# *MAXIM*

# Triple Charge-Pump TFT LCD DC-DC Converter

**EVALUATION KIT AVAILABLE**

**MAX1747**

## General Description

The MAX1747 triple charge-pump DC-DC converter provides the regulated voltages required by active matrix thin-film transistor (TFT) liquid-crystal displays (LCDs) in a low-profile TSSOP package. One high-power and two low-power charge pumps convert the +2.7V to +4.5V input supply voltage into three independent output voltages.

The primary high-power charge pump generates an output voltage ($V_{OUT}$) between 4.5V and 5.5V that is regulated within ±1%. The low-power BiCMOS control circuitry and the low on-resistance ($R_{ON}$) power MOSFETs maximize efficiency. The adjustable switching frequency (200kHz to 2MHz) provides fast transient response and allows the use of small low-profile ceramic capacitors.
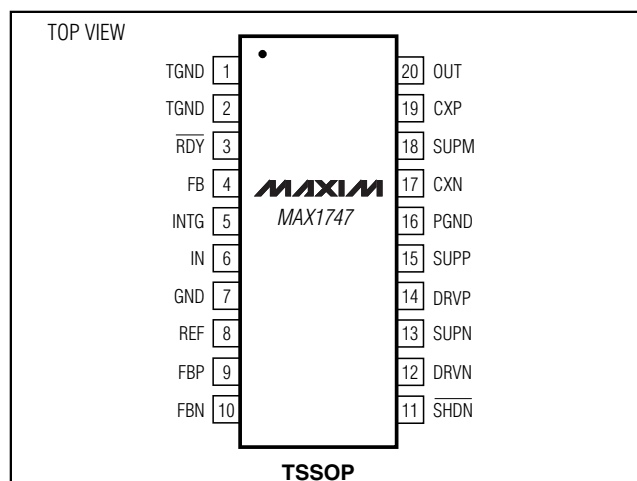
The dual low-power charge pumps independently regulate one positive output ($V_{POS}$) and one negative output ($V_{NEG}$). These additional outputs use external diode and capacitor multiplier stages (as many stages as required) to regulate output voltages up to +35V and -35V.

The constant switching frequency and a proprietary regulation algorithm minimize output ripple and capacitor sizes for all three charge pumps. The MAX1747 is available in the ultra-thin TSSOP package (1.1mm max height).

## Applications

TFT Active-Matrix LCDs

Passive-Matrix Displays

Personal Digital Assistants (PDAs)

## Pin Configuration

TOP VIEW

```
        TGND  1 |•        | 20  OUT
        TGND  2 |         | 19  CXP
         RDY  3 |         | 18  SUPM
          FB  4 | MAXIM   | 17  CXN
        INTG  5 | MAX1747 | 16  PGND
          IN  6 |         | 15  SUPP
         GND  7 |         | 14  DRVP
         REF  8 |         | 13  SUPN
         FBP  9 |         | 12  DRVN
         FBN 10 |         | 11  SHDN
```

**TSSOP**

## Features

♦ **Adjustable Outputs**

   **Up to +5.5V Main High-Power Output**

   **Up to +35V Positive Charge-Pump Output**

   **Down to -35V Negative Charge-Pump Output**

♦ **200kHz to 2MHz Adjustable Switching Frequency**

♦ **+2.7V to +4.5V Input Supply**

♦ **Internal Power MOSFETs**

♦ **0.1µA Shutdown Current**

♦ **Internal Soft-Start**

♦ **Power-Ready Output**

♦ **Internal Supply Sequencing**

♦ **Fast Transient Response**

♦ **Ultra-Thin Solution (No Inductors)**

♦ **Thin TSSOP Package (1.1mm max)**

## Ordering Information

| PART | TEMP. RANGE | PIN-PACKAGE |
|------|-------------|-------------|
| MAX1747EUP | -40°C to +85°C | 20 TSSOP |

## Typical Operating Circuit
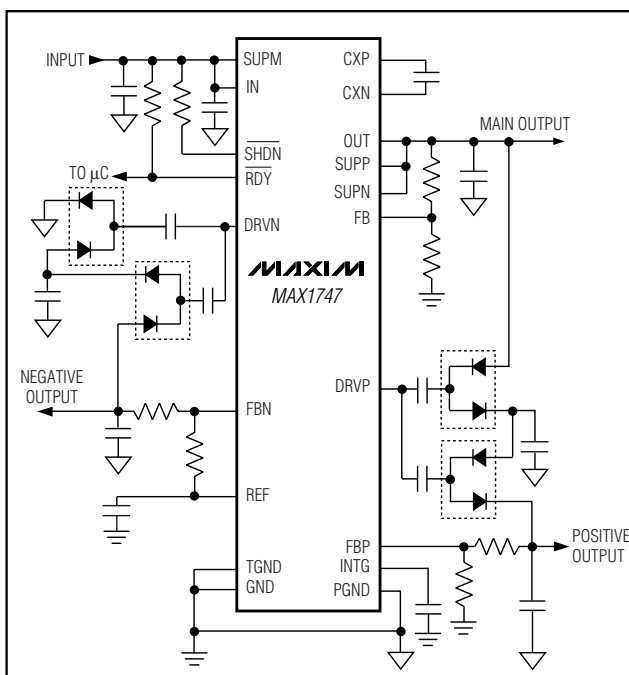


*MAXIM* _____ **Maxim Integrated Products  1**

# Triple Charge-Pump TFT LCD DC-DC Converter

## ABSOLUTE MAXIMUM RATINGS

IN, SUPM, OUT, TGND to GND................................-0.3V to +6V
$\overline{\text{SHDN}}$...................................................................-0.3V to +1V
PGND to GND....................................................................±0.3V
SUPM to IN .......................................................................±0.3V
CXN to PGND......................................-0.3V to ($V_{SUPM}$ + 0.3V)
CXP to PGND ..........................($V_{SUPM}$ - 0.3V) to ($V_{OUT}$ + 0.3V)
DRVN to GND.......................................-0.3V to ($V_{SUPN}$ + 0.3V)
DRVP to GND.......................................-0.3V to ($V_{SUPP}$ + 0.3V)
$\overline{\text{RDY}}$ to GND .........................................................-0.3V to +14V
SUPP, SUPN to GND............................................-0.3V to +14V
INTG, REF, FB, FBN, FBP to GND ...............-0.3V to ($V_{IN}$ + 0.3V)

Continuous Current into:
   SUPM, CXN, CXP, OUT .............................................±800mA
   SUPP, SUPN, DRVN, DRVP.......................................±200mA
   $\overline{\text{SHDN}}$.........................................................................+100µA
All Other Pins ...................................................................±10mA
Continuous Power Dissipation ($T_A$ = +70°C)
   20-Pin TSSOP (derate 10.9mW/°C above +70°C) .......879mW
Operating Temperature Range............................-40°C to +85°C
Junction Temperature.....................................................+150°C
Storage Temperature Range .............................-65°C to +150°C
Lead Temperature (soldering, 10s) .................................+300°C

*Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

## ELECTRICAL CHARACTERISTICS

($V_{IN}$ = $V_{SUPM}$ = +3.0V, $V_{SUPP}$ = $V_{SUPN}$ = +5V, TGND = PGND = GND, $I_{\overline{SHDN}}$ = 22µA, $C_{OUT}$ = 2 × 4.7µF, $C_{REF}$ = 0.22µF, $C_{INTG}$ = 1500pF, $V_{OUT}$ = +5V, **$T_A$ = 0°C to +85°C**, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Input Supply Range | $V_{IN}$ | | 2.7 | | 4.5 | V |
| Input Undervoltage Threshold | $V_{UVLO}$ | $V_{IN}$ falling, 40mV hysteresis (typ) | 2.2 | 2.4 | 2.6 | V |
| Input Quiescent Supply Current | $I_{IN}$ + $I_{SUPM}$ | $V_{FB}$ = $V_{FBP}$ = 1.5V, $V_{FBN}$ = -0.2V, $V_{OUT}$ = 5V, no load on DRVN and DRVP; CXN and CXP open | | 0.9 | 1.0 | mA |
| Output Quiescent Supply Current | $I_{Q(OUT)}$ | $V_{FB}$ = $V_{FBP}$ = 1.5V, $V_{FBN}$ = -0.2V, $V_{OUT}$ = 5V, no load on DRVN and DRVP; CXN and CXP open | | 2.5 | 4.0 | mA |
| Shutdown Supply Current | | $V_{\overline{SHDN}}$ = 0, $V_{SUPM}$ = 5V | | 0.1 | 20 | µA |
| Operating Frequency | $f_{OSC}$ | $I_{\overline{SHDN}}$ = 22µA | 0.65 | 1 | 1.2 | MHz |
| **MAIN CHARGE PUMP** | | | | | | |
| Output Voltage Range | $V_{OUT}$ | | 4.5 | | 5.5 | V |
| Maximum Output Current | $I_{OUT(MAX)}$ | $C_X$ = 0.47µF | 200 | | | mA |
| FB Regulation Voltage | $V_{FB}$ | | 1.237 | 1.248 | 1.263 | V |
| FB Input Bias Current | $I_{FB}$ | $V_{FB}$ = 1.25V | -50 | | +50 | nA |
| Integrator Transconductance | | | | 530 | | µS |
| FB Power-Ready Trip Level | | Rising edge | 1.09 | 1.125 | 1.16 | V |
| FB Fault Trip Level | | Falling edge | | 1.100 | | V |
| Main Soft-Start Period | | | | 4.096 / $F_{OSC}$ | | s |
| **NEGATIVE LOW-POWER CHARGE PUMP** | | | | | | |
| SUPN Input Supply Range | $V_{SUPN}$ | | 2.7 | | 13 | V |
| SUPN Quiescent Current | $I_{SUPN}$ | $V_{FBN}$ = -0.2V, no load on DRVN | | 0.6 | 0.8 | mA |
| SUPN Shutdown Current | | $V_{\overline{SHDN}}$ = 0, $V_{SUPN}$ = 13V | | 0.1 | 10 | µA |
| FBN Regulation Voltage | $V_{FBN}$ | | -50 | 0 | +50 | mV |

**MAXIM**

## ELECTRICAL CHARACTERISTICS (continued)

($V_{IN}$ = $V_{SUPM}$ = +3.0V, $V_{SUPP}$ = $V_{SUPN}$ = +5V, TGND = PGND = GND, $I_{\overline{SHDN}}$ = 22µA, $C_{OUT}$ = 2 × 4.7µF, $C_{REF}$ = 0.22µF, $C_{INTG}$ = 1500pF, $V_{OUT}$ = +5V, **$T_A$ = 0°C to +85°C**, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| FBN Input Bias Current | $I_{FBN}$ | $V_{FBN}$ = -50mV | -50 | | +50 | nA |
| DRVN PCH On-Resistance | | | | 3 | 6 | Ω |
| DRVN NCH On-Resistance | | $V_{FBN}$ = 50mV | | 1 | 5 | Ω |
| | | $V_{FBN}$ = -50mV | 20 | | | kΩ |
| FBN Power-Ready Trip Level | | Falling edge | 80 | 125 | 165 | mV |
| FBN Fault Trip Level | | Rising edge | | 140 | | mV |
| Negative Soft-Start Period | | | | 2.048/ $F_{OSC}$ | | s |
| **POSITIVE LOW-POWER CHARGE PUMP** | | | | | | |
| SUPP Input Supply Range | $V_{SUPP}$ | | 2.7 | | 13 | V |
| SUPP Quiescent Current | $I_{SUPP}$ | $V_{FBP}$ = 1.5V, no load on DRVP | | 0.6 | 0.8 | mA |
| SUPP Shutdown Current | | $V_{\overline{SHDN}}$ = 0, $V_{SUPP}$ = 13V | | 0.1 | 10 | µA |
| FBP Regulation Voltage | $V_{FBP}$ | | 1.20 | 1.25 | 1.30 | V |
| FBP Input Bias Current | $I_{FBP}$ | $V_{FBP}$ = 1.5V | -50 | | +50 | nA |
| DRVP PCH On-Resistance | | | | 3 | 6 | Ω |
| DRVP NCH On-Resistance | | $V_{FBP}$ = 1.20V | | 1.5 | 5 | Ω |
| | | $V_{FBP}$ = 1.30V | | 20 | | kΩ |
| FBP Power-Ready Trip Level | | Rising edge | 1.090 | 1.125 | 1.160 | V |
| FBP Fault Trip Level | | Falling edge | | 1.100 | | V |
| Positive Soft-Start Period | | | | 2.048/ $F_{OSC}$ | | s |
| **REFERENCE** | | | | | | |
| Reference Voltage | $V_{REF}$ | -2µA < $I_{REF}$ < 50µA | 1.231 | 1.25 | 1.269 | V |
| Reference Undervoltage Threshold | | $V_{REF}$ rising | 0.95 | 1.05 | 1.18 | V |
| **LOGIC SIGNALS** | | | | | | |
| $\overline{SHDN}$ Input Low Voltage | | | | | 0.4 | V |
| $\overline{SHDN}$ Bias Voltage | | $I_{\overline{SHDN}}$ = 22µA | 580 | 724 | 830 | mV |
| $\overline{SHDN}$ Bias Voltage Tempco | | | | 2 | | mV/°C |
| $\overline{SHDN}$ Input Current Range | $I_{\overline{SHDN}}$ | For 200kHz to 2MHz operation | 3 | | 65 | µA |
| $\overline{RDY}$ Output Low Voltage | | $I_{SINK}$ = 2mA | | 0.25 | 0.5 | V |
| $\overline{RDY}$ Output High Leakage | | $V_{\overline{RDY}}$ = 13V | | 0.01 | 1 | µA |

MAX1747

## ELECTRICAL CHARACTERISTICS

($V_{IN}$ = $V_{SUPM}$ = +3.0V, $V_{SUPP}$ = $V_{SUPN}$ = +5V, TGND = PGND = GND, $I_{\overline{SHDN}}$ = 22µA, $C_{OUT}$ = 2 × 4.7µF, $C_{REF}$ = 0.22µF, $C_{INTG}$ = 1500pF, $V_{OUT}$ = +5V, **$T_A$ = -40°C to +85°C**, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | MAX | UNITS |
|---|---|---|---|---|---|
| Input Supply Range | $V_{IN}$ | | 2.7 | 4.5 | V |
| Input Undervoltage Threshold | $V_{UVLO}$ | $V_{IN}$ falling, 40mV hysteresis (typ) | 2.2 | 2.6 | V |
| Input Quiescent Supply Current | $I_{IN}$ + $I_{SUPM}$ | $V_{FB}$ = $V_{FBP}$ = 1.5V, $V_{FBN}$ = -0.2V, $V_{OUT}$ = 5V, no load on DRVN and DRVP; CXN and CXP open | | 1.0 | mA |
| Output Quiescent Supply Current | $I_{Q(OUT)}$ | $V_{FB}$ = $V_{FBP}$ = 1.5V, $V_{FBN}$ = -0.2V, $V_{OUT}$ = 5V, no load on DRVN and DRVP; CXN and CXP open | | 4.0 | mA |
| Input Shutdown Current | | $V_{\overline{SHDN}}$ = 0, $V_{SUPM}$ = 5V | | 20 | µA |
| Operating Frequency | $f_{OSC}$ | $I_{\overline{SHDN}}$ = 22µA | 0.65 | 1.2 | MHz |
| **MAIN CHARGE PUMP** | | | | | |
| Output Voltage Range | $V_{OUT}$ | | 4.5 | 5.5 | V |
| Output Current | $I_{OUT(MAX)}$ | $C_X$ = 0.47µF | 200 | | mA |
| FB Regulation Voltage | $V_{FB}$ | | 1.222 | 1.271 | V |
| FB Input Bias Current | $I_{FB}$ | $V_{FB}$ = 1.25V | -50 | +50 | nA |
| FB Power-Ready Trip Level | | Rising edge | 1.09 | 1.16 | V |
| **NEGATIVE LOW-POWER CHARGE PUMP** | | | | | |
| SUPN Input Supply Range | $V_{SUPN}$ | | 2.7 | 13 | V |
| SUPN Quiescent Current | $I_{SUPN}$ | $V_{FBN}$ = -0.2V, no load on DRVN | | 0.8 | mA |
| SUPN Shutdown Current | | $V_{\overline{SHDN}}$ = 0, $V_{SUPN}$ = 13V | | 10 | µA |
| FBN Regulation Voltage | $V_{FBN}$ | | -50 | +50 | mV |
| FBN Input Bias Current | $I_{FBN}$ | $V_{FBN}$ = 0 | -50 | +50 | nA |
| DRVN PCH On-Resistance | | | | 6 | Ω |
| DRVN NCH On-Resistance | | $V_{FBN}$ = 50mV | | 5 | Ω |
| | | $V_{FBN}$ = -50mV | 20 | | kΩ |
| FBN Power-Ready Trip Level | | Falling edge | 80 | 165 | mV |
| **POSITIVE LOW-POWER CHARGE PUMP** | | | | | |
| SUPP Input Supply Range | $V_{SUPP}$ | | 2.7 | 13 | V |
| SUPP Quiescent Current | $I_{SUPP}$ | $V_{FBP}$ = 1.5V, no load on DRVP | | 0.8 | mA |
| SUPP Shutdown Current | | $V_{\overline{SHDN}}$ = 0, $V_{SUPP}$ = 13V | | 10 | µA |
| FBP Regulation Voltage | $V_{FBP}$ | | 1.20 | 1.30 | V |
| FBP Input Bias Current | $I_{FBP}$ | $V_{FBP}$ = 1.5V | -50 | +50 | nA |
| DRVP PCH On-Resistance | | | | 6 | Ω |
| DRVP NCH On-Resistance | | $V_{FBP}$ = 1.20V | | 5 | Ω |
| | | $V_{FBP}$ = 1.30V | 20 | | kΩ |
| FBP Power-Ready Trip Level | | Rising edge | 1.09 | 1.16 | V |

**MAXIM**

**MAX1747**

## ELECTRICAL CHARACTERISTICS (continued)

($V_{IN}$ = $V_{SUPM}$ = +3.0V, $V_{SUPP}$ = $V_{SUPM}$ = +5V, TGND = PGND = GND, $I_{\overline{SHDN}}$ = 22µA, $C_{OUT}$ = 2 × 4.7µF, $C_{REF}$ = 0.22µF, $C_{INTG}$ = 1500pF, $V_{OUT}$ = +5V, **$T_A$ = -40°C to +85°C**, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | MAX | UNITS |
|---|---|---|---|---|---|
| **REFERENCE** | | | | | |
| Reference Voltage | $V_{REF}$ | -2µA < $I_{REF}$ < 50µA | 1.222 | 1.269 | V |
| Reference Undervoltage Threshold | | $V_{REF}$ rising | 0.95 | 1.18 | V |
| **LOGIC SIGNALS** | | | | | |
| $\overline{SHDN}$ Input Low Voltage | | | | 0.4 | V |
| $\overline{SHDN}$ Bias Voltage | | $I_{\overline{SHDN}}$ = 22µA | 580 | 900 | mV |
| $\overline{SHDN}$ Input Current Range | $I_{\overline{SHDN}}$ | For 200kHz to 2MHz operation | 3 | 65 | µA |
| $\overline{RDY}$ Output Low Voltage | | $I_{SINK}$ = 2mA | | 0.5 | V |
| $\overline{RDY}$ Output High Leakage | | $V_{\overline{RDY}}$ = 13V | | 1 | µA |

**Note 1:** Specifications from 0°C to -40°C are guaranteed by design, not production tested.

_____ *Typical Operating Characteristics*

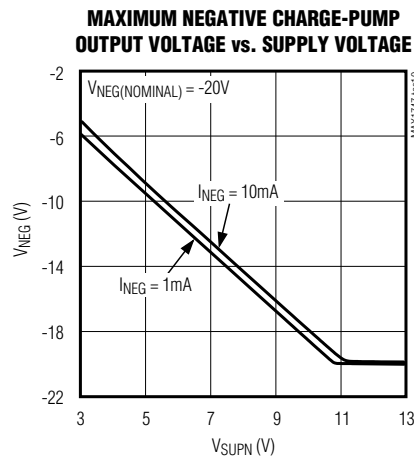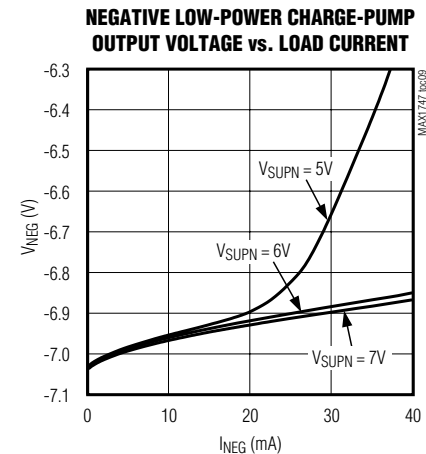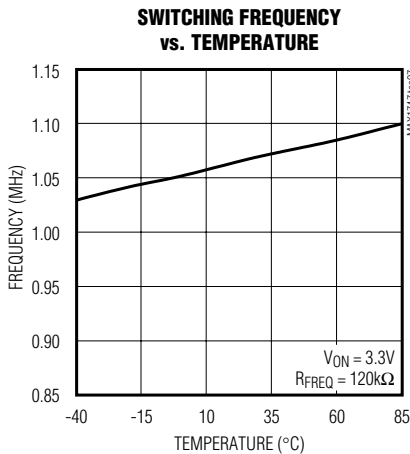(Circuit of Figure 1, $V_{IN}$ = $V_{SUPM}$ = +3.3V, $T_A$ = +25°C, unless otherwise noted.)
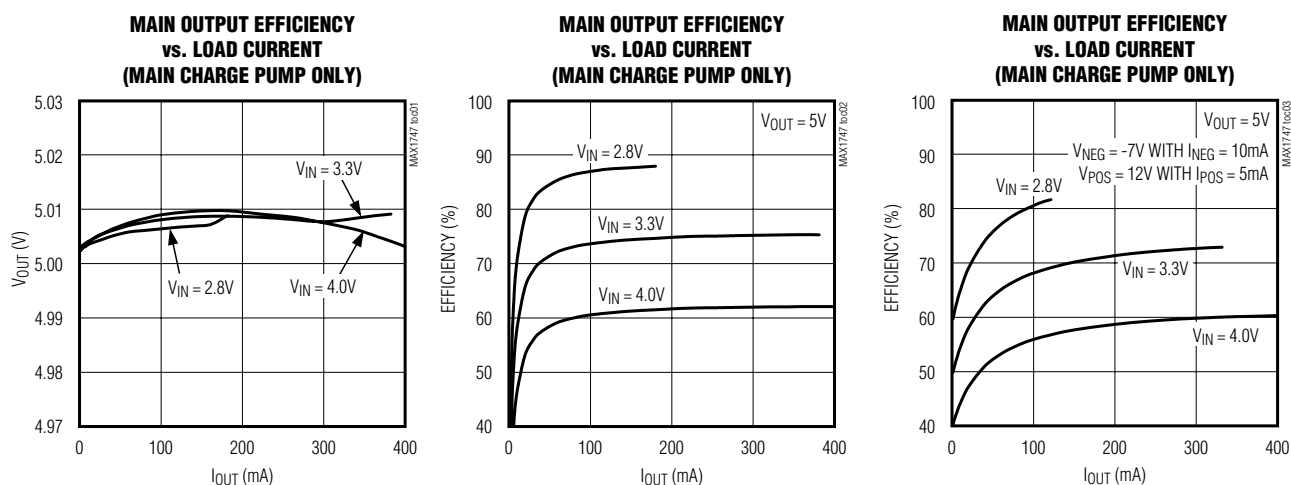


MAIN OUTPUT EFFICIENCY
vs. LOAD CURRENT
(MAIN CHARGE PUMP ONLY)



MAIN OUTPUT EFFICIENCY
vs. LOAD CURRENT
(MAIN CHARGE PUMP ONLY)



MAIN OUTPUT EFFICIENCY
vs. LOAD CURRENT
(MAIN CHARGE PUMP ONLY)

*MAXIM*

**MAX1747**

*Typical Operating Characteristics (continued)*

(Circuit of Figure 1, $V_{IN} = V_{SUPM} = +3.3V$, $T_A = +25°C$, unless otherwise noted.)

**NO-LOAD SUPPLY CURRENT vs. SWITCHING FREQUENCY**

**SWITCHING FREQUENCY vs. $I_{\overline{SHDN}}$**

**NO-LOAD SUPPLY CURRENT vs. TEMPERATURE**

**SWITCHING FREQUENCY vs. TEMPERATURE**

**NEGATIVE LOW-POWER CHARGE-PUMP EFFICIENCY vs. LOAD CURRENT**

**NEGATIVE LOW-POWER CHARGE-PUMP OUTPUT VOLTAGE vs. LOAD CURRENT**

**MAXIMUM NEGATIVE CHARGE-PUMP OUTPUT VOLTAGE vs. SUPPLY VOLTAGE**

**POSITIVE LOW-POWER CHARGE-PUMP EFFICIENCY vs. LOAD CURRENT**

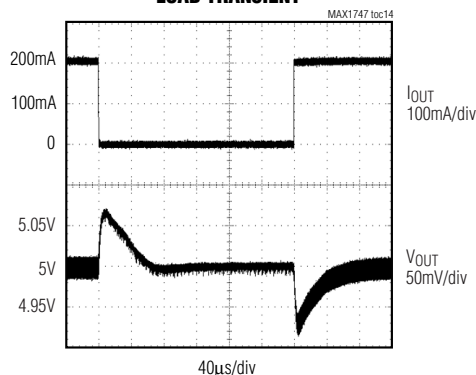**POSITIVE LOW-POWER CHARGE-PUMP OUTPUT VOLTAGE vs. LOAD CURRENT**
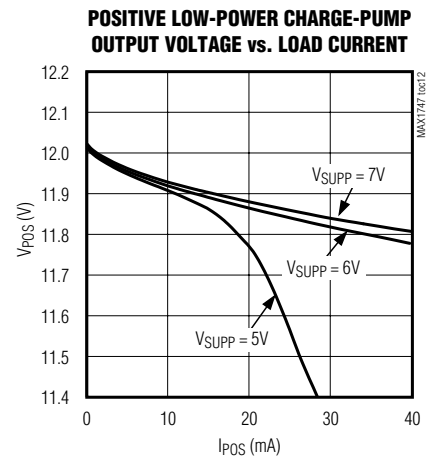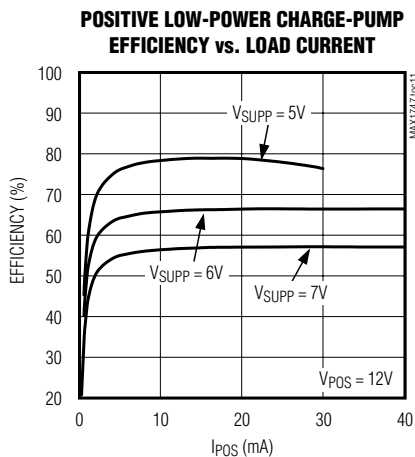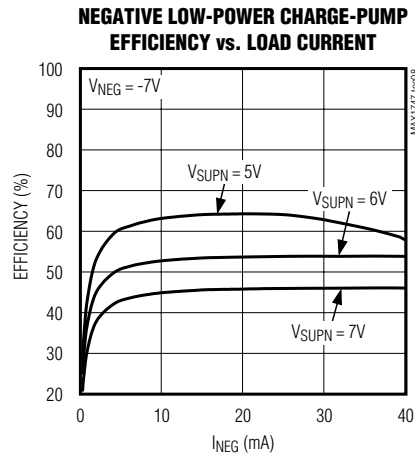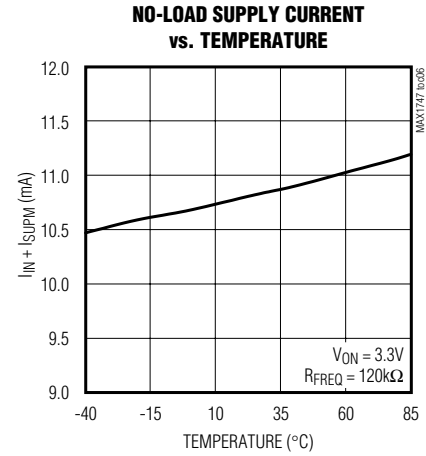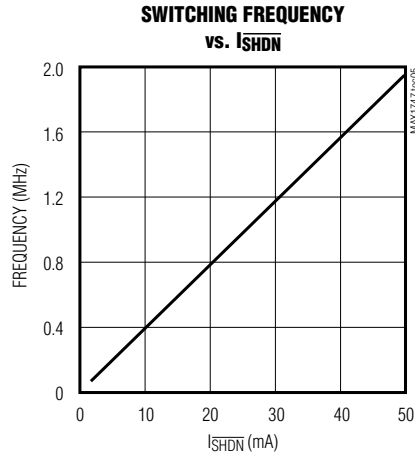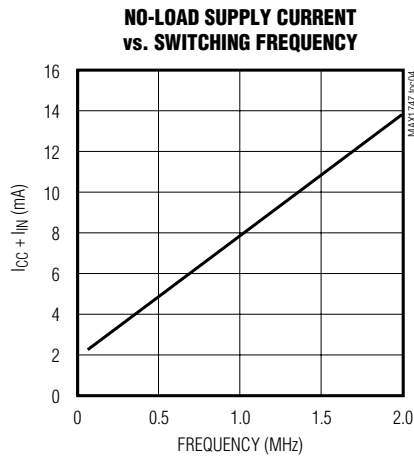
***MAXIM***

## Typical Operating Characteristics (continued)

(Circuit of Figure 1, $V_{IN}$ = $V_{SUPM}$ = +3.3V, $T_A$ = +25°C, unless otherwise noted.)

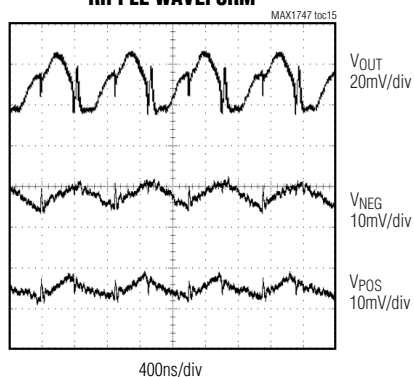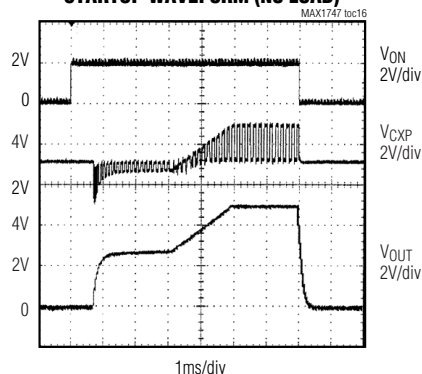**MAXIMUM POSITIVE CHARGE-PUMP OUTPUT VOLTAGE vs. SUPPLY VOLTAGE**
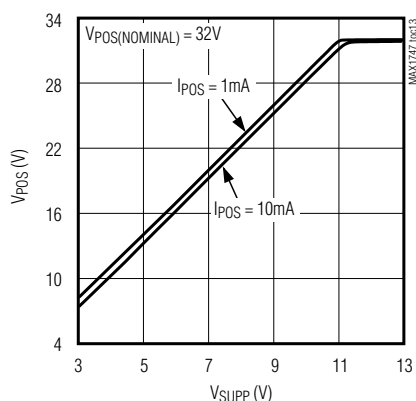


**LOAD TRANSIENT**



$V_{IN}$ = 3.3V, $V_{OUT}$ = 5.0V
$R_{OUT}$ = 500Ω TO 25Ω
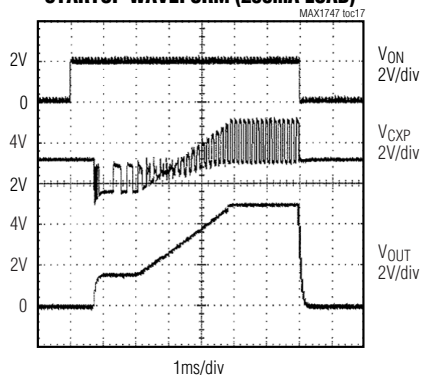$C_{INTG}$ = 1500pF

**RIPPLE WAVEFORM**



$V_{OUT}$ = +5.0V, $I_{OUT}$ = 200mA
$V_{NEG}$ = -7V, $I_{NEG}$ = 10mA
$V_{POS}$ = +12V, $I_{POS}$ = 5mA
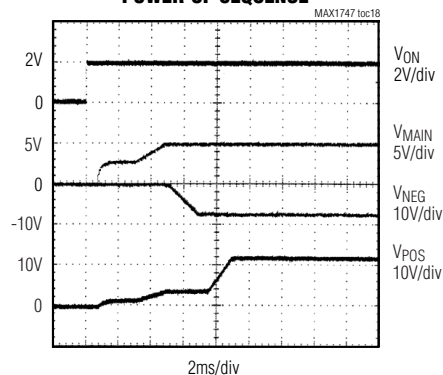
**STARTUP WAVEFORM (NO LOAD)**



$V_{OUT}$ = 5V, NO LOAD
ON CONNECTED TO $\overline{SHDN}$ THROUGH
A 58kΩ RESISTOR

**STARTUP WAVEFORM (200mA LOAD)**



$V_{OUT}$ = 5V, $R_{OUT}$ = 25Ω (200mA)
ON CONNECTED TO $\overline{SHDN}$ THROUGH
A 58kΩ RESISTOR

**POWER-UP SEQUENCE**



$V_{MAIN}$ = 5V, $V_{NEG}$ = -7V, $V_{POS}$ = 12V
ON CONNECTED TO $\overline{SHDN}$ THROUGH
A 58kΩ RESISTOR

MAX1747

**MAXIM**

_____ 7

MAX1747

| PIN | NAME | FUNCTION |
|---|---|---|
| 1, 2 | TGND | Must be connected to ground. |
| 3 | $\overline{\text{RDY}}$ | Active-Low Open-Drain Output. Indicates all outputs are ready. The $R_{ON}$ is 125$\Omega$ (typ). |
| 4 | FB | Main Charge-Pump Feedback Input. Regulates to 1.25V nominal. Connect to the center of a feedback resistive divider between the main output (OUT) and analog ground (GND). |
| 5 | INTG | Main Charge-Pump Integrator Output. If used, connect 1500pF to analog ground (GND). To disable the integrator, connect to GND. |
| 6 | IN | Supply Input. +2.7V to +4.5V input range. Powers only the logic and reference. Bypass to analog ground (GND) with a 0.1$\mu$F capacitor as close to the pin as possible. |
| 7 | GND | Analog Ground. Connect to power ground (PGND) underneath the IC. |
| 8 | REF | Internal Reference Bypass Terminal. Connect a 0.22$\mu$F capacitor from this terminal to analog ground (GND). External load capability to 50$\mu$A. REF is disabled in shutdown. |
| 9 | FBP | Positive Charge-Pump Feedback Input. Regulates to 1.25V nominal. Connect feedback resistive divider to analog ground (GND). |
| 10 | FBN | Negative Charge-Pump Regulator Feedback Input. Regulates to 0V nominal. Connect feedback resistive divider to the reference (REF). |
| 11 | $\overline{\text{SHDN}}$ | Shutdown Input. Drive $\overline{\text{SHDN}}$ through an external resistor. When $\overline{\text{SHDN}}$ is pulled low, the device turns off and draws only 0.1$\mu$A. OUT is also pulled low through an internal 10$\Omega$ resistor in shutdown mode. When current is sourced into $\overline{\text{SHDN}}$ through $R_{FREQ}$, the device activates, and the $\overline{\text{SHDN}}$ input current sets the oscillator's switching frequency:<br>$R_{FREQ}$ (k$\Omega$) = 45.5 (MHz / mA) $\times$ ($V_{ON}$ - 0.7V) / $f_{OSC}$ (MHz) |
| 12 | DRVN | Negative Charge-Pump Driver Output. Output high level is $V_{SUPN}$, and low level is PGND. |
| 13 | SUPN | Negative Charge-Pump Driver Supply Voltage. Bypass to power ground (PGND) with a 0.1$\mu$F capacitor. |
| 14 | DRVP | Positive Charge-Pump Driver Output. Output high level is $V_{SUPP}$ and low level is PGND. |
| 15 | SUPP | Positive Charge-Pump Driver Supply Voltage. Bypass to power ground (PGND) with a 0.1$\mu$F capacitor. |
| 16 | PGND | Power Ground. Connect to analog ground (GND) underneath the IC. |
| 17 | CXN | Negative Terminal of the Main Charge-Pump Flying Capacitor |
| 18 | SUPM | Main Charge-Pump Supply Voltage Input |
| 19 | CXP | Positive Terminal of the Main Charge-Pump Flying Capacitor |
| 20 | OUT | Main Charge-Pump Output. Bypass to power ground (PGND) with 10$\mu$F for a 1MHz application (see *Output Capacitor Selection*). An internal 10$\Omega$ resistor discharges the output when the device is shut down. |

_____*Detailed Description*

The MAX1747 is an efficient triple-output power supply for TFT LCD applications. The device contains one high-power charge pump and two low-power charge pumps. The MAX1747 charge pumps switch continuously at a constant frequency, so the output noise contains well-defined frequency components, and the circuit requires much smaller external capacitors for a

given output ripple. The adjustable switching frequency is set by the current into the shutdown pin (see *Frequency Selection and Shutdown*).

The main charge pump uses internal MOSFETs with low $R_{ON}$ to provide high output current. The adjustable output voltage of the main charge pump can be set up to 5.5V with external resistors. The dual low-power charge pumps independently regulate a positive output
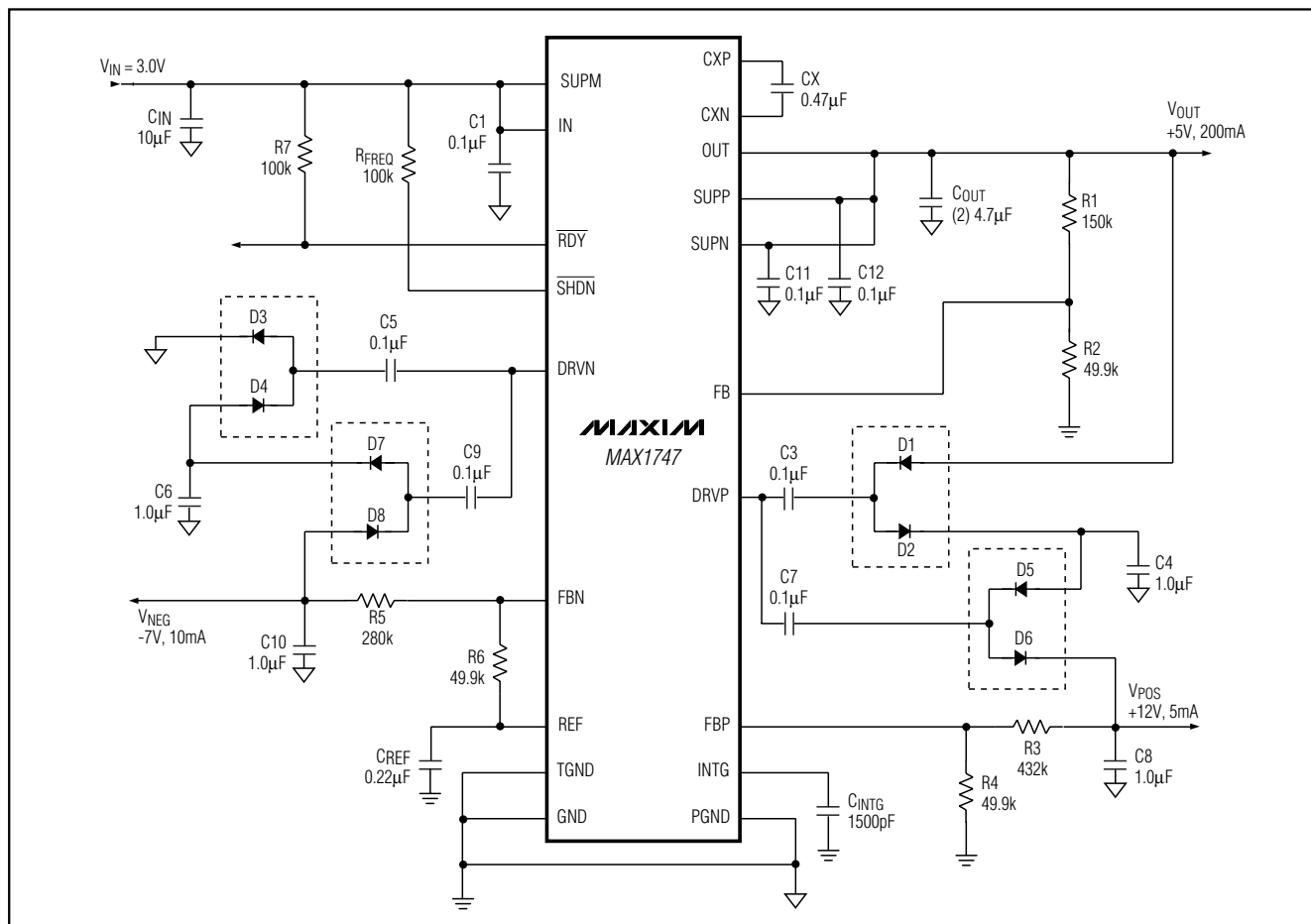
**MAXIM**

Figure 1. Typical Application Circuit

($V_{POS}$) and a negative output ($V_{NEG}$). These two outputs use external diode and capacitor stages (as many stages as required) to regulate output voltages above +35V and under -35V.

A proprietary regulation algorithm minimizes output ripple as well as capacitor sizes for all three charge pumps. Also included in the MAX1747 are a precision 1.25V reference that sources up to 50µA, shutdown, power-up sequencing, fault detection, and an active-low open-drain ready output.

### Main Charge Pump

During the first half-cycle, the MAX1747 charges the flying capacitor (CX) by connecting it between the supply voltage ($V_{SUPM}$) and ground (Figure 2). This initial charge is controlled by the variable N-channel on-resistance. During the second half-cycle, the MAX1747 level shifts the flying capacitor by stacking the voltage

across CX on top of the supply voltage. This transfers the sum of the two voltages to the output capacitor ($C_{OUT}$).

### Dual Charge-Pump Regulators

The MAX1747 contains two individual low-power charge pumps. Using a single stage, the first charge pump inverts the supply voltage ($V_{SUPN}$) and provides a regulated negative output voltage. The second charge pump doubles the supply voltage ($V_{SUPP}$) and provides a regulated positive output voltage. The MAX1747 contains internal P-channel and N-channel MOSFETs to control the power transfer. The internal MOSFETs switch at a constant frequency set by the current into the shutdown pin (see *Frequency Selection and Shutdown*).
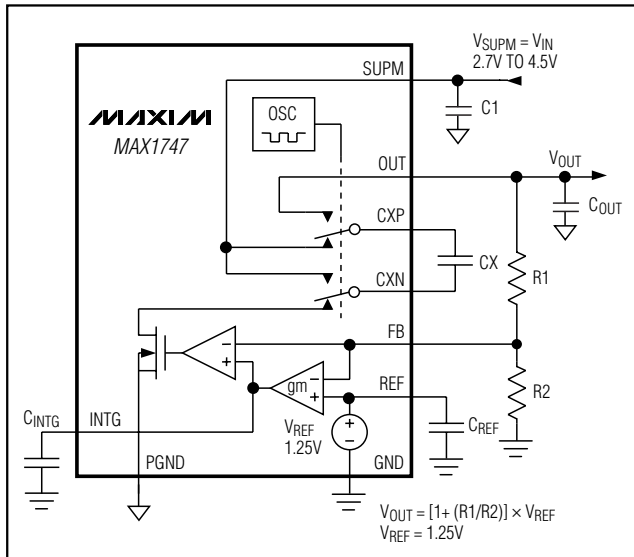
# Triple Charge-Pump TFT LCD
# DC-DC Converter



Figure 2. Main Charge-Pump Block Diagram



Figure 3. Negative Charge-Pump Block Diagram

### Negative Charge Pump

During the first half-cycle, the P-channel MOSFET turns on, and flying capacitor C5 charges to $V_{SUPN}$ minus a diode drop (Figure 3). During the second half-cycle, the P-channel MOSFET turns off, and the N-channel MOSFET turns on, level shifting C5. This connects C5 in parallel with the reservoir capacitor, C6. If the voltage across C6 minus a diode drop is lower than the voltage across C5, current flows from C5 to C6 until the diode (D4) turns off. The amount of charge transferred to the output is controlled by the variable N-channel $R_{ON}$.

### Positive Charge Pump

During the first half-cycle, the N-channel MOSFET turns on and charges the flying capacitor, C3 (Figure 4). This initial charge is controlled by the variable N-channel $R_{ON}$. During the second half-cycle, the N-channel MOSFET turns off, and the P-channel MOSFET turns on, level shifting C3 by $V_{SUPP}$ volts. This connects C3 in parallel with the reservoir capacitor, C4. If the voltage across C4 plus a diode drop ($V_{POS} + V_{DIODE}$) is smaller than the level-shifted flying capacitor voltage ($V_{C3} + V_{SUPP}$), charge flows from C3 to C4 until the diode (D2) turns off.

### Frequency Selection and Shutdown

The shutdown pin ($\overline{SHDN}$) on the MAX1747 performs a dual function: it shuts down the device and determines the oscillator frequency. The $\overline{SHDN}$ input looks like a diode to ground and should be driven through a resistor (Figure 5).
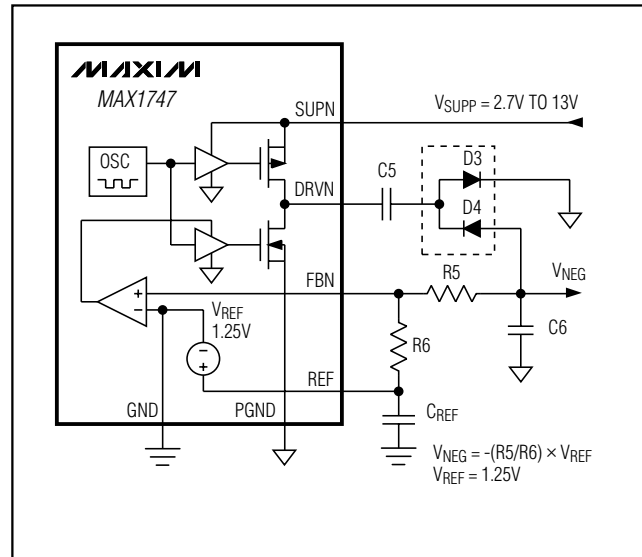
Driving $\overline{SHDN}$ low forces all three MAX1747 converters into shutdown mode. When disabled, the supply current drops to 20µA (max) to maximize battery life, and OUT is pulled to ground through an internal 10Ω resistor. For the low-power charge pumps, the output capacitance and load current determine the rate at which each output voltage will decay. The device activates (see *Power-up Sequencing*) once $\overline{SHDN}$ is forward biased (minimum of 3µA of current). Do not leave $\overline{SHDN}$ floating. For a typical application where shutdown is used only to set the switching frequency, connect $\overline{SHDN}$ to the input ($V_{IN}$ = 3.3V) with a 120kΩ resistor for a 1MHz switching frequency.

The bias current into $\overline{SHDN}$, programmed with an external resistor, determines the oscillator frequency (see *Typical Operating Characteristics*). To select the frequency, calculate the external resistor value, $R_{FREQ}$, using the following formula:

$$R_{FREQ} = 45.5 \ (MHz \ / \ mA) \times (V_{ON} - 0.7V) \ / \ f_{OSC}$$

where $R_{FREQ}$ is in kΩ and $f_{OSC}$ is in MHz. Program the frequency in the 200kHz to 2MHz range. This frequency range corresponds to $\overline{SHDN}$ input currents between 3µA to 65µA. Proper operation of the oscillator is not guaranteed beyond these limits. Forcing $\overline{SHDN}$ below 400mV disables the device.

### Soft-Start

For the MAX1747, soft-start is achieved by controlling the rise rate of the output voltage, regardless of output capacitance or output load, and limited only by the output impedance of the regulator (see Startup Waveforms

*MAXIM*
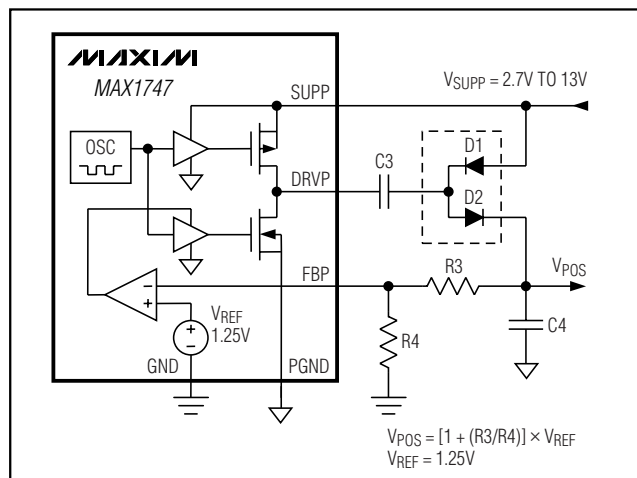
*Figure 4. Positive Charge-Pump Block Diagram*

$V_{SUPP} = 2.7V \ TO \ 13V$

$V_{POS} = [1 + (R3/R4)] \times V_{REF}$
$V_{REF} = 1.25V$



*Figure 5. Frequency Adjustment*

$R_{FREQ} = k_{FREQ} \times (V_{ON} - 0.7V)/f_{OSC}$
$R_{FREQ}$ IS IN kΩ, $k_{FREQ}$ IS 45.5MHz/mA,
AND $f_{OSC}$ IS IN MHz.

in the *Typical Operating Characteristics*). The main output voltage is controlled to be in regulation within 4096 clock cycles ($1/f_{OSC}$). The negative and positive low-power charge pumps are controlled to be in regulation within 2048 clock cycles.

### Power-Up Sequencing
Upon power-up or exiting shutdown, the MAX1747 starts a power-up sequence. First, the reference powers up. Then the primary charge pump powers up with soft-start enabled. Once the main charge pump reaches 90% of its nominal value ($V_{FB} > 1.125V$), the negative charge pump turns on. When the negative output voltage reaches approximately 90% of its nominal value ($V_{FBN} < 125mV$), the positive charge pump starts up. Finally, when the positive output voltage reaches 90% of its nominal value ($V_{FBP} > 1.125V$), the active-low ready signal ($\overline{RDY}$) goes low (see *Power Ready*).

### Fault Detection
Once $\overline{RDY}$ is low, and if any output falls below its fault detection threshold, $\overline{RDY}$ goes high impedance.

For the reference, the fault threshold is 1.05V. For the main charge pump, the fault threshold is 88% of its nominal value ($V_{FB} < 1.1V$). For the negative charge pump, the fault threshold is approximately 88% of its nominal value ($V_{FBN} > 140mV$). For the positive charge pump, the fault threshold is 88% of its nominal value ($V_{FBP} < 1.1V$).

Once an output faults, all outputs later in the power sequence shut down until the faulted output rises above its power-up threshold. For example, if the negative charge-pump output voltage falls below the fault-detection threshol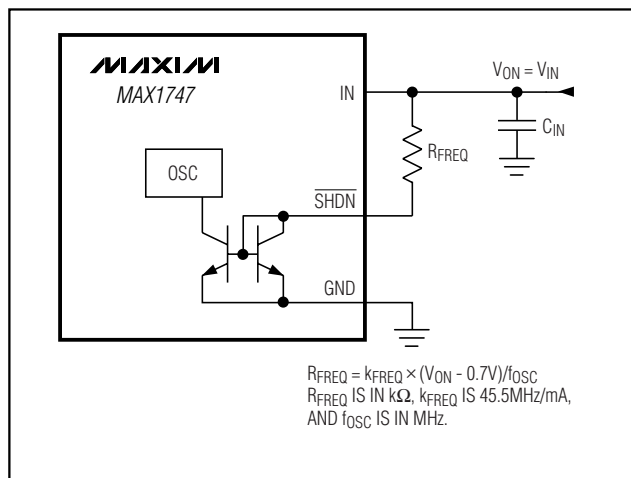d, the main charge pump remains active while the positive charge pump stops switching and its output voltage decays, depending on output capacitance and load. The positive charge-pump output will not power up until the negative charge-pump output voltage rises above its power-up threshold (see *Power-Up Sequencing*).

### Power Ready
Power ready is an open-drain output. When the power-up sequence is properly completed, the MOSFET turns on and pulls $\overline{RDY}$ low with a typical 125Ω $R_{ON}$. If a fault is detected, the internal open-drain MOSFET appears as a high impedance. Connect a 100kΩ pullup resistor between $\overline{RDY}$ and IN for a logic level output.

### Voltage Reference
The voltage at REF is nominally 1.25V. The reference can source up to 50mA with excellent load regulation (see *Typical Operating Characteristics*). Connect a 0.22µF bypass capacitor between REF and GND. During shutdown, the reference is disabled.

# Design Procedure

### Efficiency Considerations
The efficiency characteristics of the MAX1747 regulated charge pumps are similar to a linear regulator. They are dominated by quiescent current at low output currents and by the input voltage at higher output currents (see *Typical Operating Characteristics*). Therefore, the maximum efficiency may be approximated by:

Efficiency $\cong V_{OUT} / (2 \times V_{SUPM})$ for the main charge pump

Efficiency $\cong - V_{NEG} / (V_{SUPN} \times N)$ for the negative low-power charge pump

Efficiency $\cong V_{POS} / [V_{SUPP} \times (N+1)]$ for the positive low-power charge pump

where N is the number of charge-pump stages.

### Output Voltage Selection

Adjust the main output voltage by connecting a voltage-divider from the output ($V_{OUT}$) to FB and GND (see *Typical Operating Circuit*). Adjust the negative low-power output voltage by connecting a voltage-divider from the output ($V_{NEG}$) to FBN to REF. Adjust the positive low-power output voltage by connecting a voltage-divider from the output ($V_{POS}$) to FBP to GND. Select R2, R4, and R6 in the 10kΩ to 200kΩ range. Calculate the remaining resistors with the following equations:

$$R1 = R2 [(V_{OUT} / V_{REF}) - 1]$$
$$R3 = R4 [(V_{POS} / V_{REF}) - 1]$$
$$R5 = R6 |V_{NEG} / V_{REF}|$$

where $V_{REF}$ = 1.25V. $V_{OUT}$ may range from 4.5V to 5.5V, $V_{POS}$ may range from $V_{SUPP}$ to +35V, and $V_{NEG}$ may range from 0 to -35V.

### Flying Capacitors

Increasing the flying capacitor's value increases the output-current capability. Above a certain point, larger capacitor values lower the secondary pole formed by the transfer capacitor and switch $R_{ON}$, which destabilizes the output. For the main charge pump, use a ceramic capacitor based on the following equation:

$$C_X \le \frac{0.47\mu F \times MHz}{f_{OSC}}$$

For the low-power charge pumps, a 0.1µF ceramic capacitor works well in most applications. Smaller values may be used for lower current applications. Component suppliers are listed in Table 1.

### Output Capacitors

For the main charge pump, use a ceramic capacitor based on the following equation:

$$C_{OUT} \ge \left[ \left( \frac{20}{MHz} \times C_X \times f_{OSC} \right) AND \left( \frac{2\mu F \times MHz}{f_{OSC}} \right) \right]$$

For low-frequency applications (close to 200kHz), selection of the output capacitor is limited solely by the switching frequency. However, for high-frequency applications (close to 2MHz), selection of the output capacitor is limited by the secondary pole formed by the flying capacitor and switch on-resistance.

For the low-power charge pumps, the output capacitor should be anywhere from 5-times to 20-times larger than the flying capacitor, depending on the ripple tolerance. Increasing the output capacitance or decreasing the ESR reduces the output ripple voltage and the peak-to-peak transient voltage.

### Input Capacitors

Using an input capacitor with a value equal to or greater than the output capacitor is recommended. Place the capacitor as close to the IC as possible. If the source impedance or inductance of the input supply is large, additional input bypassing may be required.

For the low-power charge-pump inputs (SUPN and SUPP), using bypass capacitors with values equal to or greater than the flying capacitors is recommended. Place these capacitors as close to the supply voltage inputs as possible.

### Rectifier Diodes

Use Schottky diodes with a current rating greater than 4 times the average output current, and with a voltage rating of 1.5 times $V_{SUPP}$ for the positive charge pump and $V_{SUPN}$ for the negative charge pump.

### Integrator Capacitor

The MAX1747 contains an internal current integrator that improves the DC load regulation but increases the peak-to-peak transient voltage (see Load-Transient Waveform in the *Typical Operating Characteristics*). Connect a ceramic capacitor between INTG and GND based on the following equation:

$$C_{INTG} \ge \frac{150Hz \times C_{OUT}}{f_{OSC}}$$

## Table 1. Component Suppliers

| SUPPLIER | PHONE | FAX |
|---|---|---|
| **CAPACITORS** | | |
| AVX | 803-946-0690 | 803-626-3123 |
| Kemet | 408-986-0424 | 408-986-1442 |
| Sanyo | 619-661-6835 | 619-661-1055 |
| Taiyo Yuden | 408-573-4150 | 408-573-4159 |
| **DIODES** | | |
| Central | 516-435-1110 | 516-435-1824 |
| International Rectifier | 310-322-3331 | 310-322-3332 |
| Motorola | 602-303-5454 | 602-994-6430 |
| Nihon | 847-843-7500 | 847-843-2798 |

# Triple Charge-Pump TFT LCD DC-DC Converter

## PC Board Layout and Grounding

Careful printed circuit layout is important to minimize ground bounce and noise. First, place the main charge-pump flying capacitor less than 0.2in (5mm) from the CXP and CXN pins with wide traces and no vias. Then place 0.1µF ceramic bypass capacitors near the charge-pump input pins (SUPP and SUPN) to the PGND pin. Keep the charge-pump circuitry as close to the IC as possible, using wide traces and avoiding vias when possible. Locate all feedback resistive dividers as close 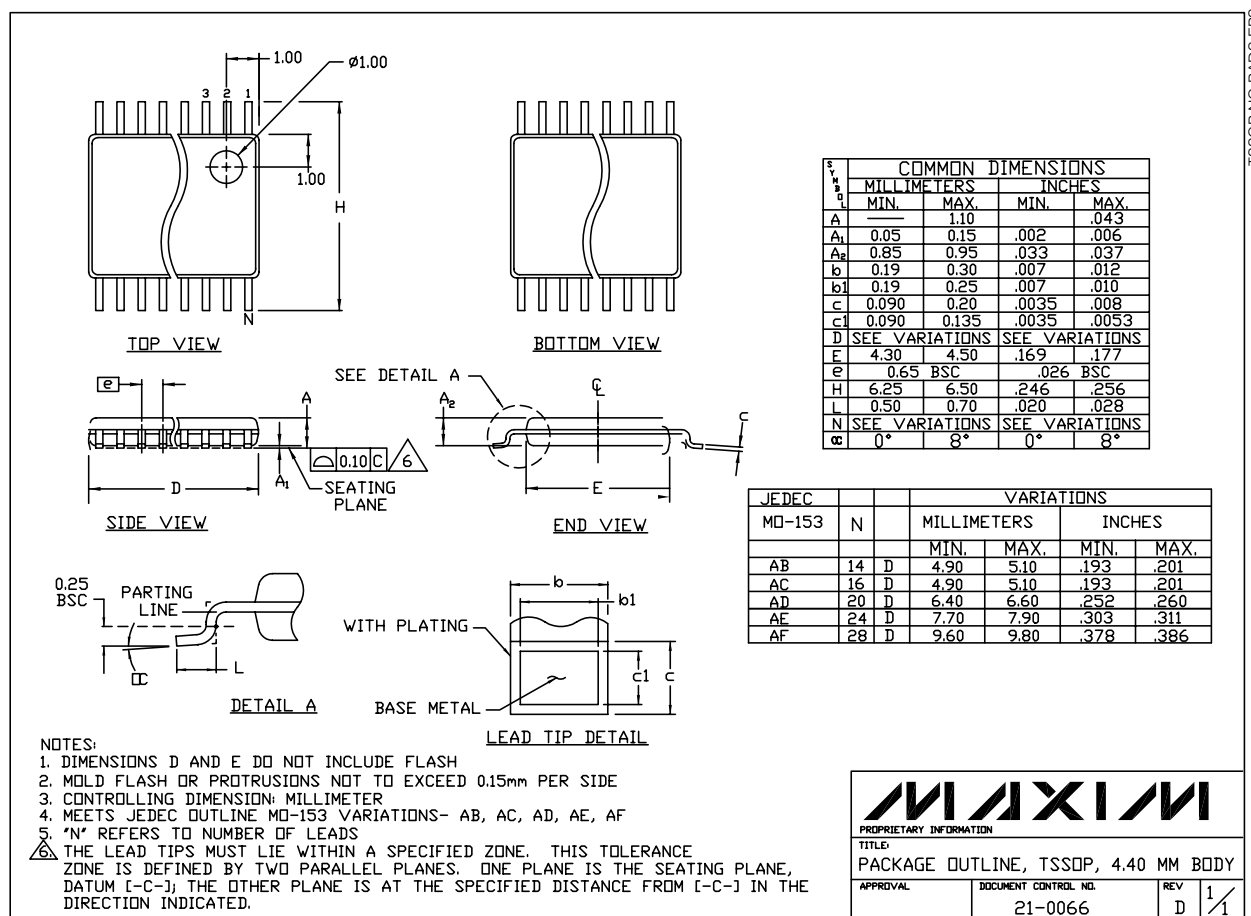to their respective feedback pins as possible. The PC board should feature separate analog and power ground areas connected at only one point under the IC. To maximize output power and efficiency, and minimize output power ripple voltage, use extra-wide power ground traces, and solder the IC's power ground pin directly to it. Avoid having sensitive traces near the switching nodes and high-current lines.

Refer to the MAX1747 evaluation kit for an example of proper board layout.

## Chip Information

TRANSISTOR COUNT: 2534

## Package Information



TSSOP,NO PADS.EPS

**COMMON DIMENSIONS**

| SYMBOL | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN. | MAX. | MIN. | MAX. |
| A | — | 1.10 | — | .043 |
| A1 | 0.05 | 0.15 | .002 | .006 |
| A2 | 0.85 | 0.95 | .033 | .037 |
| b | 0.19 | 0.30 | .007 | .012 |
| b1 | 0.19 | 0.25 | .007 | .010 |
| c | 0.090 | 0.20 | .0035 | .008 |
| c1 | 0.090 | 0.135 | .0035 | .0053 |
| D | SEE VARIATIONS | | SEE VARIATIONS | |
| E | 4.30 | 4.50 | .169 | .177 |
| e | 0.65 BSC | | .026 BSC | |
| H | 6.25 | 6.50 | .246 | .256 |
| L | 0.50 | 0.70 | .020 | .028 |
| N | SEE VARIATIONS | | SEE VARIATIONS | |
| α | 0° | 8° | 0° | 8° |

**VARIATIONS**

| JEDEC MO-153 | N | | MILLIMETERS | | INCHES | |
|---|---|---|---|---|---|---|
| | | | MIN. | MAX. | MIN. | MAX. |
| AB | 14 | D | 4.90 | 5.10 | .193 | .201 |
| AC | 16 | D | 4.90 | 5.10 | .193 | .201 |
| AD | 20 | D | 6.40 | 6.60 | .252 | .260 |
| AE | 24 | D | 7.70 | 7.90 | .303 | .311 |
| AF | 28 | D | 9.60 | 9.80 | .378 | .386 |

NOTES:
1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
3. CONTROLLING DIMENSION: MILLIMETER
4. MEETS JEDEC OUTLINE MO-153 VARIATIONS- AB, AC, AD, AE, AF
5. 'N' REFERS TO NUMBER OF LEADS
6. THE LEAD TIPS MUST LIE WITHIN A SPECIFIED ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL PLANES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED.

**ΜΑΧΙΜ**

PROPRIETARY INFORMATION

TITLE:
PACKAGE OUTLINE, TSSOP, 4.40 MM BODY

| APPROVAL | DOCUMENT CONTROL NO. | REV | |
|---|---|---|---|
| | 21-0066 | D | 1/1 |

# Mouser Electronics

Authorized Distributor


Click to View Pricing, Inventory, Delivery & Lifecycle Information:


[Maxim Integrated](#):
  [MAX1747EUP+](#)  [MAX1747EUP+T](#)