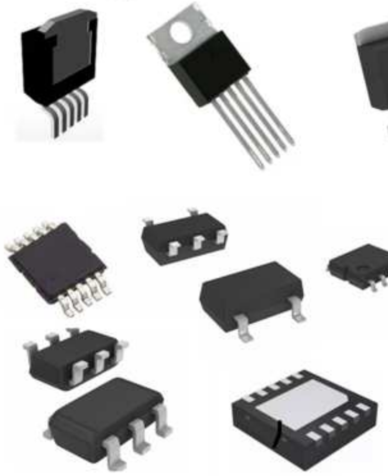
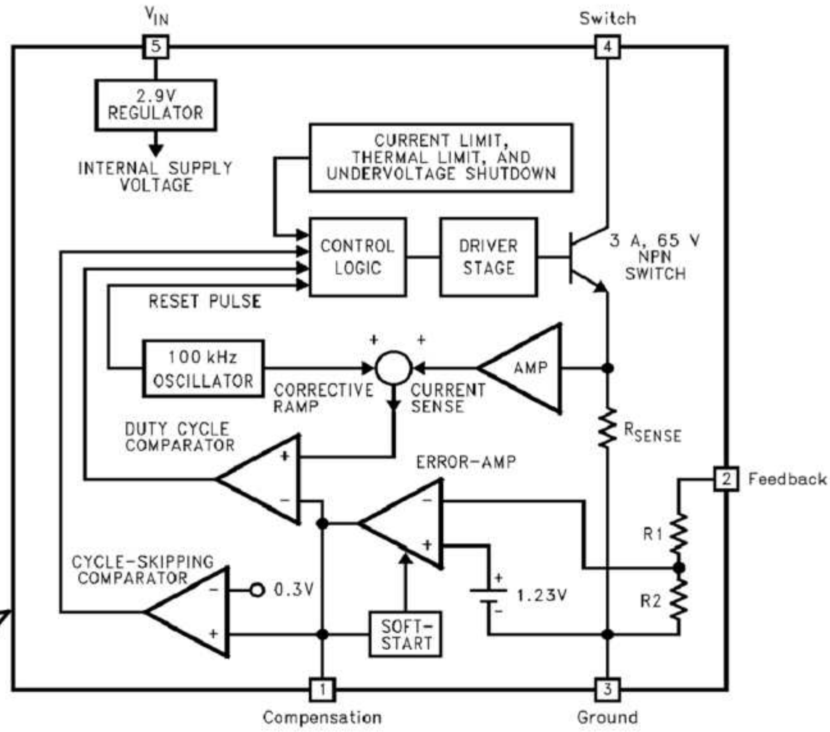
Switching Voltage Regulator





Linear Voltage Regulator		Switching Voltage Regulator	
Pros	Cons	Pros	Cons
Simple circuit configuration	Relatively poor efficiency	High efficiency	More external parts required
Few external parts	Considerable heat generation	Low heat generation	Complicated design
Low noise	Only step-down (buck) operation کاهنده	Boost/buck/ negative voltage operation possible	Increased noise

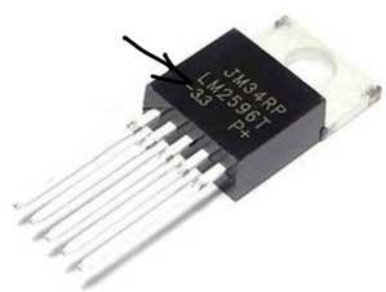
رگولاتور
~~خطی~~
سوئیچینگ

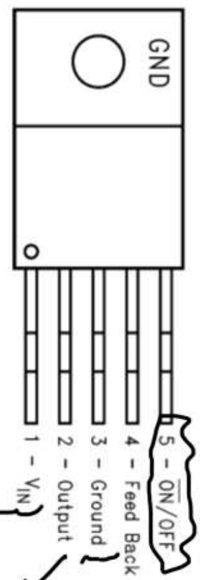
ایزوله
غیرایزوله

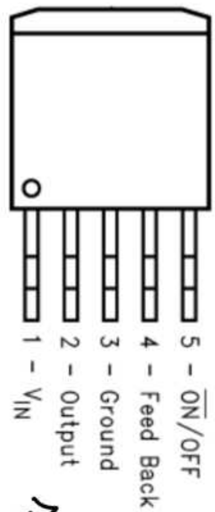
ولتاژ ثابت
~~جریان ثابت~~

ثابت fix
متغیر

افزاینده پله
کاهنده پله
[illegible]







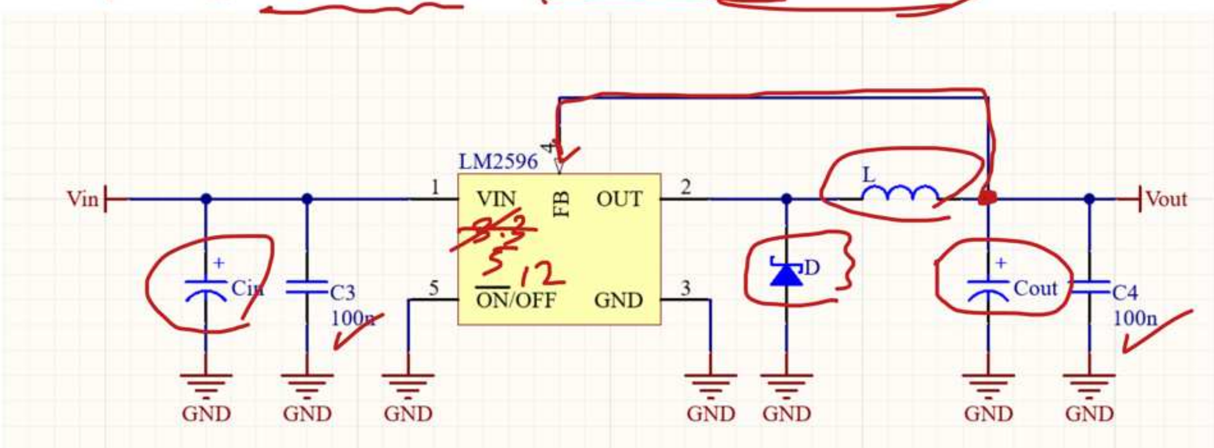
LM2596 S - 5

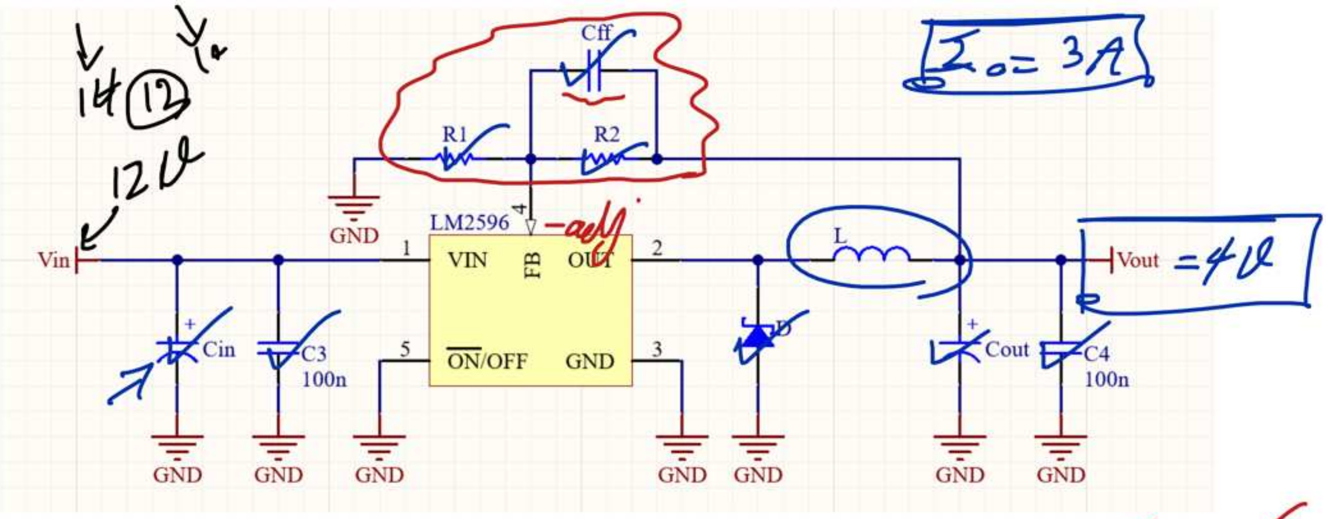
HV - 3.3

LM2596

3.0 A, Step-Down Switching Regulator

- 3.3-V, 5-V, 12-V, and adjustable output versions
- Adjustable version output voltage range: 1.2-V to 37-V ±4% maximum over line and load conditions
- Available in TO-220 and TO-263 packages
- 3-A output load current
- Input voltage range up to 40 V **(57V for HV Version)** 5
- Requires only four external components
- Excellent line and load regulation specifications
- 150-kHz fixed-frequency internal oscillator F_{sw}
- TTL shutdown capability
- Low power standby mode, I_Q, typically 80 μA
- High efficiency
- Uses readily available standard inductors
- Thermal shutdown and current-limit protection





$$V_{out} = V_{Ref} * \left(1+\frac{R_2}{R_1}\right)$$

$\boxed{V_{ref}=1.23V}$ $\boxed{1k\Omega \le R_1 \le 5k\Omega}$: طراحی شبکه فیدبک ①

$$\Rightarrow 4 = 1.23\left(1+\frac{R_2}{1\times10^3}\right) \xRightarrow{\text{Solve}} \boxed{R_2 = 2.252k\Omega} \xRightarrow[\%1]{\text{STD}} \boxed{R_2 = 2.26k\Omega}$$

$$\boxed{R_1 = 1k\Omega}$$

$$C_{ff} = \frac{1}{31\times10^3 \times R_2} = \frac{1}{31\times10^3\times2.26\times10^3} \xRightarrow{\text{Calc}} \boxed{C_{ff} = 14.27nF} \xRightarrow{\text{STD}} \boxed{C_{ff} = 15nF}$$

$\boxed{0.1nF \le C_{ff} \le 33nF}$

$\boxed{V_{out} \le 10}$ $\boxed{C_{ff} = 10nF}$

$$I_{Cin}^{RMS} = 0.5\, I_o^{max} = 0.5\times3A \xRightarrow{\text{Calc}} \boxed{I_{Cin}^{RMS} = 1.5A}$$: محاسبه Cin ②

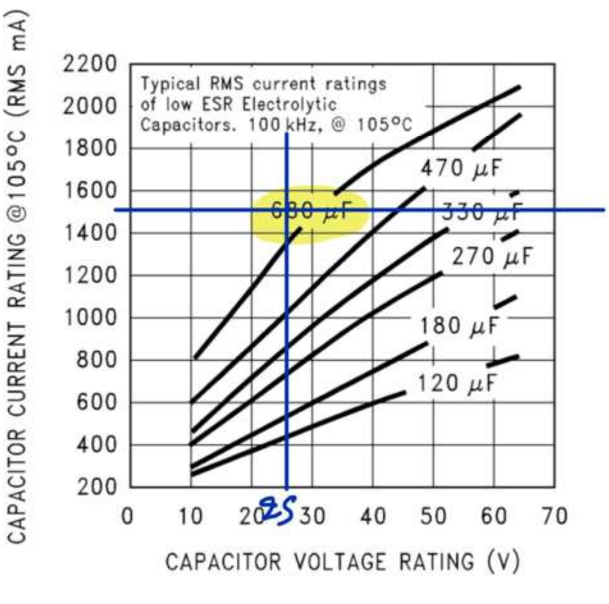
$$V_{cin} = 1.5\, V_{in}^{max} = 1.5\times12 \xRightarrow{\text{Calc}} \boxed{V_{cin} = 18V}$$

$$\xRightarrow{\text{STD}} \boxed{V_{cin} = 25}$$

$$\boxed{C_{in} = 680\mu F / 25V}$$

SMD . Low ESR

$\Leftarrow$



③ محاسبه‌ی خازن خروجی:

$V_{cout} = 1.5\, V_{out} = 1.5 \times 4 \xRightarrow{calc} \boxed{V_{cout} = 6\,V}$

$\xRightarrow{STD} \boxed{V_{cout} = 6.3\,V}$

$\boxed{C_{out} \leq 820\,\mu F}$

$\boxed{C_{out} = 330\,\mu F / 6.3\,V}$

OUTPUT VOLTAGE (V)	THROUGH-HOLE OUTPUT CAPACITOR			SURFACE-MOUNT OUTPUT CAPACITOR		
	PANASONIC HFQ SERIES (µF/V)	NICHICON PL SERIES (µF/V)	FEEDFORWARD CAPACITOR	AVX TPS SERIES (µF/V)	SPRAGUE 595D SERIES (µF/V)	FEEDFORWARD CAPACITOR
2	820/35	820/35	33 nF	330/6.3	470/4	33 nF
4	560/35	470/35	10 nF	330/6.3	390/6.3	10 nF
6	470/25	470/25	3.3 nF	220/10	330/10	3.3 nF
9	330/25	330/25	1.5 nF	100/16	180/16	1.5 nF
1 2	330/25	330/25	1 nF	100/16	180/16	1 nF
1 5	220/35	220/35	680 pF	68/20	120/20	680 pF
2 4	220/35	150/35	560 pF	33/25	33/25	220 pF
2 8	100/50	100/50	390 pF	10/35	15/50	220 pF

$I_D = 1.3\, I_o^{max} = 1.3 \times 3 \xRightarrow{calc} \boxed{I_D \geq 3.9\,A}$

$V_R = 1.25\, V_{in}^{max} = 1.25 \times 12 \xRightarrow{calc} \boxed{V_R \geq 15\,V}$

دیود حتما شاتکی باشد

$\boxed{D = SK54}$

VR	3-A DIODES				4-A TO 6-A DIODES			
	SURFACE-MOUNT		THROUGH-HOLE		SURFACE-MOUNT		THROUGH-HOLE	
	SCHOTTKY	ULTRA FAST RECOVERY	SCHOTTKY	ULTRA FAST RECOVERY	SCHOTTKY	ULTRA FAST RECOVERY	SCHOTTKY	ULTRA FAST RECOVERY
		All of these diodes are rated to at least 50V.	1N5820	All of these diodes are rated to at least 50V.		All of these diodes are rated to at least 50V.	SR502	All of these diodes are rated to at least 50V.
20 V	SK32		SR302				1N5823	
			MBR320				SB520	
	30WQ03		1N5821					
30 V	SK33		MBR330		50WQ03		SR503	
			31DQ03				1N5824	
			1N5822				SB530	
40 V	SK34		SR304		50WQ04		SR504	
	MBRS340		MBR340				1N5825	
	30WQ04	MURS320	31DQ04	MUR320		MURS620	SB540	MUR620
50 V	SK35	30WF10	SR305			50WF10		HER601
or	MBRS360		MBR350		50WQ05		SB550	
More	30WQ05		31DQ05				50SQ080	

$I_D = 5A$

$V_R = 40\,V$

$V_f = 0.55\,V$

V_D

$$\underset{V.\mu s}{ET} = (\overset{12}{V_{in}^{Max}} - \overset{4}{V_{Out}} - \overset{1.16}{V_{sat}}) * \left(\frac{\overset{4}{V_{out}} + \overset{0.55}{V_D}}{\underset{L2}{V_{in}^{Max}} - \underset{1.16}{V_{sat}} + \underset{0.55}{V_D}}\right) * \frac{10^6 \rightarrow 10^6}{150Khz \rightarrow f_{sw}}$$

$$Et = (12 - 4 - 1.16) \times \frac{4 + 0.55}{12 - 1.16 + 0.55} \times \frac{10^6}{150 \times 10^3} \xrightarrow{calc} \boxed{E.T = 18.216 V.\mu s}$$

$$\boxed{V_{sat} = 1.16 V}$$

$$\boxed{L = 33 \mu H / 3.5 A}$$

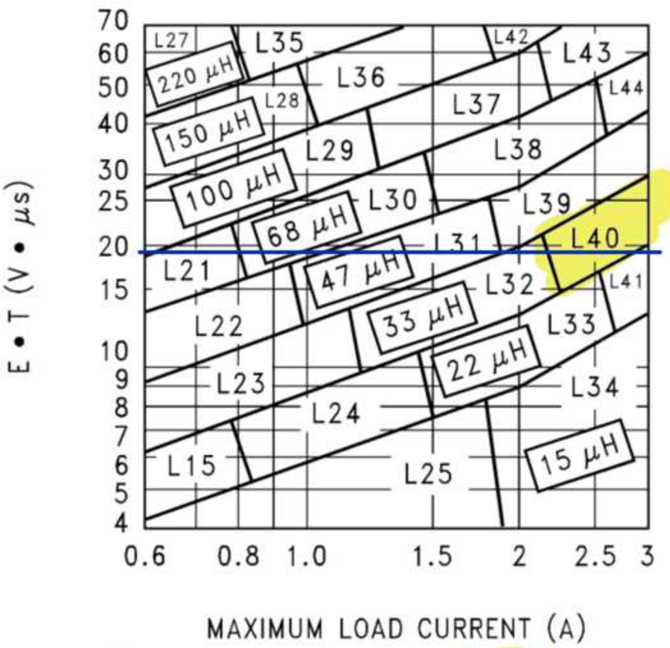


Figure 9-8. LM2596-ADJ

	INDUCTANCE (µH)	CURRENT (A)
L15	22	0.99
L21	68	0.99
L22	47	1.17
L23	33	1.40
L24	22	1.70
L25	15	2.10
L26	330	0.80
L27	220	1.00
L28	150	1.20
L29	100	1.47
L30	68	1.78
L31	47	2.20
L32	33	2.50

	INDUCTANCE (µH)	CURRENT (A)
L33	22	3.10
L34	15	3.40
L35	220	1.70
L36	150	2.10
L37	100	2.50
L38	68	3.10
L39	47	3.50
L40	33	3.50
L41	22	3.50
L42	150	2.70
L43	100	3.40
L44	68	3.40

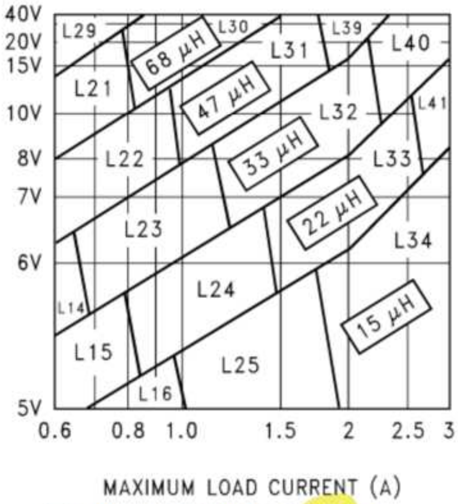


Figure 9-5. LM2596-3.3

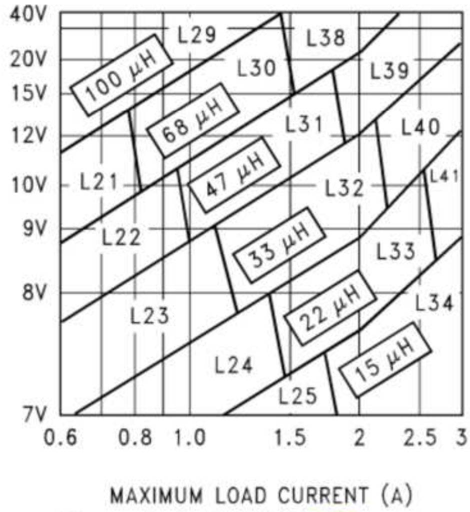


Figure 9-6. LM2596-5.0

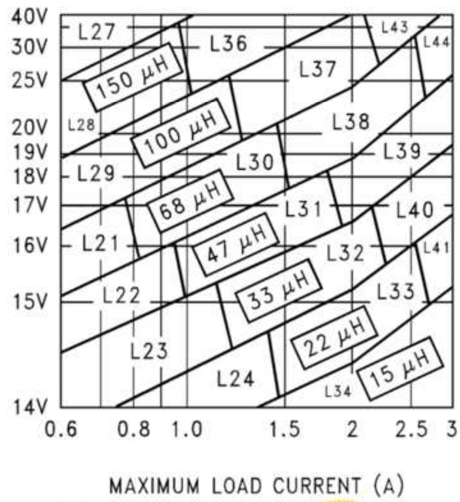
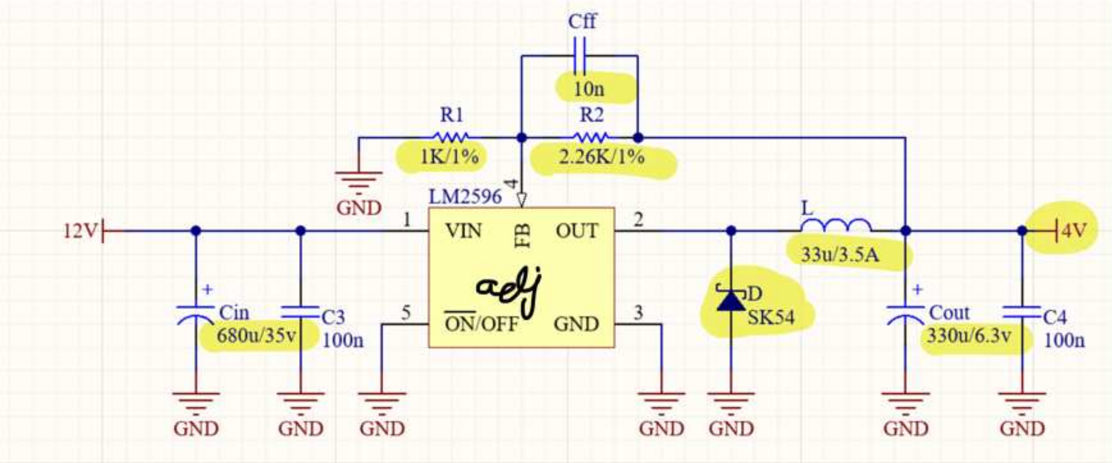
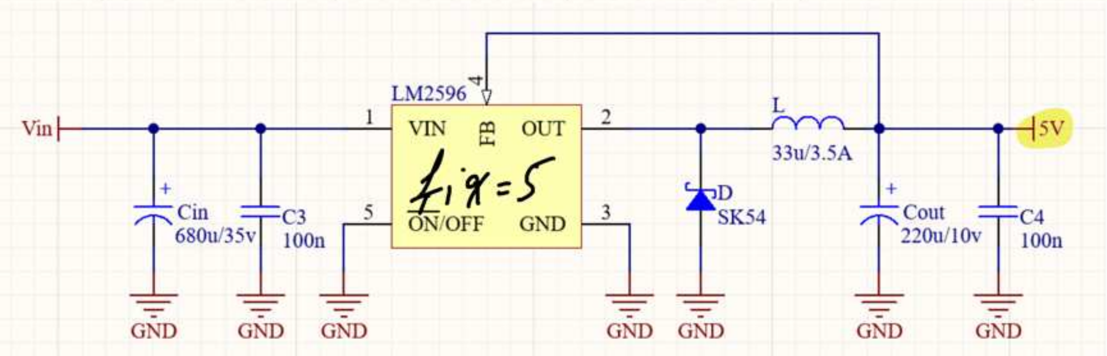


Figure 9-7. LM2596-12





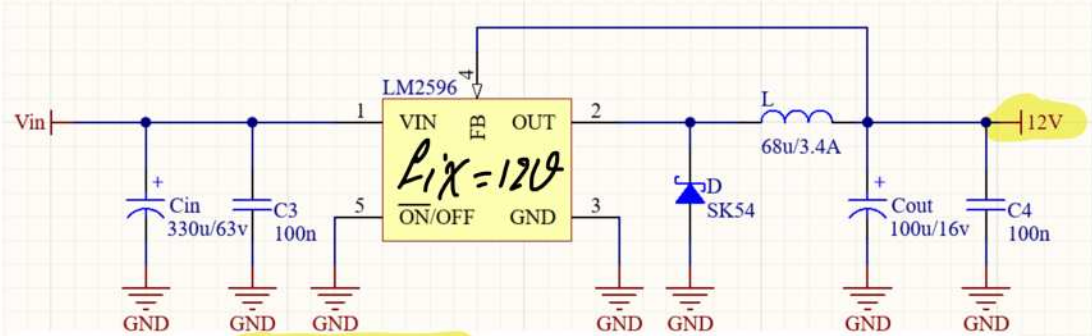
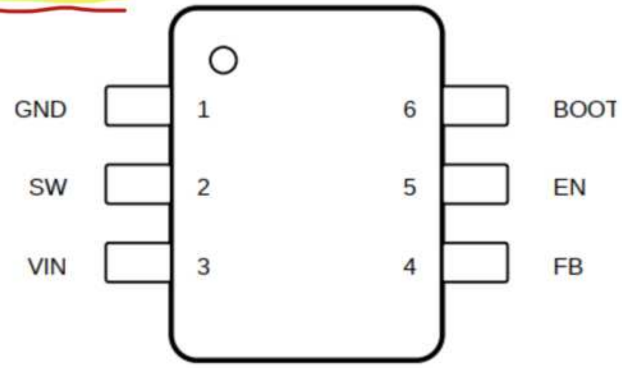


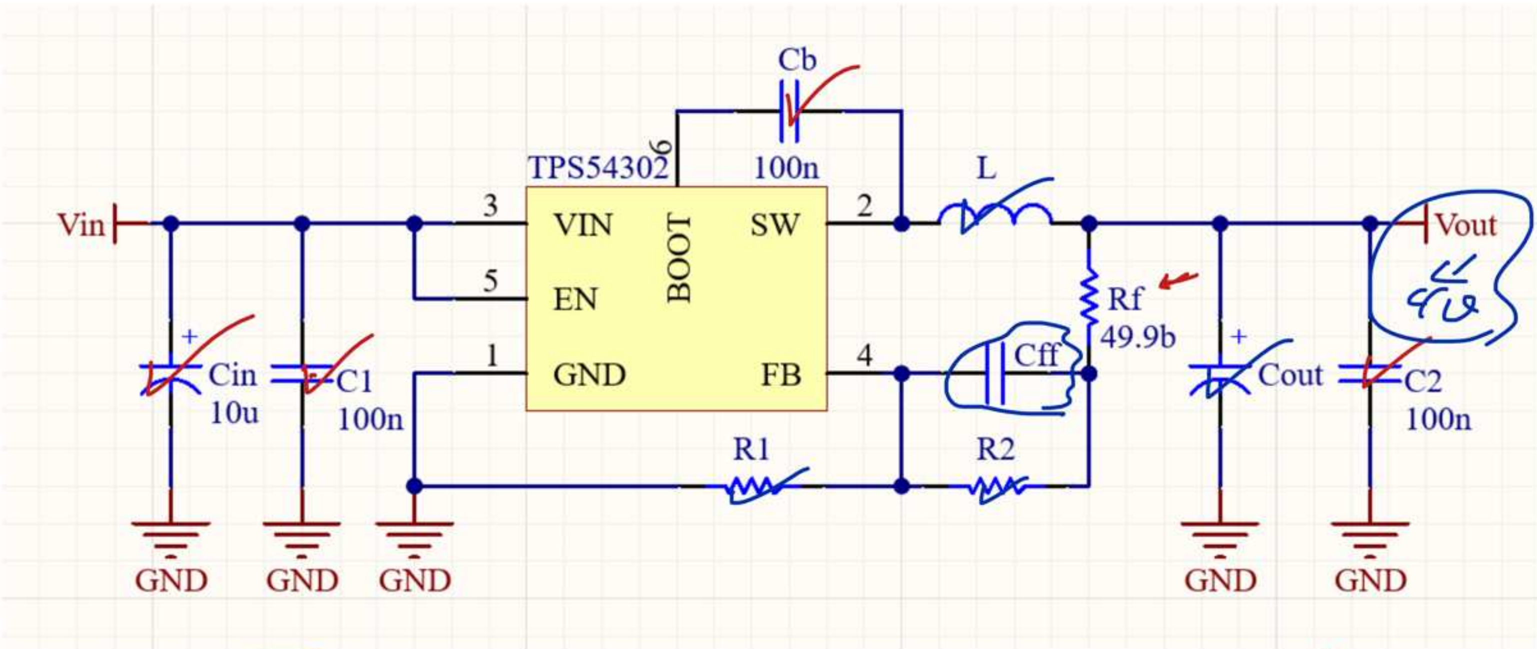
Table 9-3. LM2596 Fixed Voltage Quick Design Component Selection Table

CONDITIONS			INDUCTOR		OUTPUT CAPACITOR			
					THROUGH-HOLE ELECTROLYTIC		SURFACE-MOUNT TANTALUM	
OUTPUT VOLTAGE (V)	LOAD CURRENT (A)	MAX INPUT VOLTAGE (V)	INDUCTANCE (µH)	INDUCTOR (#)	PANASONIC HFQ SERIES (µF/V)	NICHICON PL SERIES (µF/V)	AVX TPS SERIES (µF/V)	SPRAGUE 595D SERIES (µF/V)
3.3	3	5	22	L41	470/25	560/16	330/6.3	390/6.3
		7	22	L41	560/35	560/35	330/6.3	390/6.3
		10	22	L41	680/35	680/35	330/6.3	390/6.3
		40	33	L40	560/35	470/35	330/6.3	390/6.3
	2	6	22	L33	470/25	470/35	330/6.3	390/6.3
		10	33	L32	330/35	330/35	330/6.3	390/6.3
		40	47	L39	330/35	270/50	220/10	330/10
5	3	8	22	L41	470/25	560/16	220/10	330/10
		10	22	L41	560/25	560/25	220/10	330/10
		15	33	L40	330/35	330/35	220/10	330/10
		40	47	L39	330/35	270/35	220/10	330/10
	2	9	22	L33	470/25	560/16	220/10	330/10
		20	68	L38	180/35	180/35	100/10	270/10
		40	68	L38	180/35	180/35	100/10	270/10
12	3	15	22	L41	470/25	470/25	100/16	180/16
		18	33	L40	330/25	330/25	100/16	180/16
		30	68	L44	180/25	180/25	100/16	120/20
		40	68	L44	180/35	180/35	100/16	120/20
	2	15	33	L32	330/25	330/25	100/16	180/16
		20	68	L38	180/25	180/25	100/16	120/20
		40	150	L42	82/25	82/25	68/20	68/25

TPS54302 4.5-V to 28-V Input, 3-A Output, EMI Friendly Synchronous Step-Down Converter



- 4.5-V to 28-V Wide Input Voltage Range
- Integrated 85-mΩ and 40-mΩ MOSFETs for 3-A, Continuous Output Current
- Low 2-μA Shutdown, 45-μA Quiescent Current
- Internal 5-mS Soft-Start
- Fixed 400-kHz Switching Frequency
- Frequency Spread Spectrum to Reduce EMI
- Advanced Eco-mode™ Pulse Skip
- Peak Current Mode Control
- Internal Loop Compensation
- Overcurrent Protection for Both MOSFETs with Hiccup Mode Protection
- Over Voltage Protection
- Thermal Shutdown



① طراحی شبکه فیدبک :

$\boxed{V_{ref} = 0.6}$ $\boxed{V_{out} = 4V}$

$\boxed{R_1 = 100k\Omega}$

$$V_{out} = V_{Ref} * \left(1 + \frac{R_2}{R_1}\right)$$

$$4 = 0.6\left(1 + \frac{R_2}{100\times10^3}\right) \xRightarrow{solve} \boxed{R_2 = 17.647k\Omega} \xRightarrow{STD} \boxed{R_2 = 17.8k\Omega}$$

② محاسبه سلف :

$\boxed{I_{out} = 3A}$ $\boxed{F_{sw} = 400kHz}$

$$L_{min} = \frac{\overset{4}{V_{out}} * (\overset{12}{V_{in}^{Max}} - \overset{4}{V_{Out}})}{\underset{12}{V_{in}^{Max}} * K_{ind} * \underset{3A}{I_{out}} * \underset{400kHz}{F_{sw}}} \Rightarrow L_{min} = \frac{4(12-4)}{12\times0.3\times3\times400\times10^3}$$

$0.2 \leq k \leq 0.4 \Rightarrow \boxed{k = 0.3}$

$\xRightarrow{calc} \boxed{L_{min} = 7.4\mu H} \xRightarrow{STD} \boxed{L_{min} = 10\mu H}$

$$\beta = \frac{V_{out} * (V_{in}^{Max} - V_{Out})}{V_{in}^{Max} * L * F_{sw}} \Rightarrow \beta = \frac{4(12-4)}{12 \times 10\times10^{-6} \times 400\times10^{-6}} \xrightarrow{calc} \boxed{\beta = \frac{2}{3}}$$

$$I_L^{Peak} = I_o^{max} + \frac{\beta}{1.6} = 3 + \frac{1}{1.6}\times\frac{2}{3} \xrightarrow{calc} \boxed{I_L^{Peak} = 3.416A}$$

$$I_L^{RMS} = \sqrt{(I_o^{max})^2 + \frac{1}{12}\left(\frac{\beta}{0.8}\right)^2} = \sqrt{(3)^2 + \frac{1}{12}\left(\frac{1}{0.8}\times\frac{2}{3}\right)^2}$$

$$\Rightarrow \boxed{I_L^{RMS} = 3.01A} \Rightarrow \boxed{L = 10\mu H / 3.5A}$$

$\boxed{\Delta V_{out} = 0.2}$ %5 × 4 = 0.2V

: Cout ~ 60 ③

$$C_o^1 > \frac{2\times\Delta I_{out}}{f_{sw}\times\Delta V_{out}} = \frac{2\times 2}{400\times10^3\times0.2} \xrightarrow{calc} \boxed{C_o^{min} \geq 50\mu F}$$

$$C_o^2 > \frac{1}{8 f_{sw}} \times \frac{I_{ripple}}{V_{out}^{ripple}}$$

$0.2 \leq k \leq 0.4 \rightarrow 0.3$

$$V_{out}^{r} = \%1\ V_{out} = \frac{1}{100}\times 4 \Rightarrow \boxed{V_o^{r} = 0.04}$$

$$I_{ripple} = K_{ind} \times I_o^{max} = 0.3\times 3 \xrightarrow{calc}$$

$$\boxed{I_{ripple} = 0.9A}$$

$$C_{o2} > \frac{1}{8 f_{sw}} \times \frac{I_{ripple}}{V_{out}^{ripple}} = \frac{1}{8\times 400\times 10^{3}} \times \frac{0.9}{0.04} \xrightarrow{cal}$$

$$\boxed{C_{o2}^{min} = 7\mu f}$$

$$\boxed{C_{o1}^{min} = 50\mu f} \Rightarrow C_o = 50+7 \Rightarrow \boxed{C_o = 57\mu f} \xrightarrow{STD} \boxed{C_o = 56\mu f}$$

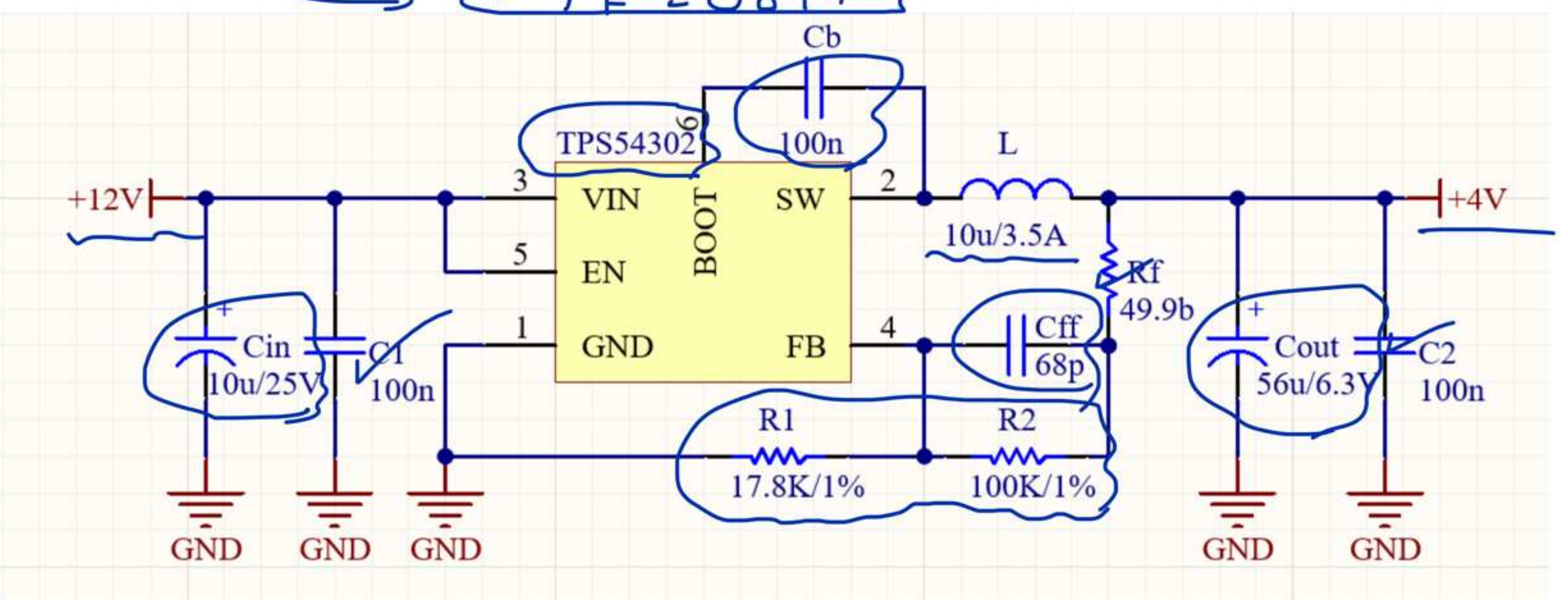
$$V_{cap} = 1.5\times 4 = 6V \xrightarrow{STD} \boxed{V_{cout} = 6.3V}$$

$$\boxed{C_{out} = 56\mu f / 6.3V}, \quad \boxed{C_{in} = 10\mu f / 25V}$$

$$V_{cin} = 1.5\times V_{in}^{max} = 1.5\times 12 = 18V \xrightarrow{STD} \boxed{V_{cin} = 25V}$$

$$C_{ff} = \frac{V_{out}\times C_{out}}{32 R_2} = \frac{4\times 56\times 10^{-6}}{32\times 100\times 10^{3}} \xrightarrow{cal} \boxed{C_{ff} = 70 pf}$$

$$\xrightarrow{STD} \boxed{C_{ff} = 68 pf}$$

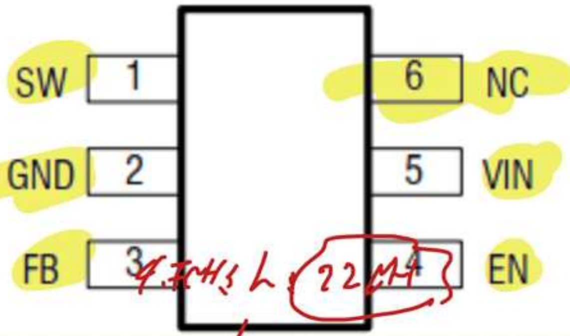


2A,High Efficiency 1.2MHz Current Mode Step-Up Converter

~~V_o~~ $< V_{in}$

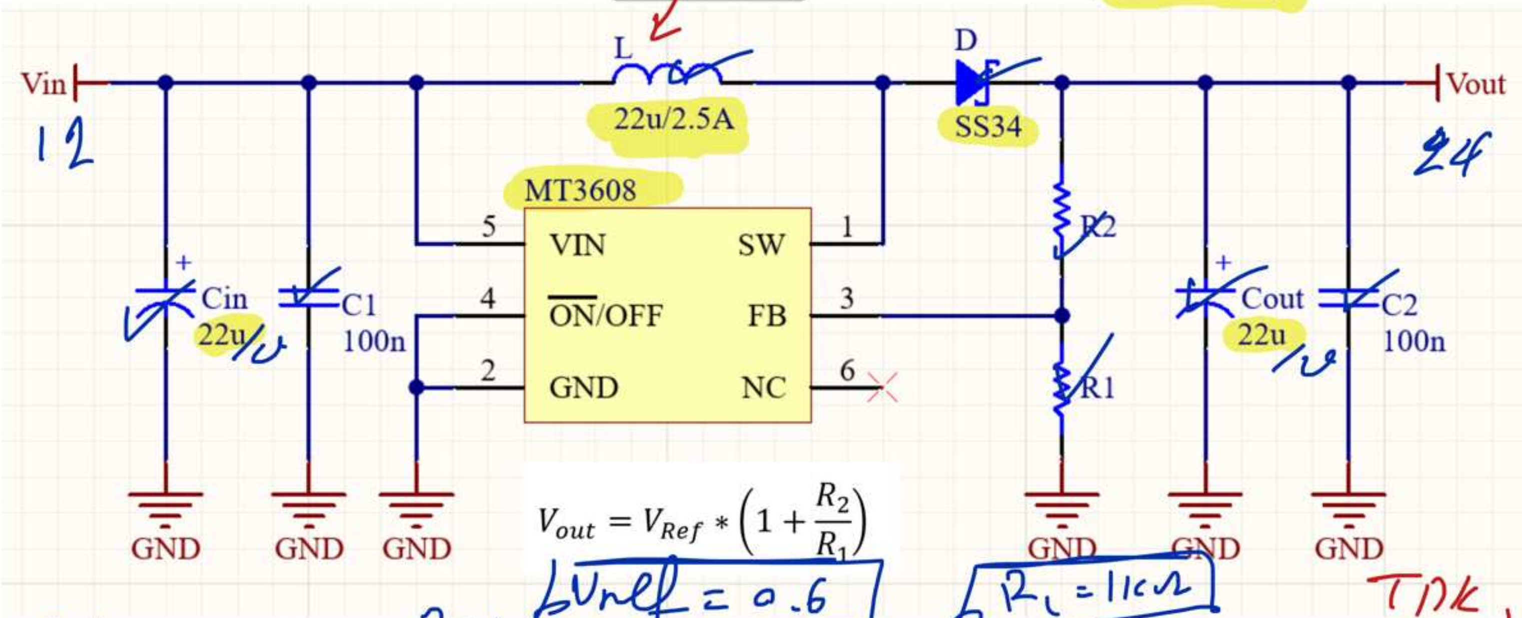
$V_o > V_{in}$ 8, 12, 5 → 24

TOP VIEW



FEATURES

- Integrated 80mΩ Power MOSFET
- 2V to 24V Input Voltage
- 1.2MHz Fixed Switching Frequency
- Internal 4A Switch Current Limit
- Adjustable Output Voltage
- Internal Compensation
- Up to 28V Output Voltage
- Automatic Pulse Frequency Modulation Mode at Light Loads
- up to 93% Efficiency



$$V_{out} = V_{Ref} * \left(1 + \frac{R_2}{R_1}\right)$$

$\boxed{V_{ref} = 0.6}$ $\boxed{R_1 = 1k\Omega}$

$24 = 0.6\left(1 + \frac{R_2}{1k \cdot 10^3}\right)$

solve $\Rightarrow \boxed{R_2 = 39k\Omega}$

$V_{cin} = 0.5 \times V_{in}^{max} = 0.5 \times 12$

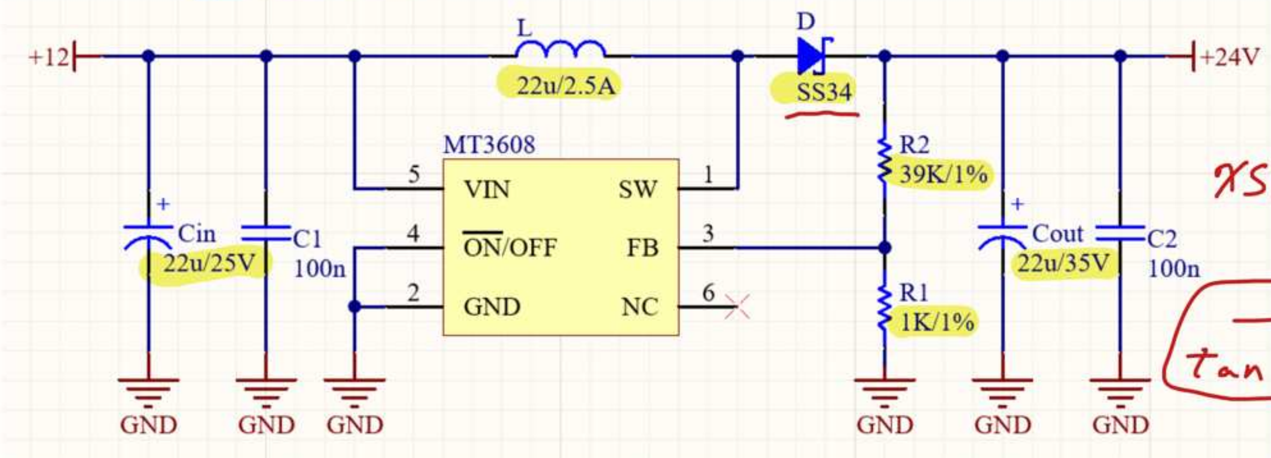
$\overset{STD}{\Rightarrow} \boxed{V_{cin} = 25V}$

$V_{cout} \geq 1.5 \times V_{out} = 1.5 \times 24$

$V_{out} = 36V \overset{STD}{\Longrightarrow} \boxed{V_{out} = 35V}$

$I_D = \sqrt{2_0^{max}} \times I_{peak}$

TDK

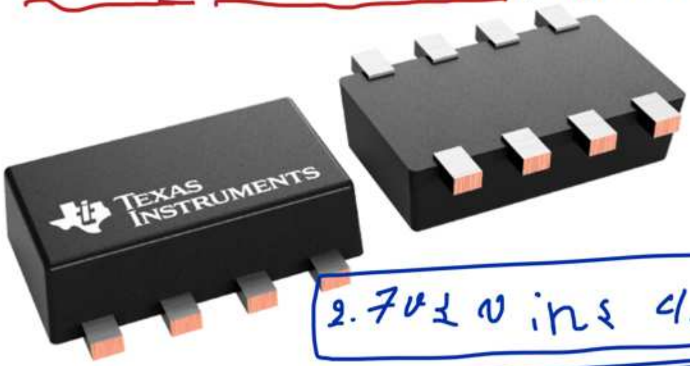


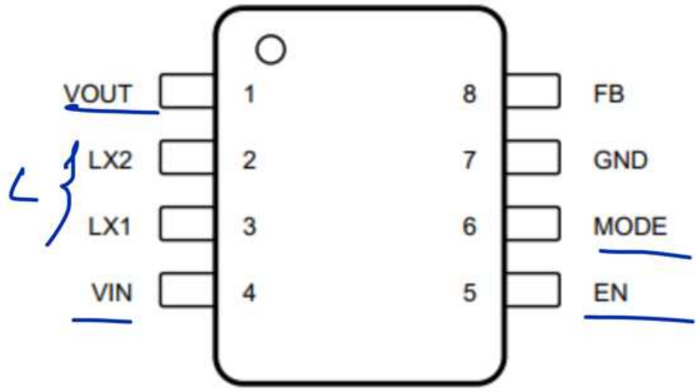
X5R

X7R

tan

TPS631000 1.5-A Output Current, High Power Density Buck-Boost Converter



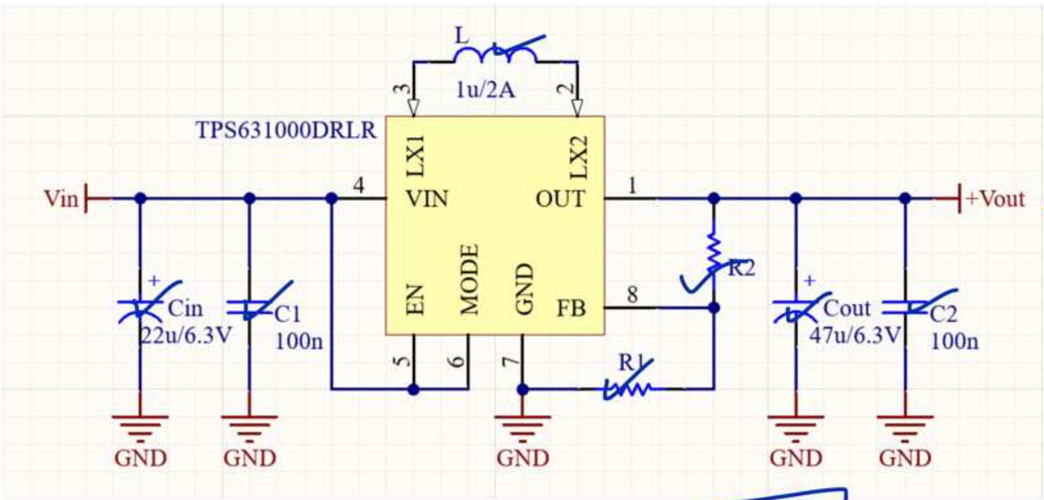


$\boxed{2.7V \leq V_{in} \leq 4.3V}$

$\boxed{V_{max} = 4.3V}$

4.4V → 3.3V

3.1V → 3.3V



= 3.3V

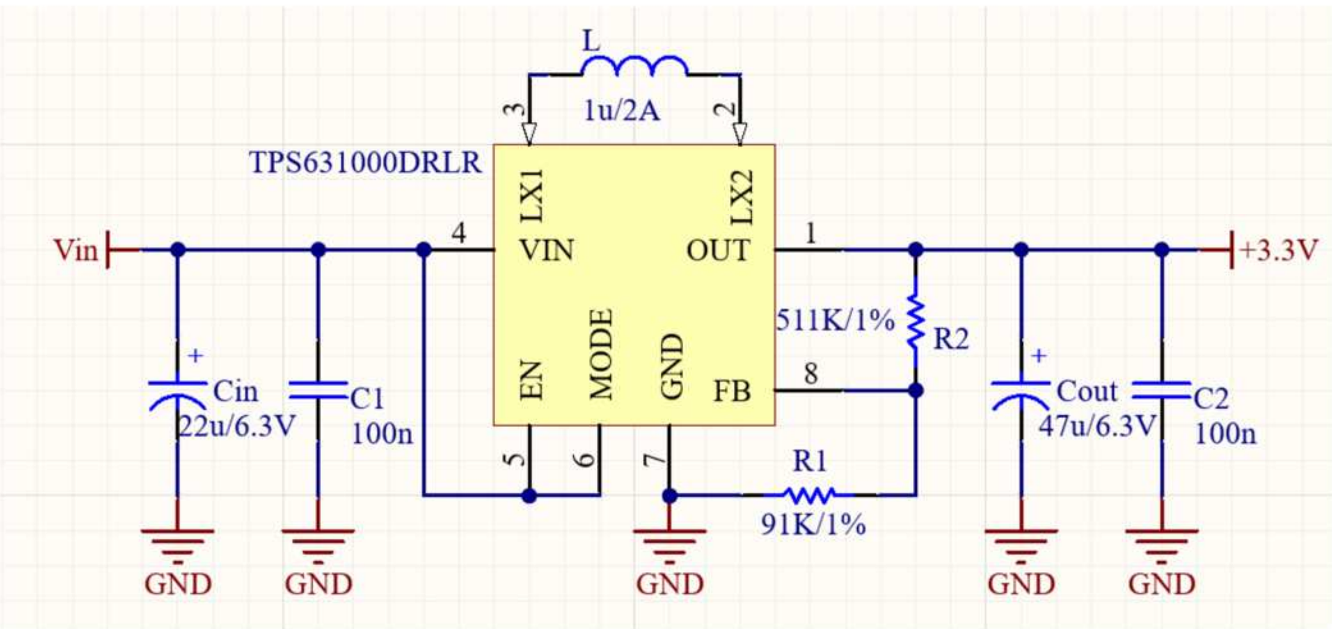
$\boxed{R_1 = 91k\Omega}$

$R_1 \leq 100k\Omega$

$$V_{out} = V_{Ref} * \left(1 + \frac{R_2}{R_1}\right)$$

$\boxed{V_{ref} = 0.5V}$

$3.3 = 0.5\left(1 + \frac{R_2}{91k}\right) \xRightarrow{\text{solve}} R_2 = 509.6k\Omega \xRightarrow{\text{std}} \boxed{R_2 = 511k\Omega}$



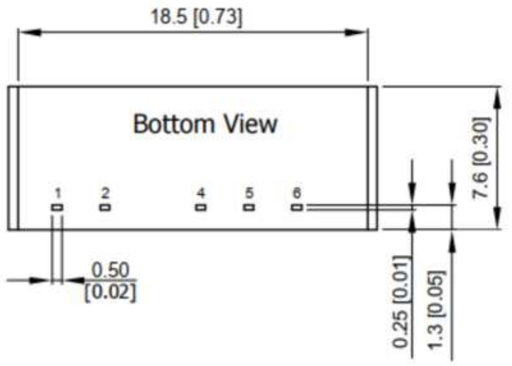
MINMAX

MAU300 SERIES

DC/DC CONVERTER 2W

- Single and Dual Output Models
- I/O-Isolation 1000 VDC

2w
MAU3xx
MAU2xx
1w



Pin Connections		
Pin	Single Output	Dual Output
1	+Vin	+Vin
2	-Vin	-Vin
4	-Vout	-Vout
5	No Pin	Common
6	+Vout	+Vout

Model Selection Guide

Model Number	Input Voltage (Range)	Output Voltage	Output Current		Input Current		Load Regulation	Max. capacitive Load	Efficiency (typ.)
2w			Max.	Min.	@Max. Load	@No Load			@Max. Load
	VDC	VDC	mA	mA	mA(typ.)	mA(typ.)	% (max.)	µF	%
MAU301	5 (4.5 ~ 5.5)	3.3	500	10	452	60	11	470	73
MAU302		5	400	8	526		11		76
MAU303		12	165	3	495		7		80
MAU304		15	133	2.5	499		7		80
MAU305		±5	±200	±4	519		10	390#	77
MAU306		±12	±83	±1.5	504		7		79
MAU307		±15	±66	±1	501		7		79
MAU311	12 (10.8 ~ 13.2)	3.3	500	10	185	30	8	470	74
MAU312		5	400	8	212		8		78
MAU313		12	165	3	200		5		82
MAU314		15	133	2.5	200		5		83
MAU315		±5	±200	±4	210		8	390#	79
MAU316		±12	±83	±1.5	201		5		82
MAU317		±15	±66	±1	200		5		82
MAU321	24 (21.6 ~ 26.4)	3.3	500	10	92	15	8	470	74
MAU322		5	400	8	108		8		77
MAU323		12	165	3	101		5		81
MAU324		15	133	2.5	101		5		82
MAU325		±5	±200	±4	105		8	390#	79
MAU326		±12	±83	±1.5	102		5		81
MAU327		±15	±66	±1	100		5		82

For each output

Input Specifications

Parameter	Model	Min.	Typ.	Max.	Unit
Input Voltage Range	5V Input Models	4.5	5	5.5	VDC
	12V Input Models	10.8	12	13.2	
	24V Input Models	21.6	24	26.4	
Input Surge Voltage (1 sec. max.)	5V Input Models	-0.7	---	9	
	12V Input Models	-0.7	---	18	
	24V Input Models	-0.7	---	30	
Reverse Polarity Input Current	All Models	---	---	0.3	A
Internal Filter Type		Pi Filter			
Internal Power Dissipation		---	---	650	mW

Output Specifications

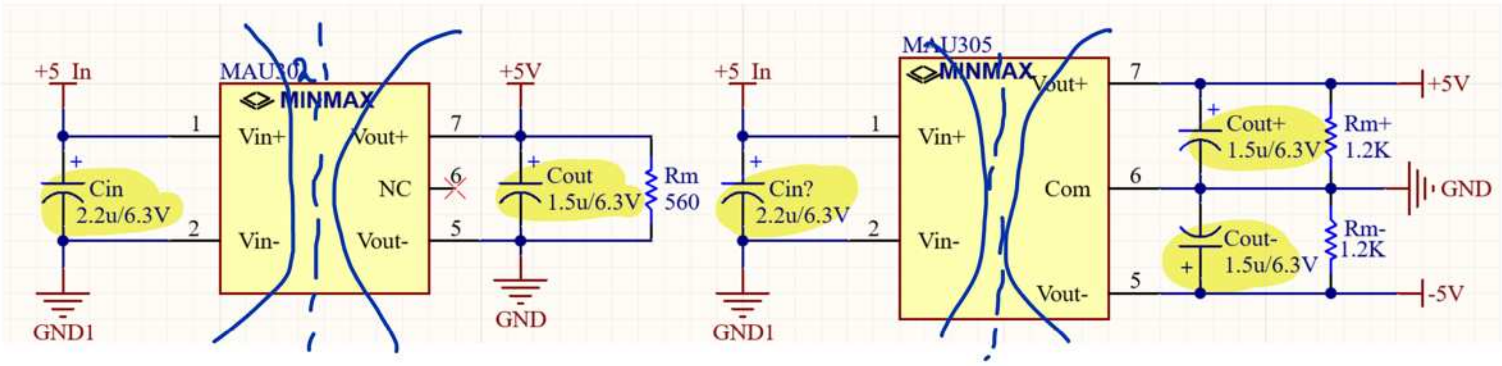
Parameter	Conditions	Min.	Typ.	Max.	Unit
Output Voltage Accuracy		---	±1.0	±3.0	%
Output Voltage Balance	Dual Output, Balanced Loads	---	±0.1	±1.0	%
Line Regulation	For Vin Change of 1%	---	±1.2	±1.5	%
Load Regulation	Io=20% to 100%	See Model Selection Guide			
Ripple & Noise	max. 20MHz Bandwidth	---	100	150	mV P-P
Temperature Coefficient		---	±0.01	±0.02	%/°C
Short Circuit Protection		0.5 Second Max.			

General Specifications

Parameter	Conditions	Min.	Typ.	Max.	Unit
I/O Isolation Voltage (rated)	60 Seconds	1000	---	---	VDC
I/O Isolation Resistance	500 VDC	1000	---	---	MΩ
I/O Isolation Capacitance	100KHz, 1V	---	80	120	pF
Switching Frequency		50	80	100	KHz
MTBF (calculated)	MIL-HDBK-217F@25°C, Ground Benign	2,000,000	---	---	Hours

Input Fuse

5V Input Models	12V Input Models	24V Input Models
1000mA Slow-Blow Type	500mA Slow-Blow Type	200mA Slow-Blow Type



$$R_m = \frac{V_{avg}}{I_o^{min}} = \frac{5}{8\times10^{-3}} \overset{Calc}{\Rightarrow} R_{min} = 625\Omega \Rightarrow \boxed{R_m = 560\Omega}$$

$625 \times 2 = 1250\Omega$

12 → 1uf

24 → 0.47uf