LM2661/3/4 Evaluation Board

National Semiconductor
Application Note 1142
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Introduction

The LM2661, LM2663, and LM2664 are part of a family of CMOS charge-pump voltage converters (*Table 2*). 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 SO-8 and MSOP-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 6.5Ω. This circuit typically draws only 500nA of supply current in shutdown mode and 120µA when operating. The internal oscillator frequency is 80kHz and the input voltage range is +2.5V to +5.5V (Note 1). The LM2661 is also capable of inverting an input voltage from +1.5V to +5.5V when used in a different configuration.

The LM2663 comes in a SO-8 package and inverts the input voltage to provide up to 200mA of output current. It has a typical efficiency of 86% at 200mA output and a typical output resistance of 3.5Ω. This circuit draws only 10µA of supply current in shutdown and 300µA when operating. The internal oscillator frequency is 150kHz and the input voltage range is +1.5V to +5.5V (Note 1). The LM2663 is also capable of doubling an input voltage from +2.5V to +5.5V when used in a different configuration.

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

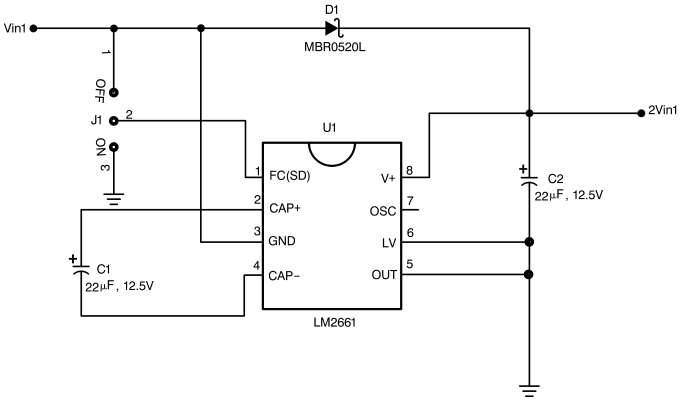
Note 1: Maximum input voltage for any input on this evaluation board is +5.5V.

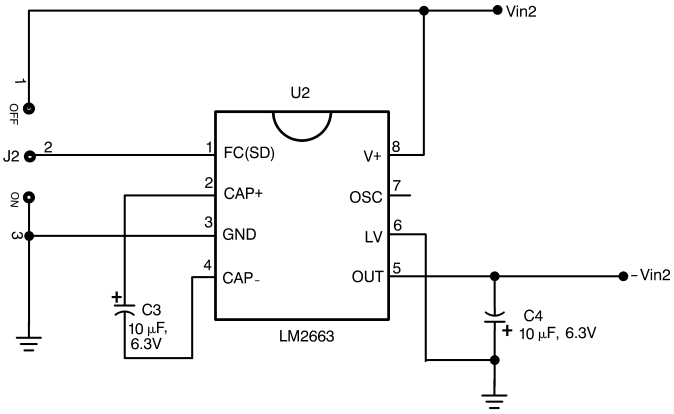
Figure 1 contains the schematic for each circuit used.

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 2*.





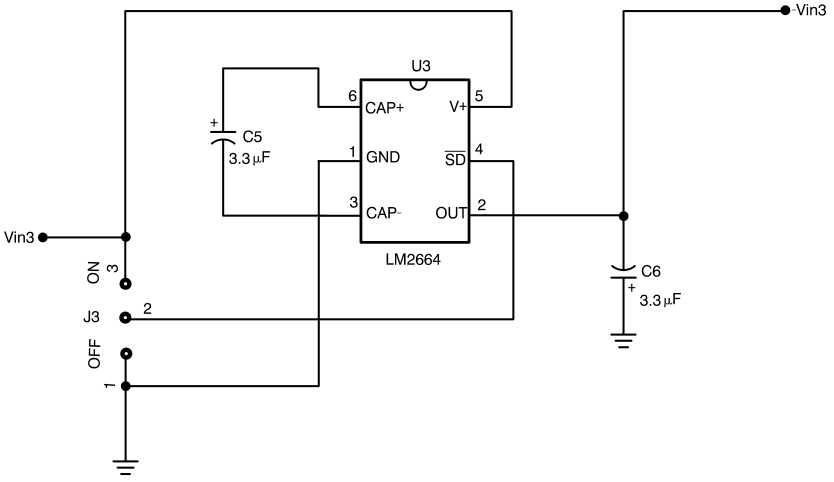


FIGURE 1. Schematics

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 80kHz. 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 20V, 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 Cornell-Dubilier ESRD type 22µF polymer electrolytic capacitors are used (Model ESRD220M12B). These capacitors are used because of their low ESR (typically 20 mΩ @ 100kHz) as well as stable temperature and frequency characteristics. Therefore they enhance the parts performance. The output voltage ripple was measured at less than 55 mV peak to peak with a 100 mA load. 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 150kHz 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 Cornell-Dubilier ESRD type 10µF polymer electrolytic capacitors are used (Model ESRD100M06B). Once again the low ESR (typically 42 mΩ @ 100kHz) and stable characteristics of these capacitors are the reasons they were chosen. Output voltage ripple was measured to be less than 140 mV peak to peak with a 200 mA load. 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 160kHz. 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 3.3µF 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.

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

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

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

Note 2: In these equations C_2 is always the output capacitor of the circuit.

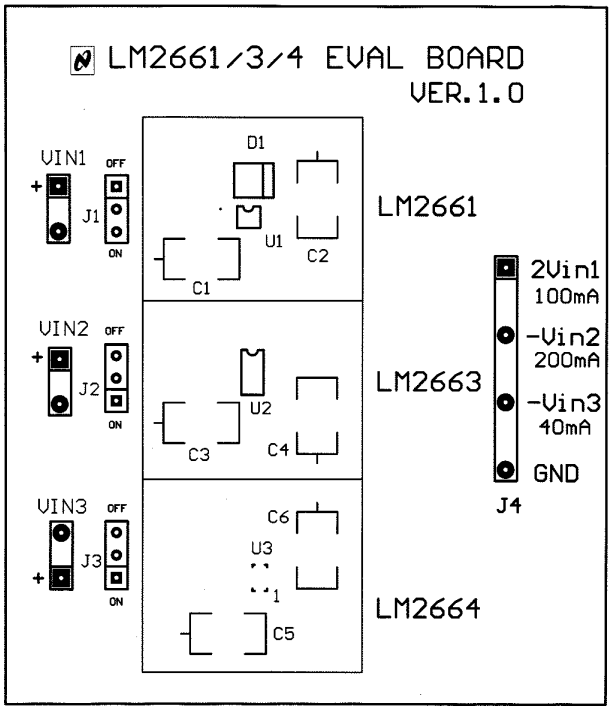


FIGURE 2. Silkscreen

TABLE 1. Components List

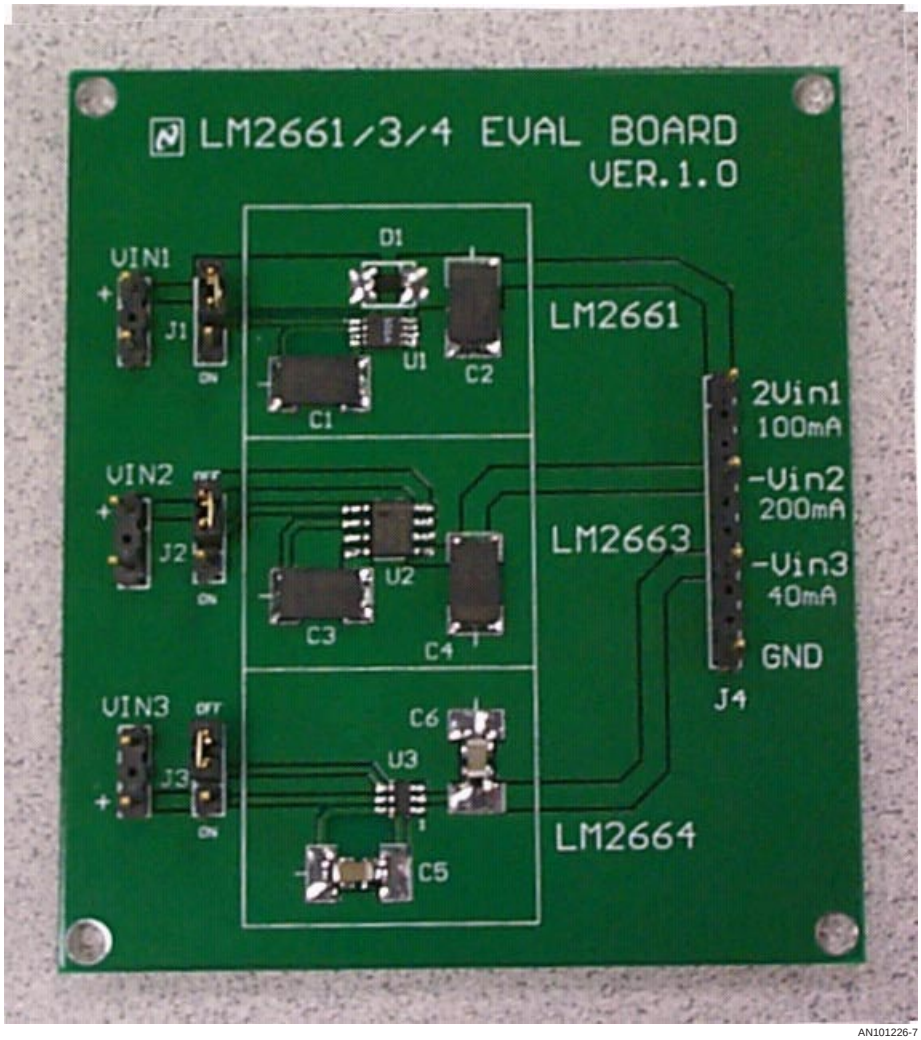
Designator	Part Type	Manufacturer and Model #	Footprint	Description
U1	LM2661	National Semiconductor Corp.	MSOP-8	Charge-pump voltage converter
D1	Diode	Motorola (MBR0520LT1)	SOD123	20V, 0.5A Start-up diode
C1	22µF	Cornell-Dubilier (ESRD220M12B)	D-Case	Low ESR charge-pump capacitor, polymer electrolytic
C2	22µF	Cornell-Dubilier (ESRD220M12B)	D-Case	Low ESR charge-pump capacitor, polymer electrolytic
U2	LM2663	National Semiconductor Corp.	SO-8	Charge-pump voltage converter
C3	10µF	Cornell-Dubilier (ESRD100M06B)	D-Case	Low ESR charge-pump capacitor, polymer electrolytic
C4	10µF	Cornell-Dubilier (ESRD100M06B)	D-Case	Low ESR charge-pump capacitor, MLCC
U3	LM2664	National Semiconductor Corp.	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

Contact Information

National Semiconductor Corp.	www.national.com	1-800-272-9959
Motorola	www.mot.com	1-800-521-6274
Cornell-Dubilier	www.cornell-dubilier.com	1-508-996-8564
Taiyo Yuden	www.T-Yuden.com	1-800-348-2496
Newark	www.Newark.com	1-800-298-3133

TABLE 2. Switched Capacitor Family

Product	Function	R_O (ohms)	I_{OUT} (mA)	V_{IN} range	f_{OSC} kHz	I_Q (µA)	Shutdown	Freq. Control	Freq. Sync	Package
LM2660	$-V_{IN}$ or $2V_{IN}$	6.5	100	1.5 to 5.5	10/80	120/400	No	Yes	Yes	MSOP-8, SO-8
LM2661	$-V_{IN}$ or $2V_{IN}$	6.5	100	1.5 to 5.5	80	1000	Yes	No	Yes	MSOP-8, SO-8
LM2662	$-V_{IN}$ or $2V_{IN}$	3.5	200	1.5 to 5.5	20/150	300/1300	No	Yes	Yes	SO-8
LM2663	$-V_{IN}$ or $2V_{IN}$	3.5	200	1.5 to 5.5	150	1300	Yes	No	Yes	SO-8
LM2664	$-V_{IN}$	12	40	1.8 to 5.5	160	220	Yes	No	No	SOT23-6
LM2665	$2V_{IN}$	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	MSOP-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	MSOP-8


LM2661/3/4 EVAL BOARD
VER.1.0
VIN1
J1
ON
D1
U1
C1
C2
LM2661
VIN2
OFF
J2
ON
U2
C3
C4
LM2663
VIN3
OFF
J3
ON
C6
U3
C5
LM2664
2Vin1
100mA
-Vin2
200mA
-Vin3
40mA
GND
J4

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Notes

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