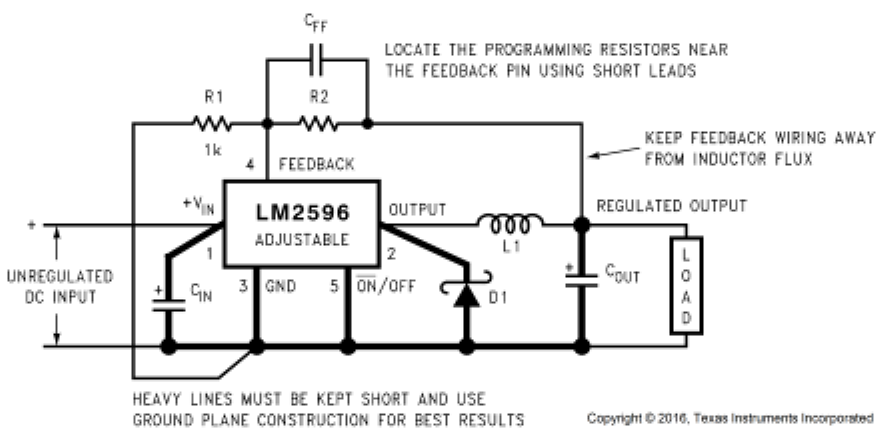
LM2596 methodology

Design Detail



Typical Design

Table 6-1. Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	V_{IN}	I	This is the positive input supply for the IC switching regulator. A suitable input bypass capacitor must be present at this pin to minimize voltage transients and to supply the switching currents required by the regulator.
2	Output	O	Internal switch. The voltage at this pin switches between approximately ($+V_{IN} - V_{SAT}$) and approximately −0.5 V, with a duty cycle of V_{OUT} / V_{IN}. To minimize coupling to sensitive circuitry, the PCB copper area connected to this pin must be kept to a minimum.
3	Ground	—	Circuit ground
4	Feedback	I	Senses the regulated output voltage to complete the feedback loop.
5	$\overline{\text{ON}}$/OFF	I	Allows the switching regulator circuit to be shut down using logic signals thus dropping the total input supply current to approximately 80 µA. Pulling this pin below a threshold voltage of approximately 1.3 V turns the regulator on, and pulling this pin above 1.3 V (up to a maximum of 25 V) shuts the regulator down. If this shutdown feature is not required, the $\overline{\text{ON}}$/OFF pin can be wired to the ground pin or it can be left open. In either case, the regulator will be in the ON condition.

7.9 Electrical Characteristics – All Output Voltage Versions

Specifications are for T_J = 25°C, I_{LOAD} = 500 mA, V_{IN} = 12 V for the 3.3-V, 5-V, and adjustable version, and V_{IN} = 24 V for the 12-V version (unless otherwise noted).

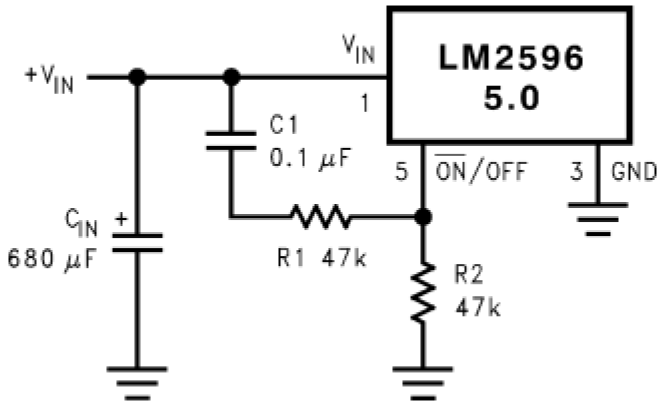
PARAMETER		TEST CONDITIONS		MIN[1]	TYP[2]	MAX[1]	UNIT
DEVICE PARAMETERS							
I_b	Feedback bias current	Adjustable version only, V_{FB} = 1.3 V	T_J = 25°C		10	50	nA
			–40°C ≤ T_J ≤ 125°C			100	
f_O	Oscillator frequency[3]	T_J = 25°C		127	150	173	kHz
		–40°C ≤ T_J ≤ 125°C		110		173	
V_{SAT}	Saturation voltage[4] [5]	I_{OUT} = 3 A	T_J = 25°C		1.16	1.4	V
			–40°C ≤ T_J ≤ 125°C			1.5	
DC	Max duty cycle (ON)[5]				100%		
	Min duty cycle (OFF)[6]				0%		
I_{CL}	Current limit[4] [5]	Peak current	T_J = 25°C	3.6	4.5	6.9	A
			–40°C ≤ T_J ≤ 125°C	3.4		7.5	
I_L	Output leakage current[4] [6]	Output = 0 V, V_{IN} = 40 V				50	µA
		Output = –1 V			2	30	mA
I_Q	Operating quiescent current[6]	See [6]			5	10	mA
I_{STBY}	Current standby quiescent	$\overline{\text{ON}}$/OFF pin = 5 V (OFF)[7]	T_J = 25°C		80	200	µA
			–40°C ≤ T_J ≤ 125°C			250	µA
SHUTDOWN/SOFT-START CONTROL (see Figure 9-13 for test circuit)							
V_{IH}	$\overline{\text{ON}}$/OFF pin logic input threshold voltage	Low (regulator ON)	T_J = 25°C		1.3		V
			–40°C ≤ T_J ≤ 125°C			0.6	
V_{IL}		High (regulator OFF)	T_J = 25°C		1.3		V
			–40°C ≤ T_J ≤ 125°C	2			
I_H	$\overline{\text{ON}}$/OFF pin input current	V_{LOGIC} = 2.5 V (regulator OFF)			5	15	µA
I_L		V_{LOGIC} = 0.5 V (regulator ON)			0.02	5	µA

(1) All room temperature limits are 100% production tested. All limits at temperature extremes are specified via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical numbers are at 25°C and represent the most likely norm.
(3) The switching frequency is reduced when the second stage current limit is activated. The amount of reduction is determined by the severity of current overload.
(4) No diode, inductor, or capacitor connected to output pin.
(5) Feedback pin removed from output and connected to 0 V to force the output transistor switch ON.
(6) Feedback pin removed from output and connected to 12 V for the 3.3-V, 5-V, and the adjustable versions, and 15 V for the 12-V version, to force the output transistor switch OFF.
(7) V_{IN} = 40 V.

Functional design

Delayed Start-up [Page 11]

The circuit in Figure 8-1 uses the ON/OFF pin to provide a time delay between the time the input voltage is applied and the time the output voltage comes up (only the circuitry pertaining to the delayed start-up is shown).
As the input voltage rises, the charging of capacitor C1 pulls the ON/OFF pin high, keeping the regulator OFF.
Once the input voltage reaches its final value and the capacitor stops charging, resistor R2 pulls the ON/OFF pin low, thus allowing the circuit to start switching. Resistor R1 is included to limit the maximum voltage applied to the ON/OFF pin (maximum of 25 V), reduces power supply noise sensitivity, and also limits the capacitor C1 discharge current. When high input ripple voltage exists, avoid long delay time, because this ripple can be coupled into the ON/OFF pin and cause problems.
This delayed start-up feature is useful in situations where the input power source is limited in the amount of current it can deliver. It allows the input voltage to rise to a higher voltage before the regulator starts operating.
Buck regulators require less input current at higher input voltages.



> I did not include the delayed start-up into our design, [NO C_1, R_1, R_2], Do we need delayed Start-up?
> It depends :
> 1. The input voltage ripple and this is determined by the wall charger.
> Experiment needed...
> 2. Design, maybe using the ON/OFF pin we can merge the output pin into 1, then we need this delayed start-up application, prevent two inputs to one.

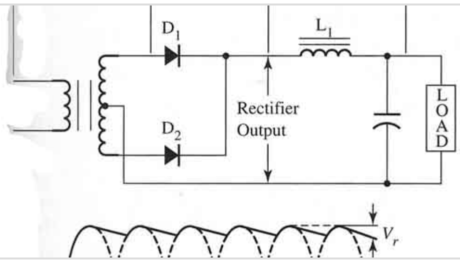
Application implementation

电源电压（V）	电容耐压（V）	电源电压（V）	电容耐压（V）
1.5以下	5	30~40	60
1.5~3	10	40~70	100
3~5	16	70~100	150
5~10	25	100~140	200
10~20	35	140~200	300
20~30	50	200~300	400

Using Capacitors & Inductors as Filters for Power Supplies

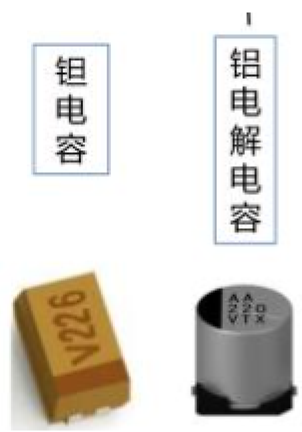
Most power supplies found in industrial electronic circuits have capacitors and inductors used as filters. A filter on the power supply circuit will reduce the amount of ripple to a point where the output

https://www.industrial-electronics.com/Industrial_Power_Supplies_Inverters_and_Converter/10_Using_Capacitors_Inductors_Filters_Power_Supplies.html



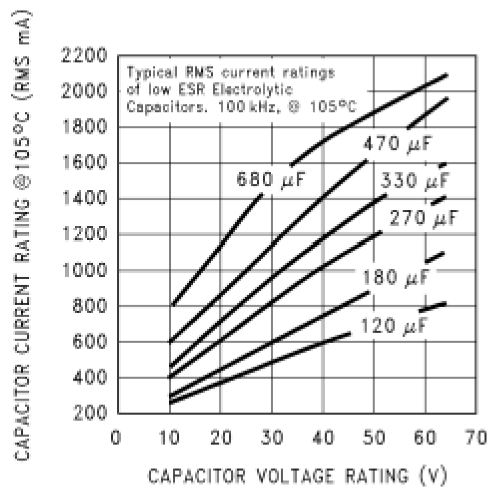
Input Capacitor C_1 [page 16]

A low ESR aluminum or tantalum bypass capacitor is required between the input pin and ground pin. It must be placed near the regulator using short leads. This capacitor prevents large voltage transients from occurring at the input and provides the instantaneous current required each time the switch turns ON.



The important parameters for the input capacitor are the voltage rating and the RMS current rating. Because of the relatively high RMS currents flowing in a input capacitor of the buck converter, this capacitor must be chosen for its RMS current rating rather than its capacitance or voltage ratings, although the capacitance value and voltage rating are directly related to the RMS current rating.
The RMS current rating of a capacitor could be viewed as a power rating of the capacitor. The RMS current flowing through the capacitors internal ESR produces power which causes the internal temperature of the capacitor to rise. The RMS current rating of a capacitor is determined by the amount of current required to raise the internal temperature approximately 10°C above an ambient temperature of 105°C. The ability of the capacitor to dissipate this heat to the surrounding air will determine the amount of current the capacitor can safely sustain. For a given capacitor value, a higher voltage electrolytic capacitor is physically larger than a lower voltage capacitor, and thus be able to dissipate more heat to the surrounding air, and therefore will have a higher RMS current rating.
The consequences of operating an electrolytic capacitor above the RMS current rating is a shortened operating life. The higher temperature speeds up the evaporation of the capacitor's electrolyte, resulting in eventual failure.
Selecting an input capacitor requires consulting the manufacturers data sheet for maximum allowable RMS ripple current. For a maximum ambient temperature of 40°C, a general guideline would be to select a capacitor with a ripple current rating of approximately 50% of the DC load current. For ambient temperatures up to 70°C, a current rating of 75% of the DC load current would be a good choice for a conservative design. The capacitor voltage rating must be at least 1.25 times greater than the

maximum input voltage, and often a much higher voltage capacitor is required to satisfy the RMS current requirements.



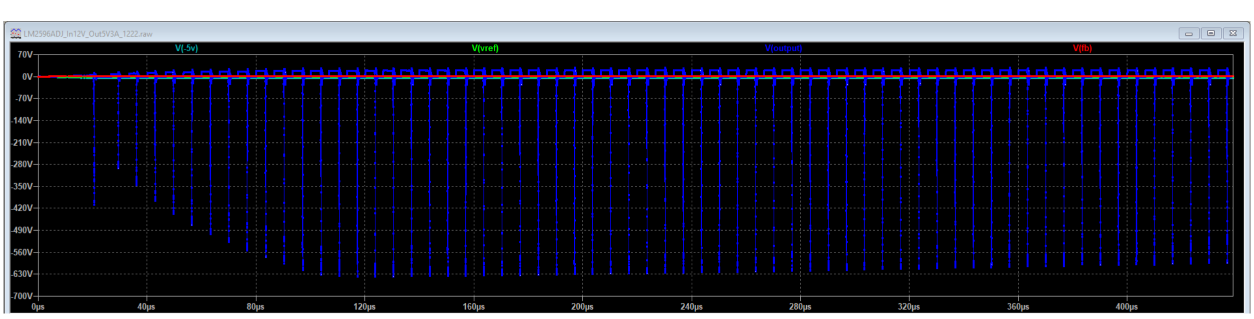
Output capacitor C_{out}

An output capacitor is required to filter the output and provide regulator loop stability. `Low impedance or low ESR electrolytic or solid tantalum capacitors` designed for switching regulator applications must be used. When selecting an output capacitor, the important capacitor parameters are the 100-kHz ESR, the RMS ripple current rating, voltage rating, and capacitance value. For the output capacitor, the ESR value is the most important parameter.
The output capacitor requires an ESR value that has an upper and lower limit. For low output ripple voltage, a low ESR value is required. This value is determined by the maximum allowable output ripple voltage, typically 1% to 2% of the output voltage. But if the selected capacitor's ESR is extremely low, there is a possibility of an unstable feedback loop, resulting in an oscillation at the output. Using the capacitors listed in the tables, orsimilar types, will provide design solutions under all conditions.

Catch Diode (SS34)

Buck regulators require a diode to provide a return path for the inductor current when the switch turns off. This must be a fast diode and must be placed close to the LM2596 using short leads and short printed-circuit traces.
Because of their very fast switching speed and low forward voltage drop, Schottky diodes provide the best performance, especially in low output voltage applications (5 V and lower). Ultra-fast recovery, or high-efficiency rectifiers are also a good choice, but some types with an abrupt turnoff characteristic may cause instability or EMI problems. Ultra-fast recovery diodes typically have reverse recovery times of 50 ns or less. Rectifiers such as the 1N5400 series are much too slow and should not be used.

without catch diode



Inductor selection

All switching regulators have two basic modes of operation; continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulators performance and requirements. Most switcher designs will operate in the discontinuous mode when the load current is low.

The LM2596 (or any of the SIMPLE SWITCHER family) can be used for both continuous or discontinuous modes of operation.

In many cases the preferred mode of operation is the continuous mode, which offers greater output power, lower peak switch, lower inductor and diode currents, and can have lower output ripple voltage. However, the continuous mode does require larger inductor values to keep the inductor current flowing continuously, especially at low output load currents or high input voltages.

To simplify the inductor selection process, an inductor selection guide (nomograph) was designed (see Figure 9-8). This guide assumes that the regulator is operating in the continuous mode, and selects an inductor that will allow a peak-to-peak inductor ripple current to be a certain percentage of the maximum design load current. This peak-to-peak inductor ripple current percentage is not fixed, but is allowed to change as different design load currents are selected (see Figure 9-4.)

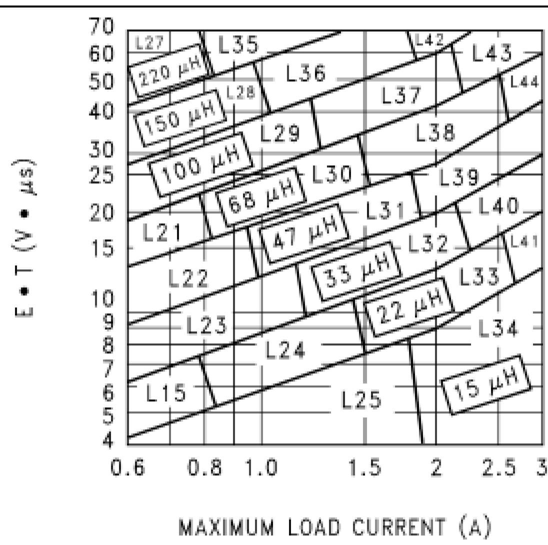


Figure 9-8. LM2596-ADJ