UNITRODE

Simple Step-Up Voltage Regulator

FEATURES

- Requires Few External Components
- NPN Output Switches 3.0A, 65V(max)
- Extended Input Voltage Range: 3.0V to 40V
- Current Mode Operation for Improved Transient Response, Line Regulation, and Current Limiting
- Soft Start Function Provides Controlled Startup
- 52kHz Internal Oscillator
- Output Switch Protected by Current Limit, Undervoltage Lockout and Thermal Shutdown
- Improved Replacement for LM2577-ADJ Series

TYPICAL APPLICATIONS

- Simple Boost and Flyback Converters
- SEPIC Topology Permits Input Voltage to be Higher or Lower than Output Voltage
- Transformer Coupled Forward Regulators
- Multiple Output Designs

DESCRIPTION

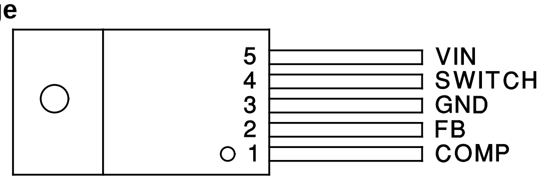
The UC2577-ADJ device provides all the active functions necessary to implement step-up (boost), flyback, and forward converter switching regulators. Requiring only a few components, these simple regulators efficiently provide up to 60V as a step-up regulator, and even higher voltages as a flyback or forward converter regulator.

The UC2577-ADJ features a wide input voltage range of 3.0V to 40V and an adjustable output voltage. An on-chip 3.0A NPN switch is included with undervoltage lockout, thermal protection circuitry, and current limiting, as well as soft start mode operation to reduce current during startup. Other features include a 52kHz fixed frequency on-chip oscillator with no external components and current mode control for better line and load regulation.

A standard series of inductors and capacitors are available from several manufacturers optimized for use with these regulators and are listed in this data sheet.

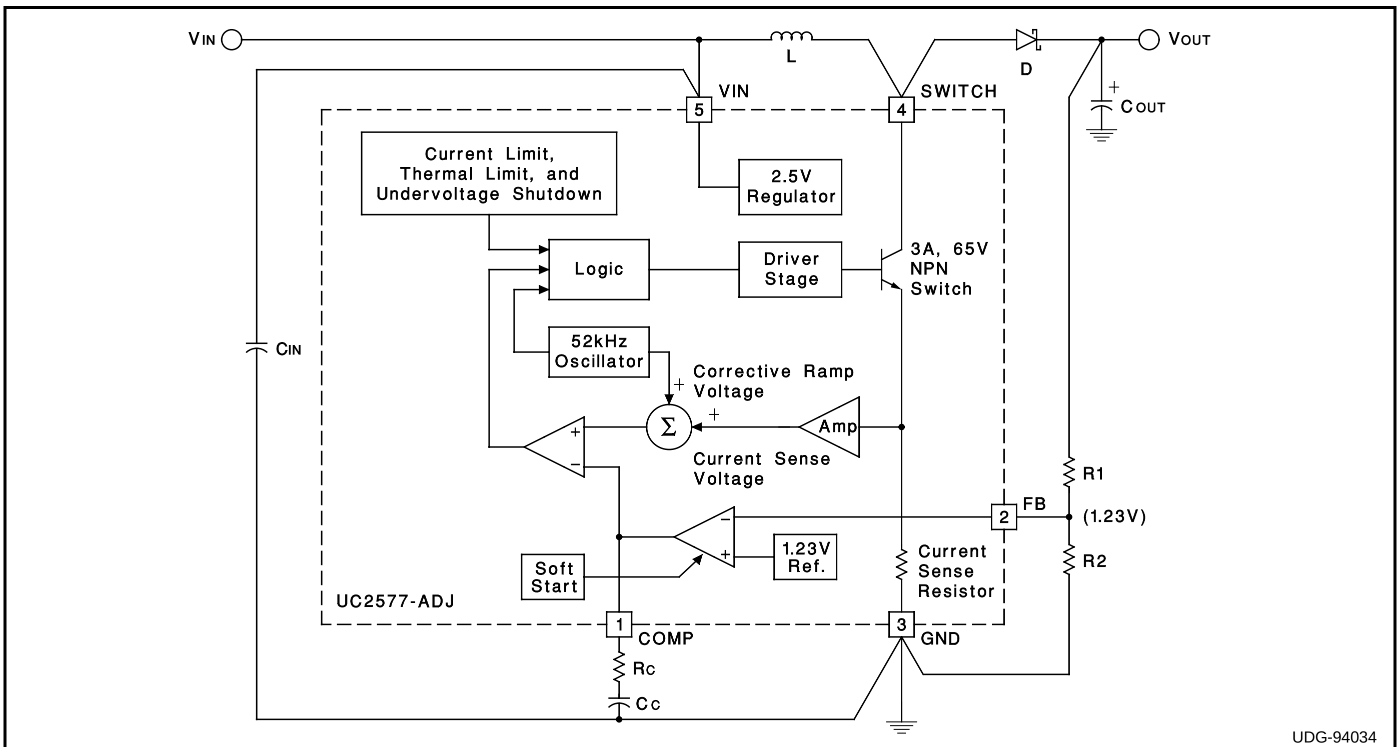
CONNECTION DIAGRAM

5-Pin TO-220 (Top View)
T Package



Also available in TO-263 Package (TD).

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage 45V
Output Switch Voltage 65V
Output Switch Current (Note 2) 6.0A
Power Dissipation. . . . . Internally Limited
Storage Temperature Range . . . . –65°C to +150°C
Lead Temperature (Soldering, 10 sec.) . . . . 260°C
Maximum Junction Temperature . . . . 150°C
Minimum ESD Rating (C = 100pF, R = 15kΩ) 2kV

RECOMMENDED OPERATING RANGE

Supply Voltage . . . . $3.0V \le V_{IN} \le 40V$
Output Switch Voltage . . . . $0V \le V_{SWITCH} \le 60V$
Output Switch Current . . . . $I_{SWITCH} \le 3.0A$
Junction Temperature Range . . . . $–40°C \le T_J \le +125°C$

ELECTRICAL CHARACTERISTICS

Unless otherwise stated, these specifications apply for T_A = –40°C to +125°C, VIN = 5V, $V_{FB} = V_{REF}$, I_{SWITCH} = 0, and $T_A = T_J$.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
System Parameters *Circuit Figure 1* (Note 3)					
Output Voltage	VIN = 5V to 10V, I_{LOAD} = 100mA to 800mA	11.40	12.0	12.60	V
	T_J = 25°C	11.60		12.40	V
Line Regulation	VIN = 3.0V to 10V, I_{LOAD} = 300mA		20	100	mV
	T_J = 25°C			50	mV
Load Regulation	VIN = 5V, I_{LOAD} = 100mA to 800mA		20	100	mV
	T_J = 25°C			50	mV
Efficiency	VIN = 5V, I_{LOAD} = 800mA		80		%
Device Parameters					
Input Supply Current	V_{FB} = 1.5V (Switch Off)		7.5	14	mA
	T_J = 25°C			10	mA
	I_{SWITCH} = 2.0A, V_{COMP} = 2.0V (Max Duty Cycle)		45	85	mA
	T_J = 25°C			70	mA
Input Supply UVLO	I_{SWITCH} = 100mA		2.70	2.95	V
	T_J = 25°C			2.85	V
Oscillator Frequency	Measured at SWITCH Pin, I_{SWITCH} = 100mA	42	52	62	kHz
	T_J = 25°C	48		56	kHz
Reference Voltage	Measured at FB Pin, VIN = 3.0V to 40V, V_{COMP} = 1.0V	1.206	1.230	1.254	V
	T_J = 25°C	1.214		1.246	V
Reference Voltage Line Regulation	VIN = 3.0V to 40V		0.5		mV
Error Amp Input Bias Current	V_{COMP} = 1.0V		100	800	nA
	T_J = 25°C			300	nA
Error Amp Transconductance	I_{COMP} = –30μA to +30μA, V_{COMP} = 1.0V	1600	3700	5800	μmho
	T_J = 25°C	2400		4800	μmho
Error Amp Voltage Gain	V_{COMP} = 0.8V to 1.6V, R_{COMP} = 1.0MW (Note 4)	250	800		V/V
	T_J = 25°C	500			V/V
Error Amplifier Output Swing	Upper Limit V_{FB} = 1.0V	2.0	2.4		V
	T_J = 25°C	2.2			V
	Lower Limit V_{FB} = 1.5V		0.3	0.55	V
	T_J = 25°C			0.40	V
Error Amp Output Current	V_{FB} = 1.0V to 1.5V, V_{COMP} = 1.0V	±90	±200	±400	μA
	T_J = 25°C	±130		±300	μA
Soft Start Current	V_{FB} = 1.0V, V_{COMP} = 0.5V	1.5	5.0	9.5	μA
	T_J = 25°C	2.5		7.5	μA
Maximum Duty Cycle	V_{COMP} = 1.5V, I_{SWITCH} = 100mA	90	95		%
	T_J = 25°C	93			%

ELECTRICAL CHARACTERISTICS Unless otherwise stated, these specifications apply for T_A = –40°C to +125°C, VIN = 5V, $V_{FB} = V_{REF}$, I_{SWITCH} = 0, and $T_A = T_J$.

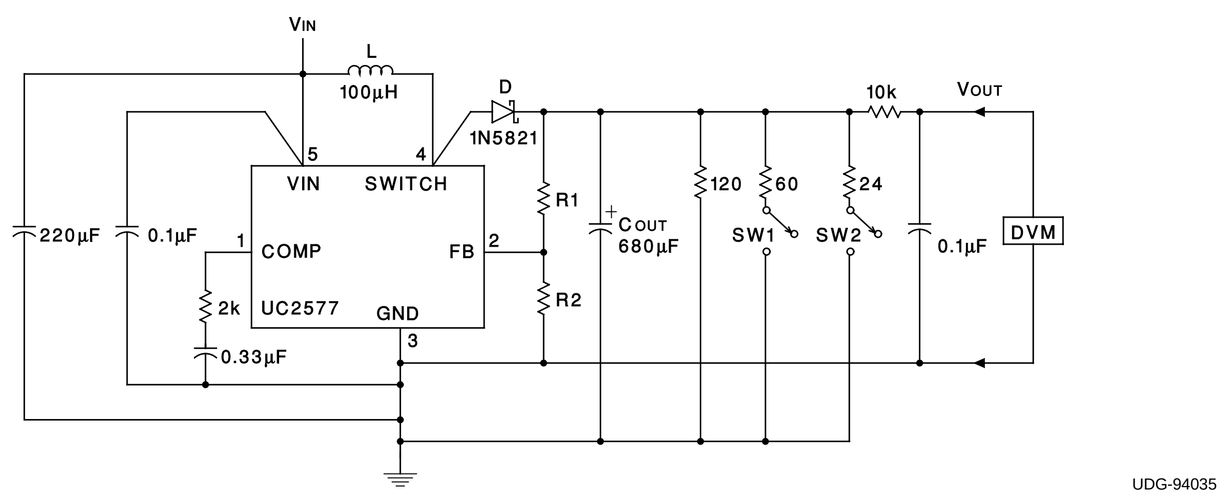
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Device Parameters (cont.)					
Switch Transconductance			12.5		A/V
Switch Leakage Current	V_{SWITCH} = 65V, V_{FB} = 1.5V (Switch Off)		10	600	µA
	T_J = 25°C			300	µA
Switch Saturation Voltage	I_{SWITCH} = 2.0A, V_{COMP} = 2.0V (Max Duty Cycle)		0.5	0.9	V
	TJ = 25°C			0.7	V
NPN Switch Current Limit	V_{COMP} = 2.0V	3.0	4.3	6.0	A
Thermal Resistance	Junction to Ambient		65		°C/W
	Junction to Case		2		°C/W
COMP Pin Current	V_{COMP} = 0		25	50	µA
	T_J = 25°C			40	µA

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating ratings indicate conditions during which the device is intended to be functional, but device parameter specifications may not be guaranteed under these conditions. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Note 2: Output current cannot be internally limited when the UC2577 is used as a step-up regulator. To prevent damage to the switch, its current must be externally limited to 6.0A. However, output current is internally limited when the UC2577 is used as a flyback or forward converter regulator.

Note 3. External components such as the diode, inductor, input and output capacitors can affect switching regulator performance. When the UC2577 is used as shown in the Test Circuit, system performance will be as specified by the system parameters.

Note 4: A 1.0MΩ resistor is connected to the compensation pin (which is the error amplifier's output) to ensure accuracy in measuring A_{VOL}. In actual applications, this pin's load resistance should be ≥ 10MΩ, resulting in A_{VOL} that is typically twice the guaranteed minimum limit.



L = 415-0930 (AIE)
D = any manufacturer

C_{OUT} = Sprague Type 673D Electrolytic 680µF, 20V

R1 = 48.7k in series with 511Ω (1%)
R2 = 5.62k (1%)

Figure 1. Circuit Used to Specify System Parameters

APPLICATIONS INFORMATION

Step-up (Boost) Regulator

The Block Diagram shows a step-up switching regulator utilizing the UC2577. The regulator produces an output voltage higher than the input voltage. The UC2577 turns its switch on and off at a fixed frequency of 52kHz, thus storing energy in the inductor (L). When the NPN switch is on, the inductor current is charged at a rate of VIN/L. When the switch is off, the voltage at the SWITCH terminal of the inductor rises above VIN, discharging the stored current through the output diode (D) into the output capacitor (C_{OUT}) at a rate of (V_{OUT} - VIN)/L. The energy stored in the inductor is thus transferred to the output.

The output voltage is controlled by the amount of energy transferred, which is controlled by modulating the peak inductor current. This modulation is accomplished by feeding a portion of the output voltage to an error amplifier which amplifies the difference between the feedback voltage and an internal 1.23V precision reference voltage. The output of the error amplifier is then compared to a voltage proportional to the switch current, or the inductor current, during the switch on time. A comparator terminates the switch on time when the two voltages are equal and thus controls the peak switch current to maintain a constant output voltage. Figure 2 shows voltage and current waveforms for the circuit. Formulas for calculation are shown in Figure 3.

STEP-UP REGULATOR DESIGN PROCEDURE

Refer to the Block Diagram

Given:

V_{INmin} = Minimum input supply voltage

V_{OUT} = Regulated output voltage

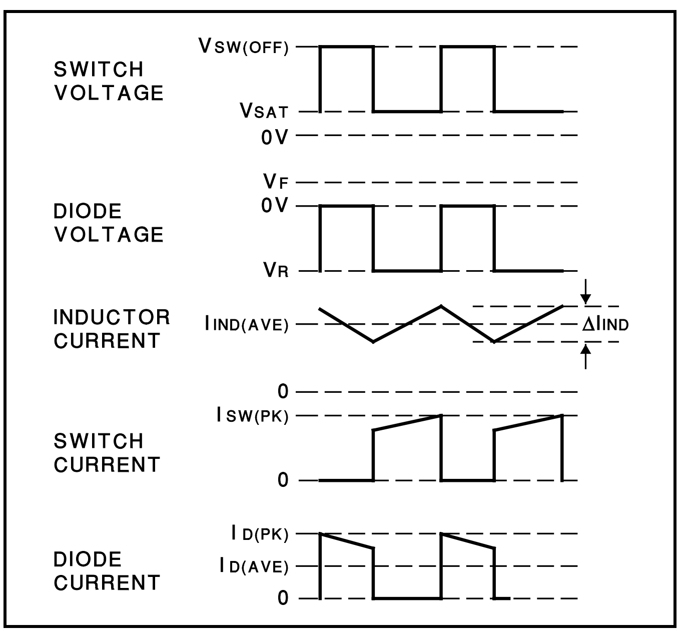


Figure 2. Step-up Regulator Waveforms

Duty Cycle	D	$\frac{V_{OUT} + V_F - V_{IN}}{V_{OUT} + V_F - V_{SAT}} \approx \frac{V_{OUT} - V_{IN}}{V_{OUT}}$
Avg. Inductor Current	$I_{IND(AVG)}$	$\frac{I_{LOAD}}{1 - D}$
Inductor Current Ripple	ΔI_{IND}	$\frac{V_{IN} - V_{SAT}}{L} \bullet \frac{D}{52{,}000}$
Peak Inductor Current	$I_{IND(PK)}$	$\frac{I_{LOAD}}{1-D} + \frac{\Delta I_{IND}}{2}$
Peak Switch Current	$I_{SW(PK)}$	$\frac{I_{LOAD}}{1-D} + \frac{\Delta I_{IND}}{2}$
Switch Voltage when Off	$V_{SW(OFF)}$	$V_{OUT} + V_F$
Diode Reverse Voltage	V_R	V_{OUT} - V_{SAT}
Avg. Diode Current	$I_{D(AVG)}$	I_{LOAD}
Peak Diode Current	$I_{D(PK)}$	$\frac{I_{LOAD}}{1-D} + \frac{\Delta I_{IND}}{2}$.
Power Dissipation	P_D	$0.25\Omega \left(\frac{I_{LOAD}}{1-D}\right)^2 D + \frac{I_{LOAD} \bullet D \bullet V_{IN}}{50\,(1-D)}$

V_F = Forward Biased Diode Voltage, I_{LOAD} = Output Load

Figure 3. Step-up Regulator Formulas

First, determine if the UC2577 can provide these values of V_{OUT} and $I_{LOADmax}$ when operating with the minimum value of V_{IN}. The upper limits for V_{OUT} and $I_{LOADmax}$ are given by the following equations.

$V_{OUT} \leq 60V$ and

$V_{OUT} \leq 10 \bullet V_{INmin}$

$$I_{LOADmax} \leq \frac{2.1A \bullet V_{INmin}}{V_{OUT}}$$

These limits must be greater than or equal to the values specified in this application.

1. Output Voltage Section

Resistors R1 and R2 are used to select the desired output voltage. These resistors form a voltage divider and present a portion of the output voltage to the error amplifier which compares it to an internal 1.23V reference. Select R1 and R2 such that:

$$\frac{R1}{R2} = \frac{V_{OUT}}{1.23V} - 1$$

APPLICATIONS INFORMATION (cont.)

2. Inductor Selection (L)

A. Preliminary Calculations

To select the inductor, the calculation of the following three parameters is necessary:

Dmax, the maximum switch duty cycle ($0 \le D \le 0.9$):

$$D_{max} = \frac{V_{OUT} + V_F - V_{INmin}}{V_{OUT} + V_F - 0.6V}$$

where typically V_F = 0.5V for Schottky diodes and V_F = 0.8V for fast recovery diodes.

E • T, the product of volts • time that charges the inductor:

$$E \bullet T = \frac{D_{max} \bullet (V_{INmin} - 0.6V)10^6}{52{,}000Hz} \ (V \bullet \mu s)$$

$I_{IND,\ DC}$, the average inductor current under full load:

$$I_{IND,\ DC} = \frac{1.05 \bullet I_{LOADmax}}{1 - D_{max}}$$

B. Identify Inductor Value:

1. From Figure 4, identify the inductor code for the region indicated by the intersection of E • T and $I_{IND,\ DC}$. This code gives the inductor value in microhenries. The L or H prefix signifies whether the inductor is rated for a maximum E • T of 90Vµs (L) or 250Vµs (H).

2. If D < 0.85, go to step C. If D ≥ 0.85, calculate the minimum inductance needed to ensure the switching regulator’s stability:

If L_{min} is smaller than the inductor values found in step B1, go on to step C. Otherwise, the inductor value found in step B1 is too low; an appropriate inductor code should be obtained from the graph as follows:

1. Find the lowest value inductor that is greater than L_{min} .
2. Find where E • T intersects this inductor value to determine if it has an L or H prefix. If E • T intersects both the L and H regions, select the inductor with an H prefix.

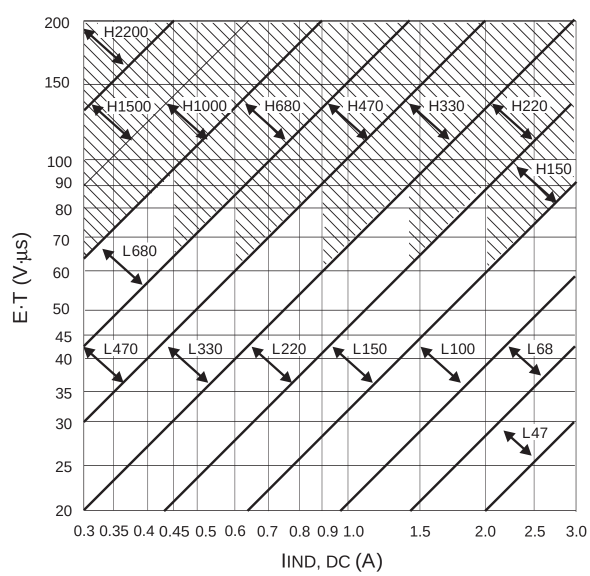
C. *Inductor Selection*

Select an inductor from the table of Figure 5 which cross references the inductor codes to the part numbers of the three different manufacturers. The inductors listed in this table have the following characteristics:

AIE (ferrite, pot-core inductors): Benefits of this type are low electromagnetic interference (EMI), small physical size, and very low power dissipation (core loss).

Pulse (powdered iron, toroid core inductors): Benefits are low EMI and ability to withstand E • T and peak current above rated value better than ferrite cores.

Renco (ferrite, bobbin-core inductors): Benefits are low cost and best ability to withstand E • T and peak current above rated value. Be aware that these inductors generate more EMI than the other types, and this may interfere with signals sensitive to noise.



Note: This chart assumes that the inductor ripple current inductor is approximately 20% to 30% of the average inductor current (when the regulator is under full load). Greater ripple current causes higher peak switch currents and greater output ripple voltage. Lower ripple current is achieved with larger value inductors. The factor of 20% to 30% is chosen as a convenient balance between the two extremes.

Figure 4. Inductor Selection Graph

APPLICATIONS INFORMATION (cont.)

Inductor Code	Manufacturer's Part Number		
	AIE	Pulse	Renco
L47	415 - 0932	PE - 53112	RL2442
L68	415 - 0931	PE - 92114	RL2443
L100	415 - 0930	PE - 92108	RL2444
L150	415 - 0953	PE - 53113	RL1954
L220	415 - 0922	PE - 52626	RL1953
L330	415 - 0926	PE - 52627	RL1952
L470	415 - 0927	PE - 53114	RL1951
L680	415 - 0928	PE - 52629	RL1950
H150	415 - 0936	PE - 53115	RL2445
H220	430 - 0636	PE - 53116	RL2446
H330	430 - 0635	PE - 53117	RL2447
H470	430 - 0634	PE - 53118	RL1961
H680	415 - 0935	PE - 53119	RL1960
H1000	415 - 0934	PE - 53120	RL1959
H1500	415 - 0933	PE - 53121	RL1958
H2200	415 - 0945	PE - 53122	RL2448

AIE Magnetics, Div. Vernitron Corp., (813)347-2181
2801 72nd Street North, St. Petersburg, FL 33710
Pulse Engineering, (619)674-8100
12220 World Trade Drive, San Diego, CA 92128
Renco Electronics, Inc., (516)586-5566
60 Jeffryn Blvd. East, Deer Park, NY 11729

Figure 5. Table of Standardized Inductors and Manufacturer's Part Numbers

3. Compensation Network (R_C, C_C) and Output Capacitor (C_{OUT}) Selection

The compensation network consists of resistor R_C and capacitor C_C which form a simple pole-zero network and stabilize the regulator. The values of R_C and C_C depend upon the voltage gain of the regulator, $I_{LOADmax}$, the inductor L, and output capacitance C_{OUT}. A procedure to calculate and select the values for R_C, C_C, and C_{OUT} which ensures stability is described below. It should be noted, however, that this may not result in optimum compensation. To guarantee optimum compensation a standard procedure for testing loop stability is recommended, such as measuring V_{OUT} transient responses to pulsing I_{LOAD}.

A. Calculate the maximum value for R_C.

$$R_C \le \frac{750 \bullet I_{LOADmax} \bullet V_{OUT}^2}{V_{INmin}^2}$$

Select a resistor less than or equal to this value, not to exceed 3kΩ.

B. Calculate the minimum value for C_{OUT} using the following two equations.

$$C_{OUT} \ge \frac{0.19 \bullet L \bullet R_C \bullet I_{LOADmax}}{V_{INmin} \bullet V_{OUT}} \quad \text{and}$$

$$C_{OUT} \ge \frac{V_{INmin} \bullet R_C \bullet (V_{INmin} + (3.74 \bullet 10^5 \bullet L))}{487{,}800 \bullet V_{OUT}^3}$$

The larger of these two values is the minimum value that ensures stability.

C. Calculate the minimum value of C_C.

$$C_C \ge \frac{58.5 \bullet V_{OUT}^2 \bullet C_{OUT}}{R_C^2 \bullet V_{INmin}}$$

The compensation capacitor is also used in the soft start function of the regulator. When the input voltage is applied to the part, the switch duty cycle is increased slowly at a rate defined by the compensation capacitor and the soft start current, thus eliminating high input currents. Without the soft start circuitry, the switch duty cycle would instantly rise to about 90% and draw large currents from the input supply. For proper soft starting, the value for C_C should be equal or greater than 0.22µF.

Figure 6 lists several types of aluminum electrolytic capacitors which could be used for the output filter. Use the following parameters to select the capacitor.

Working Voltage (WVDC): Choose a capacitor with a working voltage at least 20% higher than the regulator output voltage.

Ripple Current: This is the maximum RMS value of current that charges the capacitor during each switching cycle. For step-up and flyback regulators, the formula for ripple current is:

$$I_{RIPPLErms} = \frac{I_{LOADmax} \bullet D_{max}}{1 - D_{max}}$$

Choose a capacitor that is rated at least 50% higher than this value at 52kHz.

Equivalent Series Resistance (ESR): This is the primary cause of output ripple voltage, and it also affects the values of R_C and C_C needed to stabilize the regulator. As a result, the preceding calculations for C_C and R_C are only valid if the ESR does not exceed the maximum value specified by the following equations.

$$ESR \le \frac{0.01 \bullet 15V}{I_{RIPPLE(P-P)}} \quad \text{and} \quad \le \frac{8.7 \bullet 10^{-3} \bullet V_{IN}}{I_{LOADmax}} \quad \text{where}$$

$$I_{RIPPLE(P-P)} = \frac{1.15 \bullet I_{LOADmax}}{1 - D_{max}}$$

Select a capacitor with an ESR, at 52kHz, that is less than or equal to the lower value calculated. Most electrolytic capacitors specify ESR at 120kHz which is 15% to 30% higher than at 52kHz. Also, note that ESR increases by a factor of 2 when operating at –20°C.

In general, low values of ESR are achieved by using large value capacitors (C ≥ 470µF), and capacitors with high WVDC, or by paralleling smaller value capacitors.

APPLICATIONS INFORMATION (cont.)

4. Input Capacitor Selection (C_{IN})

To reduce noise on the supply voltage caused by the switching action of a step-up regulator (ripple current noise), VIN should be bypassed to ground. A good quality 0.1µF capacitor with low ESR should provide sufficient decoupling. If the UC2577 is located far from the supply source filter capacitors, an additional electrolytic (47µF, for example) is required.

Nichicon - Types PF, PX, or PZ
927 East StateParkway, Schaumburg, IL 60173
(708)843-7500

United Chemi-CON - Types LX, SXF, or SXJ
9801 West Higgens, Rosemont, IL 60018
(708)696-2000

Figure 6. Aluminum Electrolytic Capacitors Recommended for Switching Regulators

5. Output Diode Selection (D)

In the step-up regulator, the switching diode must withstand a reverse voltage and be able to conduct the peak output current of the UC2577. Therefore a suitable diode must have a minimum reverse breakdown voltage greater than the circuit output voltage, and should also be rated for average and peak current greater than $I_{LOADmax}$ and I_{Dpk}. Because of their low forward voltage drop (and thus higher regulator efficiencies), Schottky barrier diodes are often used in switching regulators. Refer to Figure 7 for recommended part numbers and voltage ratings of 1A and 3A diodes.

V_{OUTmax}	Schottky		Fast Recovery	
	1A	3A	1A	3A
20V	1N5817 MBR120P	1N5820 MBR320P		
30V	1N5818 MBR130P 11DQ03	1N5821 MBR330P 31DQ03		
40V	1N5819 MBR140P 11DQ04	1N5822 MBR340P 31DQ04		
50V	MBR150 11DQ05	MBR350 31DQ05	1N4933 MUR105	
100V			1N4934 MUR110 10DL1	MR851 30DL1 MR831

MBRxxx and MURxxx are manufactured by Motorola.
1DDxxx, 11Cxx and 31Dxx are manufactured by
International Rectifier

Figure 7. Diode Selection Chart

ORDERING INFORMATION

Unitrode Type Number
UC2577T-ADJ 5 Pin TO-220 Plastic Package
UC2577TD-ADJ 5 Pin TO-263 Plastic Package

UNITRODE CORPORATION
7 CONTINENTAL BLVD. • MERRIMACK, NH 03054
TEL. (603) 424-2410 • FAX (603) 424-3460