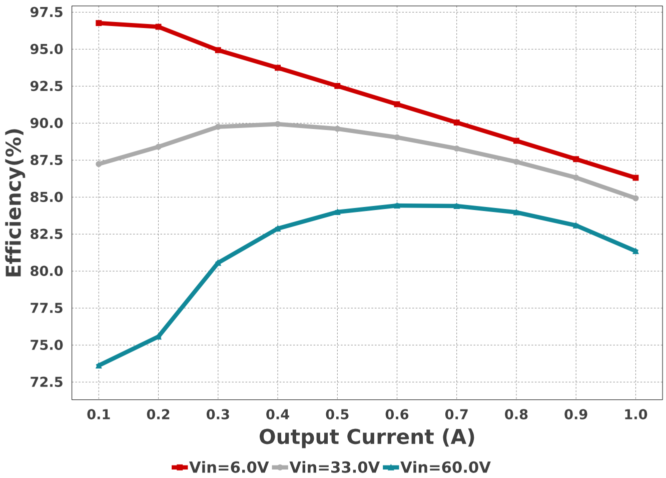



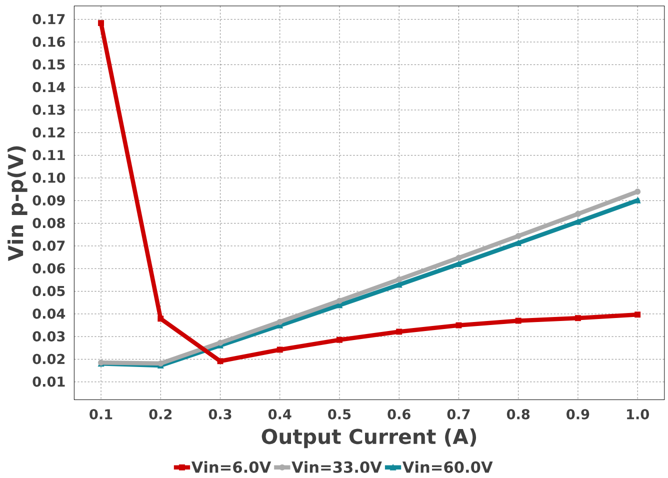



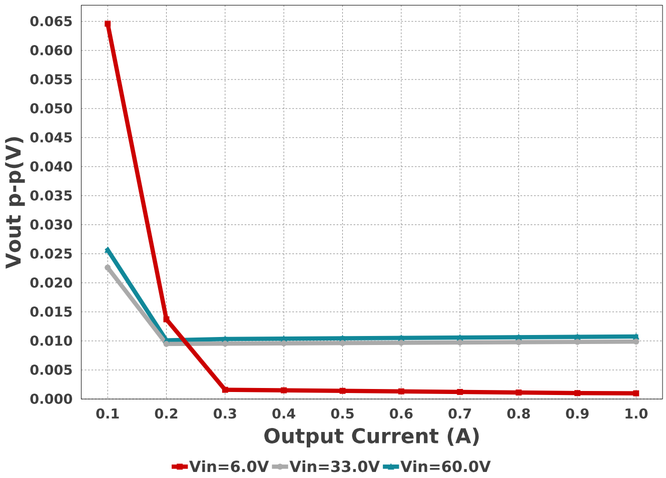
## Efficiency



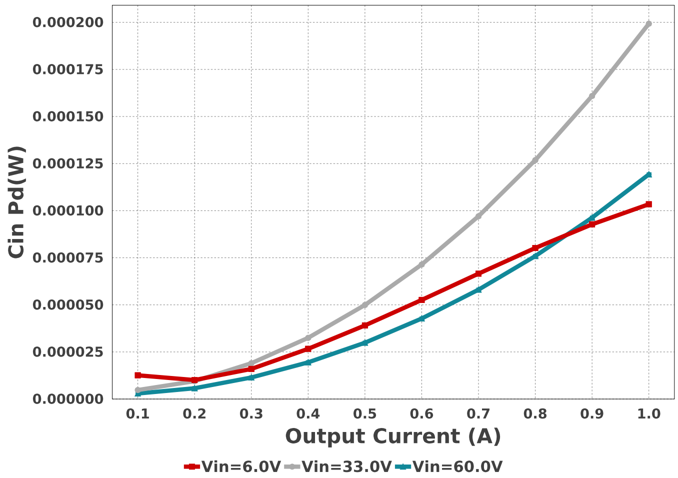

## Vin p-p



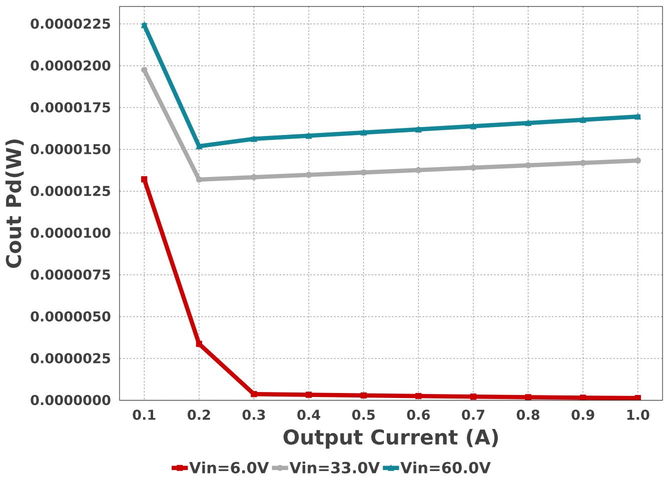

## Vout p-p



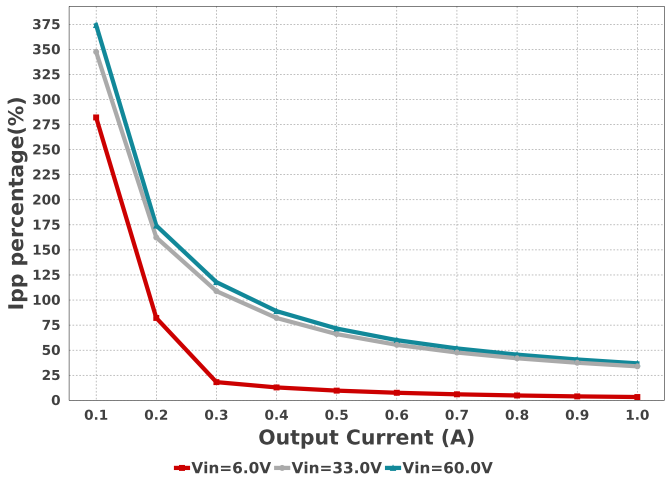

## Cin Pd

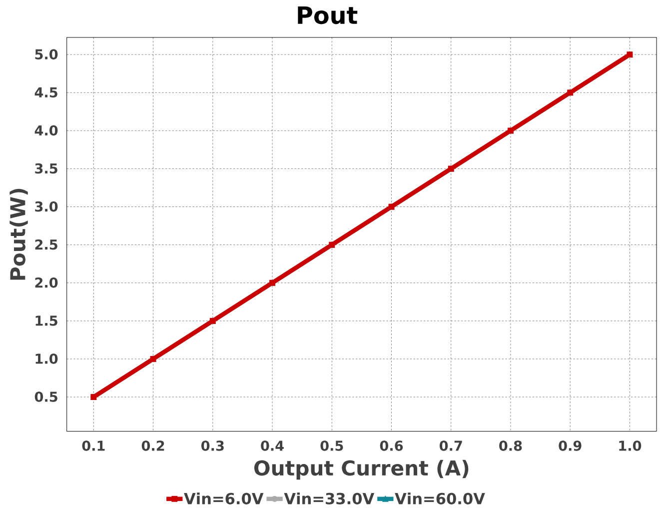


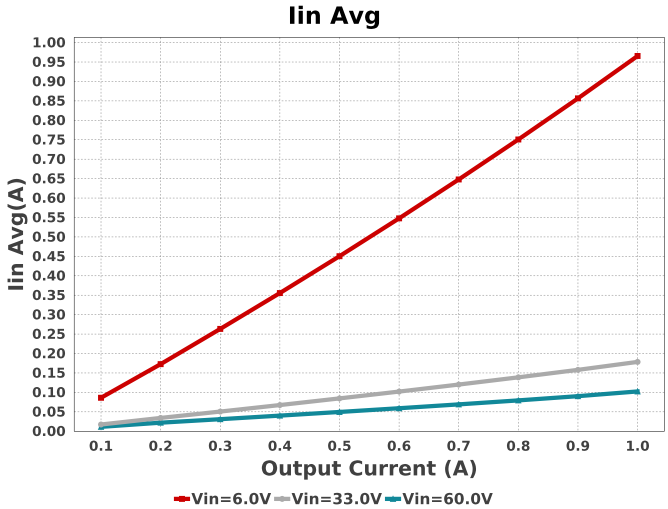

## Cout Pd

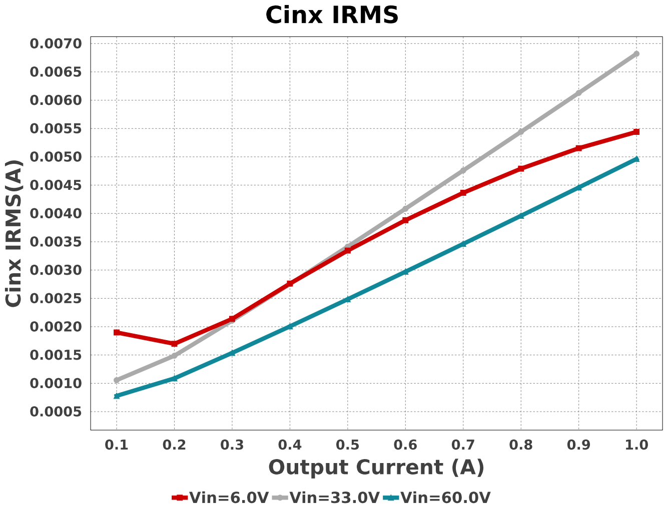


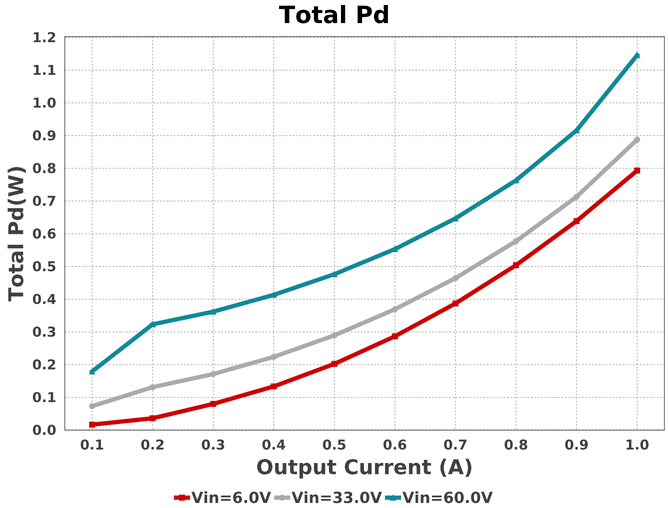

## Ipp percentage

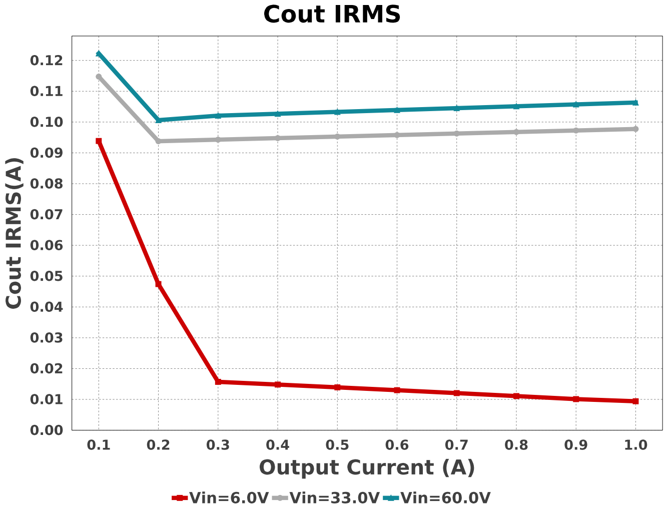


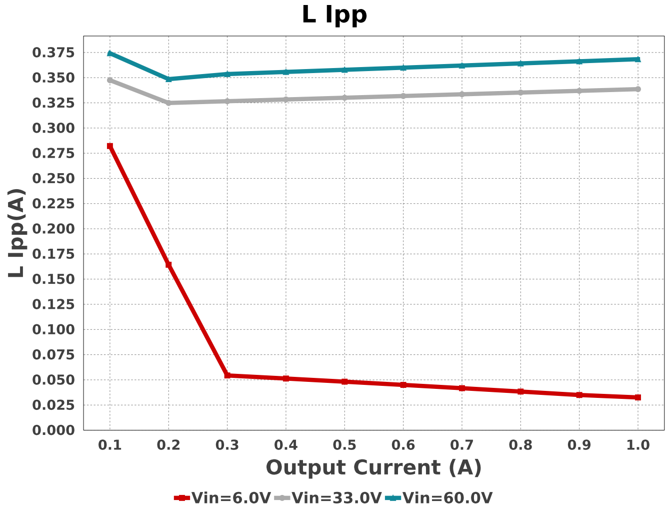

Pout
Pout(W)
Output Current (A)
Vin=6.0V Vin=33.0V Vin=60.0V

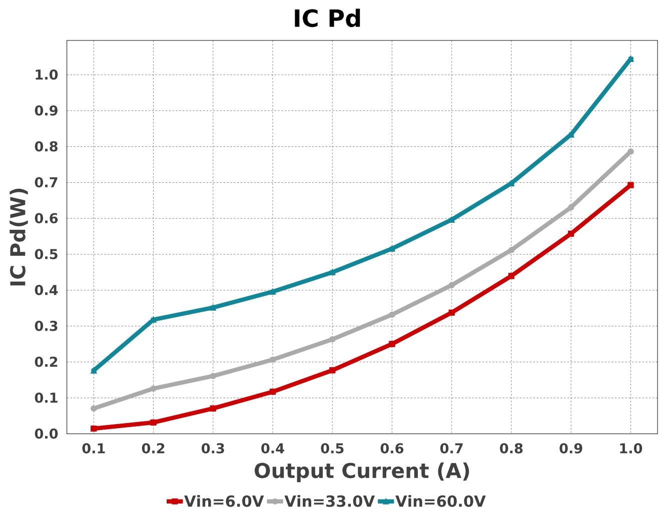

Iin Avg
Iin Avg(A)
Output Current (A)
Vin=6.0V Vin=33.0V Vin=60.0V

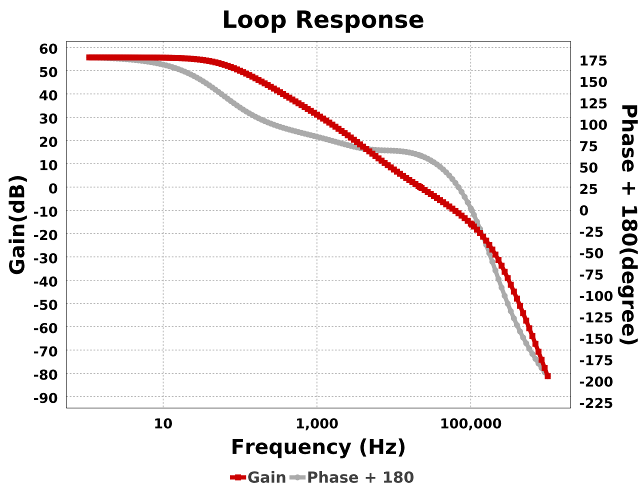

Cinx IRMS
Cinx IRMS(A)
Output Current (A)
Vin=6.0V Vin=33.0V Vin=60.0V

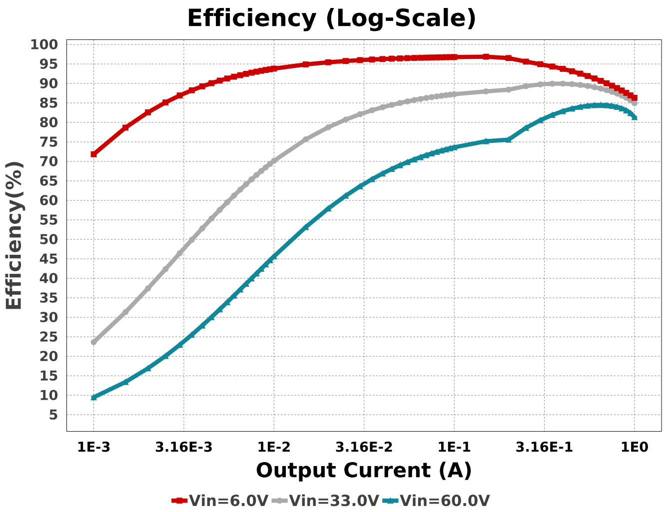

Total Pd
Total Pd(W)
Output Current (A)
Vin=6.0V Vin=33.0V Vin=60.0V


Cout IRMS
Cout IRMS(A)
Output Current (A)
Vin=6.0V Vin=33.0V Vin=60.0V


L Ipp
L Ipp(A)
Output Current (A)
Vin=6.0V Vin=33.0V Vin=60.0V




## Operating Values

| # | Name | Value | Category | Description |
|---|---|---|---|---|
| 1. | Cin IRMS | 281.972 mA | Capacitor | Input capacitor RMS ripple current |
| 2. | Cin Pd | 119.26 µW | Capacitor | Input capacitor power dissipation |
| 3. | Cinx IRMS | 4.963 mA | Capacitor | Bulk capacitor RMS ripple current |
| 4. | Cinx Pd | 24.628 nW | Capacitor | Bulk capacitor power dissipation |
| 5. | Cout IRMS | 106.333 mA | Capacitor | Output capacitor RMS ripple current |
| 6. | Cout Pd | 16.96 µW | Capacitor | Output capacitor power dissipation |
| 7. | IC Ipk | 1.184 A | IC | Peak switch current in IC |
| 8. | IC Pd | 1.044 W | IC | IC power dissipation |
| 9. | IC Tj | 113.553 degC | IC | IC junction temperature |
| 10. | IC Tolerance | 12.0 mV | IC | IC Feedback Tolerance |
| 11. | ICThetaJA Effective | 80.0 degC/W | IC | Effective IC Junction-to-Ambient Thermal Resistance |
| 12. | Iin Avg | 102.43 mA | IC | Average input current |
| 13. | Ipp percentage | 36.835 % | Inductor | Inductor ripple current percentage (with respect to average inductor current) |
| 14. | L Ipp | 368.35 mA | Inductor | Peak-to-peak inductor ripple current |
| 15. | L Pd | 101.13 mW | Inductor | Inductor power dissipation |
| 16. | Cin Pd | 119.26 µW | Power | Input capacitor power dissipation |
| 17. | Cinx Pd | 24.628 nW | Power | Bulk capacitor power dissipation |
| 18. | Cout Pd | 16.96 µW | Power | Output capacitor power dissipation |
| 19. | IC Pd | 1.044 W | Power | IC power dissipation |
| 20. | L Pd | 101.13 mW | Power | Inductor power dissipation |
| 21. | Total Pd | 1.146 W | Power | Total Power Dissipation |
| 22. | BOM Count | 9 | System Information | Total Design BOM count |
| 23. | Cross Freq | 21.938 kHz | System Information | Bode plot crossover frequency |
| 24. | Duty Cycle | 8.93 % | System Information | Duty cycle |
| 25. | Efficiency | 81.355 % | System Information | Steady state efficiency |
| 26. | FootPrint | 268.0 $mm^2$ | System Information | Total Foot Print Area of BOM components |

| # | Name | Value | Category | Description |
|---|---|---|---|---|
| 27. | Frequency | 400.0 kHz | System Information | Switching frequency |
| 28. | Gain Marg | -16.128 dB | System Information | Bode Plot Gain Margin |
| 29. | Inductor ripple current requirement used for Inductor selection | 40.0 % | System Information | Custom Inductor ripple current (% of average inductor current) requirement used for Inductor selection |
| 30. | Iout | 1.0 A | System Information | Iout operating point |
| 31. | Iout transient step used for Cout calculations | 500.0 mA | System Information | Custom Transient current step requirement that was used for Cout selection (A). |
| 32. | Low Freq Gain | 55.696 dB | System Information | Gain at 1Hz |
| 33. | Mode | CCM | System Information | Conduction Mode |
| 34. | Overshoot Value | 76.964 mV | System Information | Theoretical Vout Overshoot Value |
| 35. | Phase Marg | 64.419 deg | System Information | Bode Plot Phase Margin |
| 36. | Pout | 5.0 W | System Information | Total output power |
| 37. | Total BOM | $1.78 | System Information | Total BOM Cost |
| 38. | Undershoot Value | 113.891 mV | System Information | Theoretical Vout Undershoot Value |
| 39. | Vin | 60.0 V | System Information | Vin operating point |
| 40. | Vin p-p | 90.113 mV | System Information | Peak-to-peak input voltage |
| 41. | Vout | 5.0 V | System Information | Operational Output Voltage |
| 42. | Vout Actual | 4.988 V | System Information | Vout Actual calculated based on selected voltage divider resistors |
| 43. | Vout Ripple requirement used for Cout calculations | 3.0 % | System Information | Custom maximum output ripple requirement that was used for Cout selection(% of Vout). |
| 44. | Vout Tolerance | 3.222 % | System Information | Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable |
| 45. | Vout p-p | 10.76 mV | System Information | Peak-to-peak output ripple voltage |
| 46. | Vout transient requirement used for Cout calculations | 3.0 % | System Information | Custom Transient voltage change requirement that was used for Cout selection (% of Vout). |

## Design Inputs

| Name | Value | Description |
|---|---|---|
| Iout | 1.0 | Maximum Output Current |
| VinMax | 60.0 | Maximum input voltage |
| VinMin | 6.0 | Minimum input voltage |
| Vout | 5.0 | Output Voltage |
| base_pn | LMR51610-Q1 | Base Product Number |
| source | DC | Input Source Type |
| Ta | 30.0 | 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

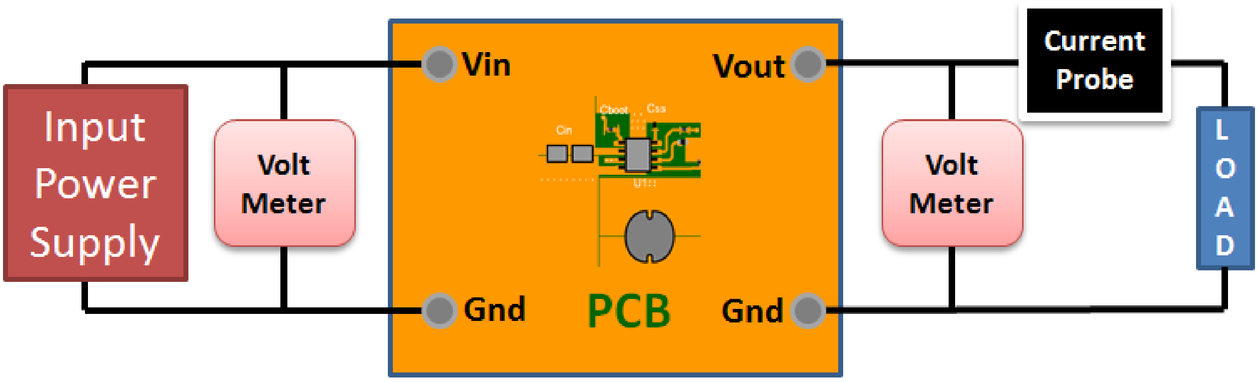
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 6.0V 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

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2. Master key : 7627B22B384BF7EAE268D1E513DC6F75[v1]

3. **LMR51610-Q1** Product Folder : http://www.ti.com/product/LMR51610%2DQ1 : contains the data sheet and other resources.

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