AN-1142 LM2661/3/4 Evaluation Board

1 Introduction

The LM2661, LM2663, and LM2664 are part of a family of CMOS charge-pump voltage converters (Table 3). Each uses two small capacitors to achieve voltage inversion or voltage doubling without the cost, size, and EMI of inductor based converters. Each device has a shutdown feature and the LM2661 and LM2663 also provide the ability to run the clock oscillator from an external source. You may also slow the clock with an external capacitor on the LM2661 and LM2663. The small size and low profile of these circuits makes them attractive for cellular phones, laptop computers, Op Amp power supplies, interface power supplies, medical instruments, PDAs, and handheld instruments.

The LM2661 comes in SOIC-8 and VSSOP-8 packages and requires only an extra diode to double the input voltage and provide up to 100mA of output current. It has a typical efficiency of 88% at 100mA output and a typical output resistance of 6.5 Ω. This circuit typically draws only 500 nA of supply current in shutdown mode and 120 µA when operating. The internal oscillator frequency is 80 kHz and the input voltage range is +2.5 V to +5.5 V . The LM2661 is also capable of inverting an input voltage from +1.5 V to +5.5 V when used in a different configuration.

The LM2663 comes in a SOIC-8 package and inverts the input voltage to provide up to 200mA of output current. It has a typical efficiency of 86% at 200 mA output and a typical output resistance of 3.5 Ω. This circuit draws only 10 µA of supply current in shutdown and 300 µA when operating. The internal oscillator frequency is 150 kHz and the input voltage range is +1.5 V to +5.5 V . The LM2663 is also capable of doubling an input voltage from +2.5 V to +5.5 V when used in a different configuration.

The LM2664 comes in a SOT23-6 package and inverts the input voltage to provide up to 40 mA of output current. It has a typical efficiency of 91% at 40 mA output and a typical output resistance of 12 Ω. This circuit draws only 1 µA of supply current in shutdown and 220 µA when on. The oscillator frequency is 160 kHz and the input voltage range is +1.8 V to +5.5 V [(1)]

Figure 1 contains the schematic for each circuit used.

A silkscreen for the evaluation board is shown in Figure 2.

A listing of the products used is shown in Table 1.

A listing of the switched capacitor family is given in Table 3.

(1) Maximum input voltage for any input on this evaluation board is +5.5 V.

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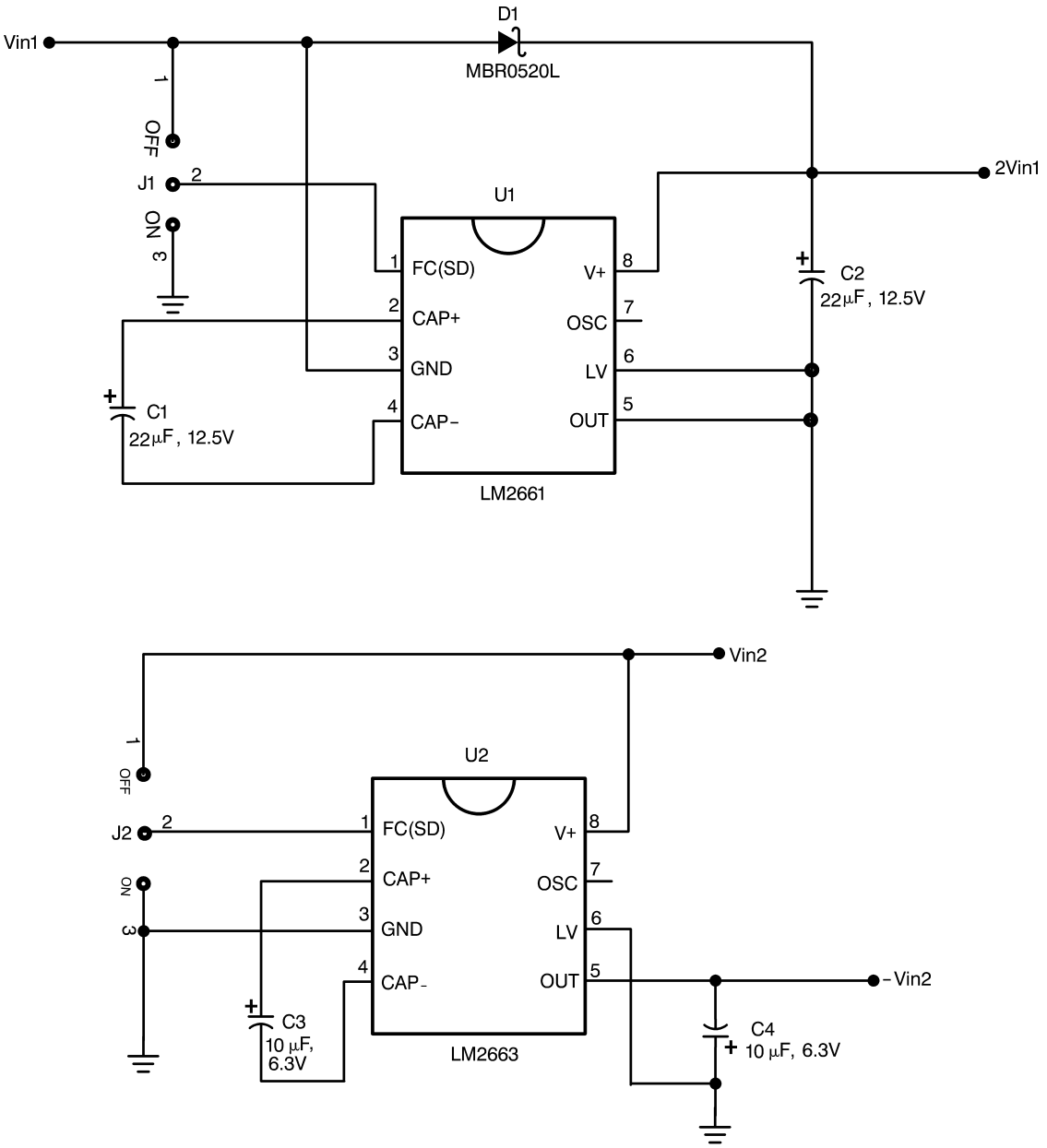

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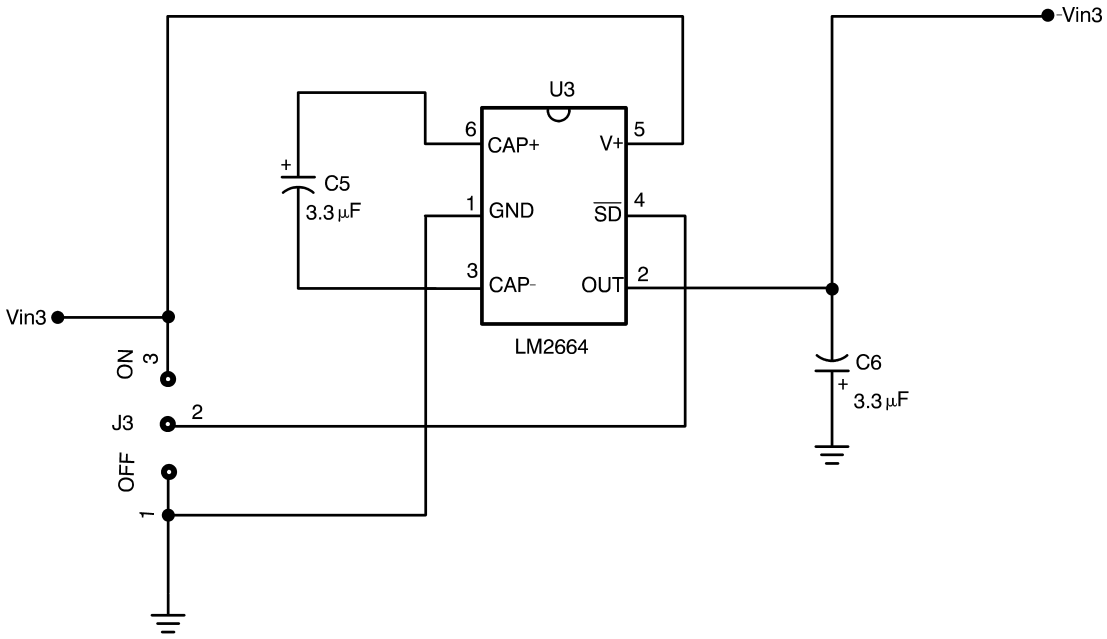

Figure 1. Schematics

2 Discussion and Component Selection

On this evaluation board, the LM2661 is used in the doubling configuration. This configuration uses only two capacitors and one diode. There is a manual shutdown jumper designated as J1 included. The internal oscillator is used with a frequency of 80 kHz. In doubling mode, the oscillator frequency can only be modified using an external capacitor and cannot be driven by an external clock. The Schottky diode D1 is needed only for start-up but should be able to handle the current required to charge the output capacitor (I=C*dV/dt). An MBR0520LT1 20 V, 0.5A diode is used on this board. Capacitor selection is very important. The capacitors chosen determine the output voltage ripple as well as the output resistance (Equation 1 and Equation 2). From these equations it is easy to see how capacitor value and ESR help determine the output resistance and output voltage ripple. For this circuit Taiyo-Yuden type 22µF ceramic capacitors are used (Model EMK432BJ226MM). These capacitors are used because of their low ESR as well as stable temperature and frequency characteristics. Therefore, they enhance the parts performance. Tantalum and ceramic capacitors and other values may be used as well to fit different performance, size, or cost requirements. Universal pads have been put on the evaluation board so that the capacitors can be replaced with those of a different size.

The LM2663 is configured as an inverter on this board. A manual shutdown is included and designated J2. The internal oscillator frequency of 150 kHz is used. The capacitor selection here is important as well since the output resistance and voltage ripple equations are the same as they are for the LM2661 (Equation 1 and Equation 2). This circuit runs at a higher frequency than the LM2661 so smaller capacitor values can be used. For this circuit Taiyo-Yuden type 10µF ceramic capacitors are used (Model JMK316BJ106ML-T). Once again the low ESR and stable characteristics of these capacitors are the reasons they were chosen. Other types and sizes of capacitors may be used here as well for different performance, size, or cost requirements.

The LM2664 is also used as an inverter on this board. A manual shutdown designated as J3 is included. The LM2664 does not have an adjustable frequency; it is fixed at 160 kHz. This circuit has the same equations for output resistance and output voltage ripple as the previous two circuits and the capacitor selection is once again important (Equation 1 and Equation 2). Taiyo Yuden multi-layer ceramic chip 3.3 µF capacitors are used for this circuit (Model LMK316BJ335ML-T). These capacitors are chosen for their low ESR (measured ≅ 25 mΩ) and small (1206) case size. They show the high performance of the LM2664 as well as the small size for the complete circuit. The output voltage ripple was measured to be less than 75mV peak to peak with a 40 mA load. Again other types and sizes of capacitors may be used for different performance and/or size requirements.

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In these equations C_2 is always the output capacitor of the circuit.

$$R_{OUT} \cong 2\,R_{SW} + \frac{2}{f_{OSC} \times C_1} + 4\,ESR_{C1} + ESR_{C2} \quad (1)$$

where R_{SW} is the sum of the ON resistance of the internal switches. R_{SW} is typically 1.4 Ω for the LM2661, 0.9 Ω for the LM2663, and 4 Ω for the LM2664.

$$V_{RIPPLE} = \frac{I_L}{f_{OSC} \times C_2} + 2 \times I_L \times ESR_{C2} \quad (2)$$

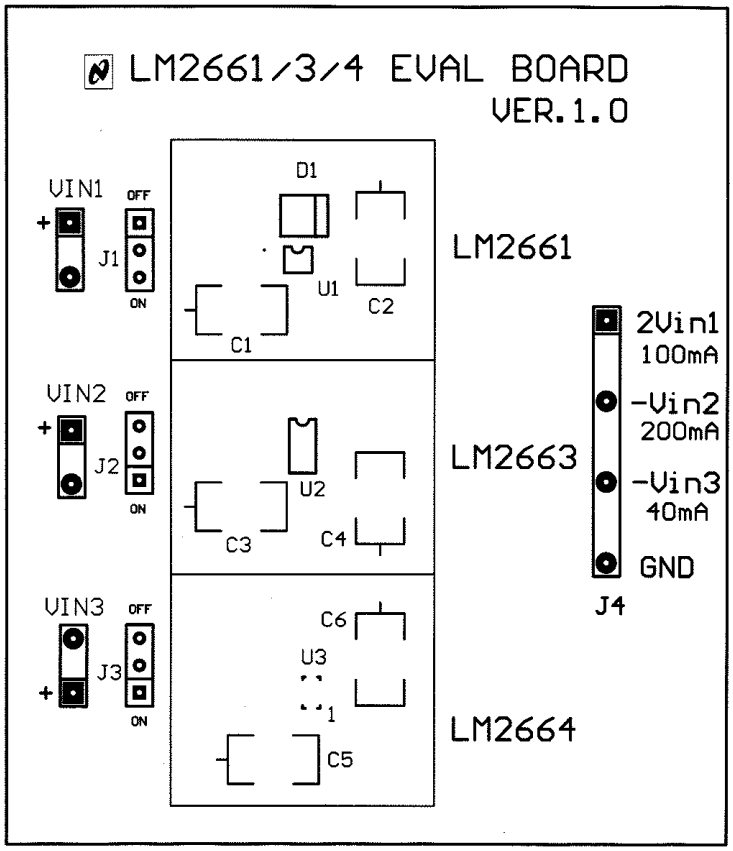

Figure 2. Silkscreen

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Table 1. Components List

Designator	Part Type	Manufacturer and Model No	Footprint	Description
U1	LM2661	Texas Instruments	VSSOP-8	Charge-pump voltage converter
D1	Diode	Motorola (MBR0520LT1)	SOD123	20 V, 0.5A Start-up diode
C1	22µF	Taiyo-Yuden (EMK432BJ226MM)	1206	Low ESR charge-pump capacitor, MLCC
C2	22µF	Taiyo-Yuden (EMK432BJ226MM)	1206	Low ESR charge-pump capacitor, MLCC
U2	LM2663	Texas Instruments	SO-8	Charge-pump voltage converter
C3	10µF	Taiyo-Yuden (JMK316BJ106ML-T)	1206	Low ESR charge-pump capacitor, MLCC
C4	10µF	Taiyo-Yuden (JMK316BJ106ML-T)	1206	Low ESR charge-pump capacitor, MLCC
U3	LM2664	Texas Instruments	SOT23-6	Charge-pump voltage converter
C5	3.3µF	Taiyo Yuden (LMK316BJ335ML-T)	1206	Low ESR charge-pump capacitor, MLCC
C6	3.3µF	Taiyo Yuden (LMK316BJ335ML-T)	1206	Low ESR charge-pump capacitor, MLCC
VIN1, VIN2, VIN3, J1, J2, J3, J4	Headers (36 posts per strip)	Amphenol (842-800-272-015) Newark stock # 87F6830	0.1" spacing	Connectors for input voltage, output voltage, and ON/OFF jumpers (2/3 strip used, 22 posts used, 19 actual pins used per board)
J1, J2, J3	Shunts	Circuit Assembly Corp. (CA-02SJC-B) Newark stock # 90F9279		Shunts for ON/OFF jumpers, shorts 2 pins, 3 shunts used per board

Table 2. Contact Information

Texas Instruments	www.ti.com	1-800-272-9959
Motorola	www.mot.com	1-800-521-6274
Taiyo Yuden	www.T-Yuden.com	1-800-348-2496
Newark	www.Newark.com	1-800-298-3133

Table 3. Switched Capacitor Family

Product	Function	R_O (Ω)	I_{OUT} (mA)	V_{IN} Range	f_{OSC} kHz	I_Q (µA)	Shut down	Freq. Control	Freq. Sync	Package
LM2660	$-V_{IN}$ or 2 V_{IN}	6.5	100	1.5 to 5.5	10/80	120/400	No	Yes	Yes	VSSOP-8, SOIC-8
LM2661	$-V_{IN}$ or 2 V_{IN}	6.5	100	1.5 to 5.5	80	1000	Yes	No	Yes	VSSOP-8, SOIC-8
LM2662	$-V_{IN}$ or 2 V_{IN}	3.5	200	1.5 to 5.5	20/150	300/1300	No	Yes	Yes	SOIC-8
LM2663	$-V_{IN}$ or 2 V_{IN}	3.5	200	1.5 to 5.5	150	1300	Yes	No	Yes	SOIC-8
LM2664	$-V_{IN}$	12	40	1.8 to 5.5	160	220	Yes	No	No	SOT23-6
LM2665	2 V_{IN}	12	40	1.8 to 5.5	160	550	Yes	No	No	SOT23-6
LM3350	3/2 V_{IN} or 2/3 V_{IN}	4.2/1.8	50	1.5 to 5.5	1600	3750	Yes	No	No	VSSOP-8
LM3351	3/2 V_{IN} or 2/3 V_{IN}	4.2/1.8	50	1.5 to 5.5	400	1110	Yes	No	No	VSSOP-8

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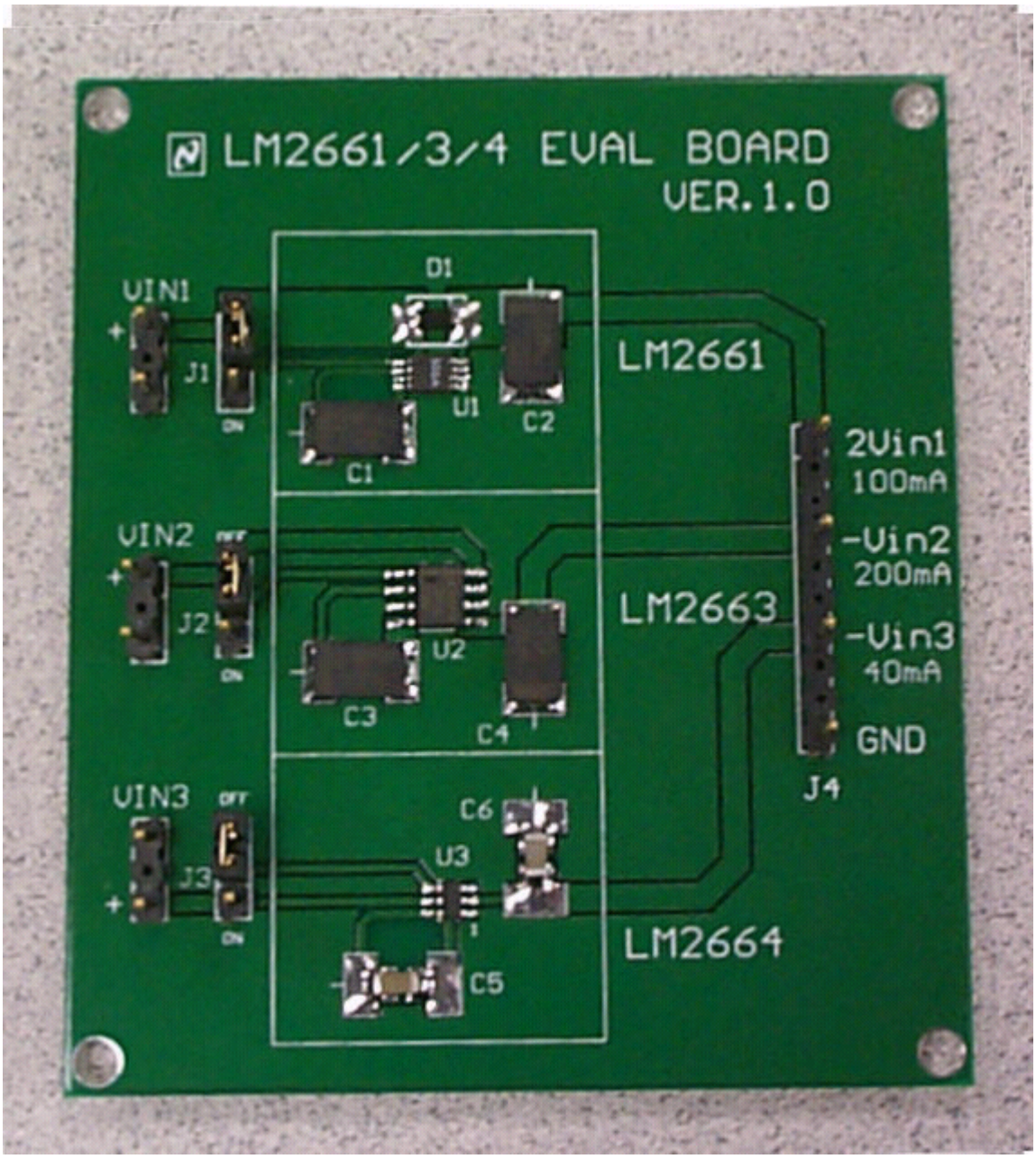

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