

## 4-Channel DC/DC Controller

EL7520 and EL7520A are 4-channel DC/DC controllers that provide a complete power supply system for TFT-LCD applications. They consist of a 1MHz PWM boost controller, which generates the main voltage for the column driver, and three LDO controllers for  $V_{ON}$ ,  $V_{OFF}$ , and  $V_{LOGIC}$  supplies. They also include integrated start-up sequence and start-up delay control.

EL7520 and EL7520A operate from 3V to 5.5V. The boost controller can drive a wide range of output current depending on the external FET. It can be programmed to operate in either P-mode for fast transient response or PI-mode for improved load regulation. The EL7520 and EL7520A also integrate fault protection for all four output channels. When a fault is detected, the device is latched off until either the input supply voltage or enable is cycled. Therefore, they are ideal to use in any size of TFT-LCD panels.

The EL7520 and EL7520A are available in a 20 Ld 4x4 QFN package with maximum height of 0.9mm and is specified for operation of the -40°C to +85°C temperature range.

## Ordering Information

| PART NUMBER<br>(NOTE) | PACKAGE<br>(Pb-FREE) | TAPE &<br>REEL | PKG.<br>DWG. # |
|-----------------------|----------------------|----------------|----------------|
| EL7520ILZ             | 20 Ld 4x4 QFN        | -              | MDP0046        |
| EL7520ILZ-T7          | 20 Ld 4x4 QFN        | 7"             | MDP0046        |
| EL7520ILZ-T13         | 20 Ld 4x4 QFN        | 13"            | MDP0046        |
| EL7520AILZ            | 20 Ld 4x4 QFN        | -              | MDP0046        |
| EL7520AILZ-T7         | 20 Ld 4x4 QFN        | 7"             | MDP0046        |
| EL7520AILZ-T13        | 20 Ld 4x4 QFN        | 13"            | MDP0046        |

NOTE: Intersil Pb-free plus anneal products employ special Pb-free material sets; molding compounds/die attach materials and 100% matte tin plate termination finish, which are RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.

## Features

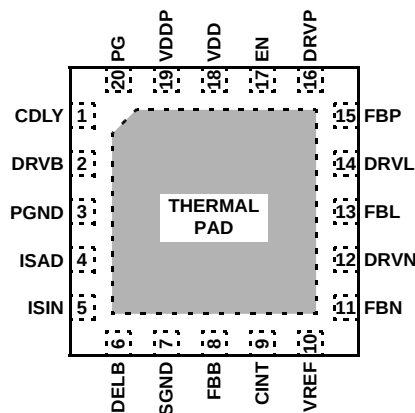
- Complete TFT-LCD supply controller
  - 1MHz PWM boost controller
  - $V_{ON}$  LDO controller
  - $V_{OFF}$  LDO controller
  - Logic supply LDO controller
- Integrated start-up sequence for  $V_{LOGIC}/V_{BOOST}$ ,  $V_{OFF}$ ,  $V_{ON}$  or  $V_{LOGIC}$ ,  $V_{OFF}$ ,  $V_{BOOST}$ ,  $V_{ON}$ 
  - $V_{LOGIC}$  permanently enabled in 'A' version (EL7520A)
- Programmable sequence delay
- In-rush current control
- Fully fault protected
- Thermal shutdown
- Internal soft-start
- 3V to 5.5V  $V_{DD}$
- 20 Ld 4x4 QFN package
- Low cost
- Pb-Free plus anneal available (RoHS compliant)

## Applications

- LCD monitors (15"+)
- LCD-TV (up to 40"+)
- Notebook displays (up to 16")
- Industrial/medical LCD displays

## Pinout

EL7520 AND EL7520A  
(20 LD 4X4 QFN)  
TOP VIEW



## Absolute Maximum Ratings (T<sub>A</sub> = 25°C)

|                                          |      |
|------------------------------------------|------|
| V <sub>DELB</sub> .....                  | 25V  |
| V <sub>DRVP</sub> .....                  | 36V  |
| V <sub>DRVN</sub> .....                  | -20V |
| V <sub>DDP</sub> , V <sub>DD</sub> ..... | 6.5V |

## Thermal Information

|                                               |                        |                        |
|-----------------------------------------------|------------------------|------------------------|
| Thermal Resistance (Typical, Notes 1, 2)      | θ <sub>JA</sub> (°C/W) | θ <sub>JC</sub> (°C/W) |
| QFN Package .....                             | 40                     | 7.5                    |
| V <sub>DRVL</sub> .....                       | 6.5V                   |                        |
| Storage Temperature .....                     | -65°C to +150°C        |                        |
| Ambient Operating Temperature .....           | -40°C to +85°C         |                        |
| Maximum Continuous Junction Temperature ..... | 125°C                  |                        |

**CAUTION:** Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

### NOTES:

1. θ<sub>JA</sub> is measured in free air with the component mounted on a high effective thermal conductivity test board with "direct attach" features. See Tech Brief TB379.
2. For θ<sub>JC</sub>, the "case temp" location is the center of the exposed metal pad on the package underside.

**IMPORTANT NOTE:** All parameters having Min/Max specifications are guaranteed. Typ values are for information purposes only. Unless otherwise noted, all tests are at the specified temperature and are pulsed tests, therefore: T<sub>J</sub> = T<sub>C</sub> = T<sub>A</sub>

**Electrical Specifications** V<sub>DD</sub> = 5V, V<sub>BOOST</sub> = 11V, I<sub>LOAD</sub> = 40mA, V<sub>ON</sub> = 15V, V<sub>OFF</sub> = -5V, V<sub>LOGIC</sub> = 2.5V, over temperature from -40°C to 85°C, unless otherwise specified.

| PARAMETER                                | DESCRIPTION                    | CONDITION                                                                          | MIN   | TYP   | MAX   | UNIT |
|------------------------------------------|--------------------------------|------------------------------------------------------------------------------------|-------|-------|-------|------|
| <b>SUPPLY</b>                            |                                |                                                                                    |       |       |       |      |
| V <sub>S</sub>                           | Supply Voltage                 |                                                                                    | 3     |       | 5.5   | V    |
| I <sub>S</sub>                           | Quiescent Current              | Enabled, LX not switching                                                          |       | 1.6   | 2.5   | mA   |
|                                          |                                | Disabled, EL7520                                                                   |       | 5     | 30    | μA   |
|                                          |                                | Disabled, EL7520A                                                                  |       | 640   | 800   | μA   |
| F <sub>OSC</sub>                         | Oscillator Frequency           |                                                                                    | 900   | 1000  | 1100  | kHz  |
| <b>BOOST</b>                             |                                |                                                                                    |       |       |       |      |
| V <sub>REF</sub>                         | Reference Voltage              | T <sub>A</sub> = 25°C                                                              | 1.19  | 1.215 | 1.235 | V    |
|                                          |                                |                                                                                    | 1.187 | 1.215 | 1.238 | V    |
| C <sub>REF</sub>                         | V <sub>REF</sub> Capacitor     |                                                                                    |       | 100   |       | nF   |
| V <sub>FBB</sub>                         | Feedback Reference Voltage     | T <sub>A</sub> = 25°C                                                              | 1.192 | 1.205 | 1.218 | V    |
|                                          |                                |                                                                                    | 1.188 | 1.205 | 1.222 | V    |
| V <sub>F_FBB</sub>                       | FBB Fault Trip Point           | V <sub>FBB</sub> falling                                                           |       | 1     |       | V    |
| D <sub>MAX</sub>                         | Maximum Duty Cycle             |                                                                                    | 85    |       |       | %    |
| Eff                                      | Boost Efficiency               | Test with 24mΩ R <sub>DS(ON)</sub> MOSFET, I <sub>LOAD</sub> = 400mA               |       | 90    |       | %    |
| I(V <sub>REF</sub> )                     | Feedback Input Bias Current    | PI mode, V <sub>FBB</sub> = 1.35V                                                  |       | 50    | 500   | nA   |
| ΔV <sub>BOOST</sub> /ΔV <sub>IN</sub>    | Line Regulation                | C <sub>INT</sub> = 2.2nF, I <sub>OUT</sub> = 200mA<br>V <sub>IN</sub> = 3V to 5.5V |       | 0.05  |       | %/V  |
| ΔV <sub>BOOST</sub> /ΔI <sub>BOOST</sub> | Load Regulation - "P" Mode     | C <sub>INT</sub> pin strapped to V <sub>DD</sub>                                   |       | 3     |       | %    |
| ΔV <sub>BOOST</sub> /ΔI <sub>BOOST</sub> | Load Regulation - "PI" Mode    | I <sub>OUT</sub> = 10mA to 200mA                                                   |       | 0.1   |       | %    |
| V <sub>CINT_T</sub>                      | CINT PI Mode Select Threshold  |                                                                                    |       | 4.7   | 4.8   | V    |
| <b>V<sub>ON</sub> LDO</b>                |                                |                                                                                    |       |       |       |      |
| V <sub>FBP</sub>                         | FBP Regulation Voltage         | I <sub>DRVP</sub> = 0.2mA, T <sub>A</sub> = 25°C                                   | 1.181 | 1.211 | 1.229 | V    |
|                                          |                                | I <sub>DRVP</sub> = 0.2mA                                                          | 1.177 | 1.211 | 1.233 | V    |
| V <sub>F_FBP</sub>                       | FBP Fault Trip Point           | V <sub>FBP</sub> falling                                                           | 0.95  | 1     | 1.05  | V    |
| I <sub>FBP</sub>                         | FBP Input Bias Current         | V <sub>FBP</sub> = 1.35V                                                           | -250  |       | 250   | nA   |
| GMP                                      | FBP Effective Transconductance | V <sub>DRVP</sub> = 25V, I <sub>DRVP</sub> = 0.2 to 2mA                            |       | 50    |       | mS   |

**Electrical Specifications**  $V_{DD} = 5V$ ,  $V_{BOOST} = 11V$ ,  $I_{LOAD} = 40mA$ ,  $V_{ON} = 15V$ ,  $V_{OFF} = -5V$ ,  $V_{LOGIC} = 2.5V$ , over temperature from  $-40^{\circ}C$  to  $85^{\circ}C$ , unless otherwise specified. **(Continued)**

| PARAMETER                              | DESCRIPTION                                     | CONDITION                                        | MIN   | TYP   | MAX   | UNIT        |
|----------------------------------------|-------------------------------------------------|--------------------------------------------------|-------|-------|-------|-------------|
| $\Delta V_{ON}/\Delta I(V_{ON})$       | $V_{ON}$ Load Regulation                        | $I(V_{ON}) = 0mA$ to $20mA$                      |       | -0.5  |       | %           |
| $I_{DRV P}$                            | DRV P Sink Current                              | $V_{FBP} = 1.1V$ , $V_{DRV P} = 25V$             | 2     | 4     |       | mA          |
| $I_{L\_DRV P}$                         | DRV P Leakage Current                           | $V_{FBL} = 1.5V$ , $V_{DRV L} = 35V$             |       | 0.1   | 5     | $\mu A$     |
| V <sub>OFF</sub> LDO                   |                                                 |                                                  |       |       |       |             |
| $V_{FBN}$                              | FBN Regulation Voltage                          | $I_{DRV N} = 0.2mA$ , $T_A = 25^{\circ}C$        | 0.173 | 0.203 | 0.233 | V           |
|                                        |                                                 | $I_{DRV N} = 0.2mA$                              | 0.171 | 0.203 | 0.235 | V           |
| $V_{F\_FBN}$                           | FBN Fault Trip Point                            | $V_{FBN}$ falling                                | 0.38  | 0.4   | 0.48  | V           |
| $I_{FBN}$                              | FBN Input Bias Current                          | $V_{FBN} = 1.25V$                                | -250  |       | 250   | nA          |
| GMN                                    | FBN Effective Transconductance                  | $V_{DRV N} = -6V$ , $I_{DRV N} = 0.2mA$ to $2mA$ |       | 50    |       | mS          |
| $\Delta V_{OFF}/\Delta I(V_{OFF})$     | $V_{OFF}$ Load Regulation                       | $I(V_{OFF}) = 0mA$ to $20mA$                     |       | -0.15 |       | %           |
| $I_{DRV N}$                            | DRV N Source Current                            | $V_{FBN} = 0.3V$ , $V_{DRV N} = -6V$             | 2     | 4     |       | mA          |
| $I_{L\_DRV N}$                         | DRV N Leakage Current                           | $V_{FBN} = 0V$ , $V_{DRV N} = -20V$              |       | 0.1   | 5     | $\mu A$     |
| V <sub>LOGIC</sub> LDO                 |                                                 |                                                  |       |       |       |             |
| $V_{FBL}$                              | FBL Regulation Voltage                          | $I_{DRV L} = 1mA$ , $T_A = 25^{\circ}C$          | 1.176 | 1.2   | 1.224 | V           |
|                                        |                                                 | $I_{DRV L} = 1mA$                                | 1.174 | 1.2   | 1.226 | V           |
| $V_{F\_FBL}$                           | FBL Fault Trip Point                            | $V_{FBL}$ falling                                | 0.90  | 1     | 1.05  | V           |
| $I_{FBL}$                              | FBL Input Bias Current                          | $V_{FBL} = 1.25V$                                | -500  |       | 500   | nA          |
| GML                                    | FBL Effective Transconductance                  | $V_{DRV L} = 2.5V$ , $I_{DRV P} = 1mA$ to $8mA$  |       | 200   |       | mS          |
| $\Delta V_{LOGIC}/\Delta I(V_{LOGIC})$ | $V_{LOGIC}$ Load Regulation                     | $I(V_{LOGIC}) = 0mA$ to $500mA$                  |       | -0.5  |       | %           |
| $I_{DRV L}$                            | DRV L Sink Current                              | $V_{FBL} = 1.1V$ , $V_{DRV L} = 2.5V$            | 5     | 16    |       | mA          |
| $I_{L\_DRV L}$                         | DRV L Leakage Current                           | $V_{FBL} = 1.5V$ , $V_{DRV L} = 5.5V$            |       | 0.1   | 5     | $\mu A$     |
| SEQUENCING                             |                                                 |                                                  |       |       |       |             |
| $t_{ON}$                               | Turn On Delay                                   | $C_{DLY} = 0.1\mu F$                             |       | 30    |       | ms          |
| $t_{SS}$                               | Soft-start Time                                 | $C_{DLY} = 0.1\mu F$                             |       | 2     |       | ms          |
| $t_{DEL1}$                             | Delay Between $A_{VDD}$ and $V_{OFF}$           | $C_{DLY} = 0.1\mu F$                             |       | 10    |       | ms          |
| $t_{DEL2}$                             | Delay Between $V_{ON}$ and $V_{OFF}$            | $C_{DLY} = 0.1\mu F$                             |       | 17    |       | ms          |
| $t_{DEL3}$                             | Delay Between $V_{OFF}$ and Delayed $V_{BOOST}$ | $C_{DLY} = 0.1\mu F$                             |       | 10    |       | ms          |
| $I_{DELB}$                             | DELB Pull-down Current                          | $V_{DELB} > 0.6V$                                |       | 50    |       | $\mu A$     |
|                                        |                                                 | $V_{DELB} < 0.6V$                                |       | 1.4   |       | mA          |
| $C_{DEL}$                              | Delay Capacitor                                 |                                                  |       | 100   |       | nF          |
| FAULT DETECTION                        |                                                 |                                                  |       |       |       |             |
| $T_{FAULT}$                            | Fault Time Out                                  | $C_{DLY} = 0.1\mu F$                             |       | 50    |       | ms          |
| OT                                     | Over-temperature Threshold                      |                                                  |       | 140   |       | $^{\circ}C$ |
| $I_{PG}$                               | PG Pull-down Current                            | $V_{PG} > 0.6V$                                  |       | 15    |       | $\mu A$     |
|                                        |                                                 | $V_{PG} < 0.6V$                                  |       | 1.7   |       | mA          |
| LOGIC                                  |                                                 |                                                  |       |       |       |             |
| $V_{HI}$                               | Logic High Threshold                            |                                                  | 2.2   |       |       | V           |
| $V_{LO}$                               | Logic Low Threshold                             |                                                  |       |       | 0.8   | V           |
| $I_{LOW}$                              | Logic Low bias Current                          |                                                  | -1    | 0.1   | 1     | $\mu A$     |
| $I_{HIGH}$                             | Logic High bias Current                         |                                                  | 12    | 18    | 24    | $\mu A$     |

## Typical Performance Curves

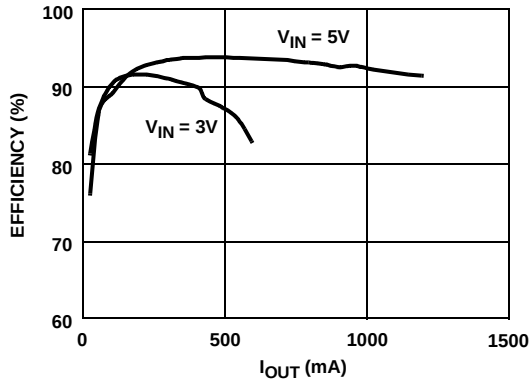


FIGURE 1.  $V_{\text{BOOST}}$  EFFICIENCY vs  $I_{\text{OUT}}$  (PI MODE)

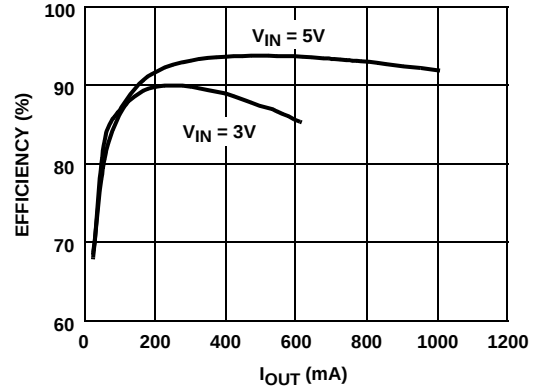


FIGURE 2.  $V_{\text{BOOST}}$  EFFICIENCY vs  $I_{\text{OUT}}$  (P MODE)

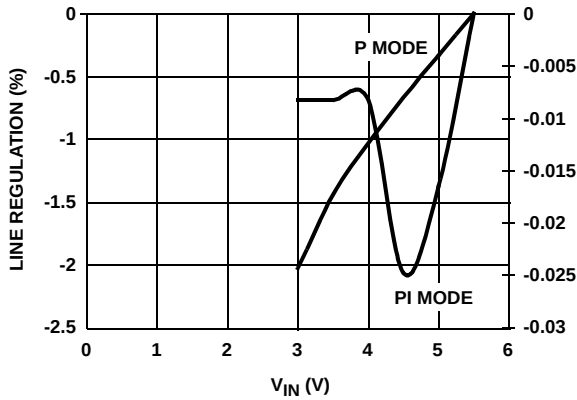


FIGURE 3.  $V_{\text{BOOST}}$  LINE REGULATION

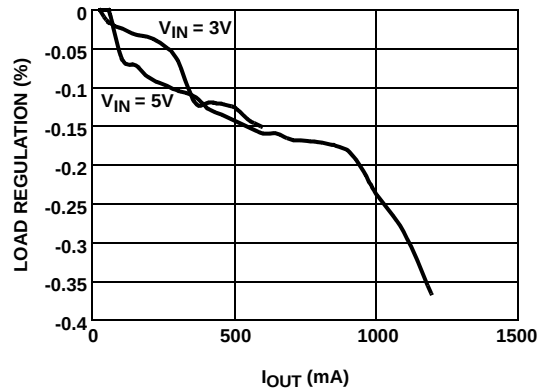


FIGURE 4.  $V_{\text{BOOST}}$  LOAD REGULATION (PI MODE)

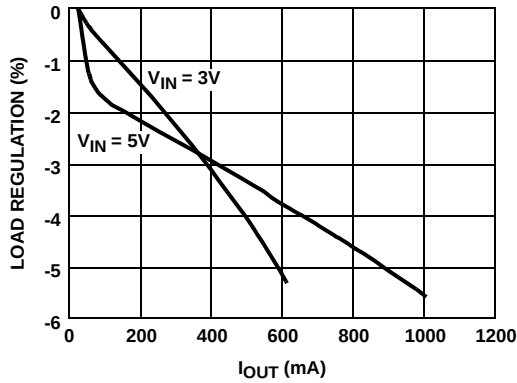


FIGURE 5.  $V_{\text{BOOST}}$  LOAD REGULATION (P MODE)

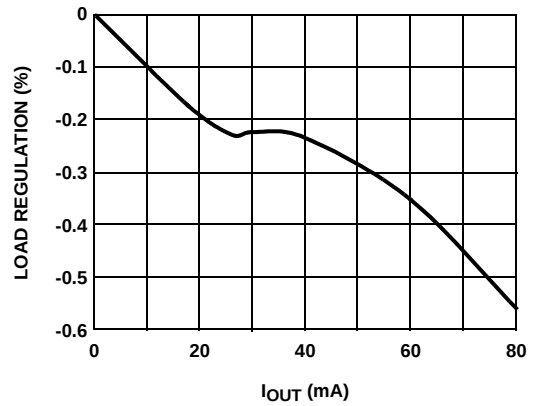


FIGURE 6.  $V_{\text{ON}}$  LOAD REGULATION

Typical Performance Curves (Continued)

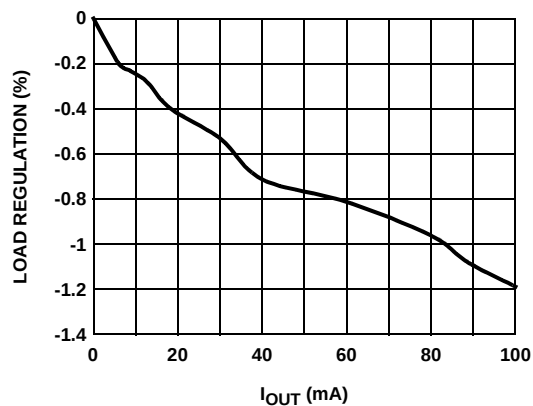


FIGURE 7.  $V_{OFF}$  LOAD REGULATION

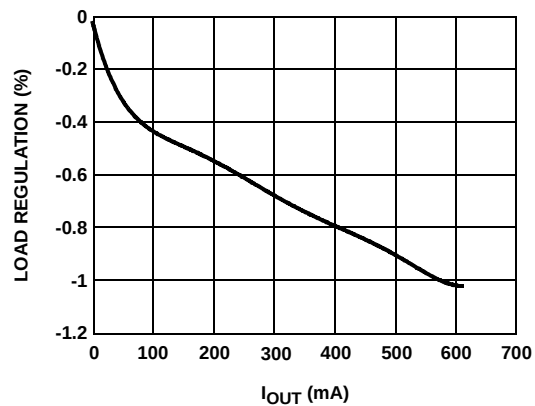


FIGURE 8.  $V_{LOGIC}$  LOAD REGULATION

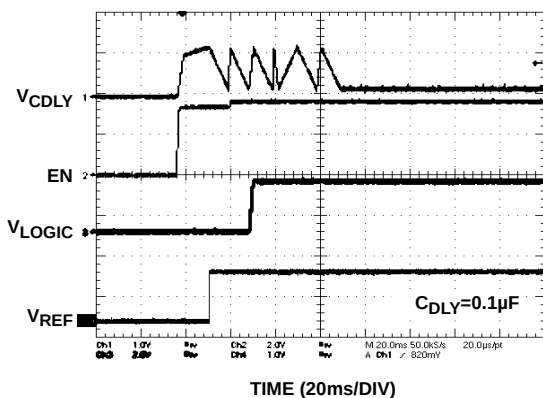


FIGURE 9. EL7520 START-UP SEQUENCE

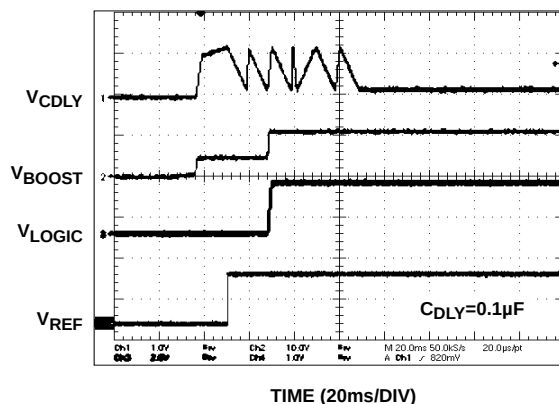


FIGURE 10. EL7520 START-UP SEQUENCE

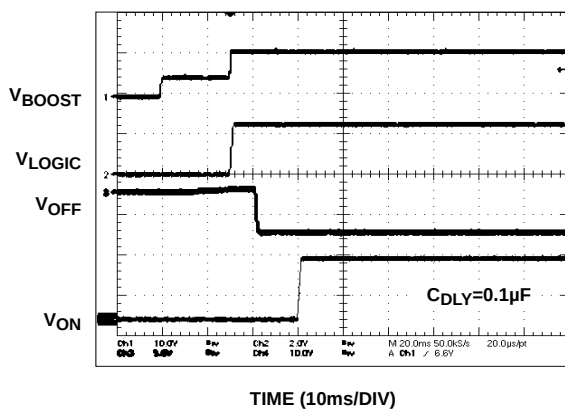


FIGURE 11. EL7520 START-UP SEQUENCE

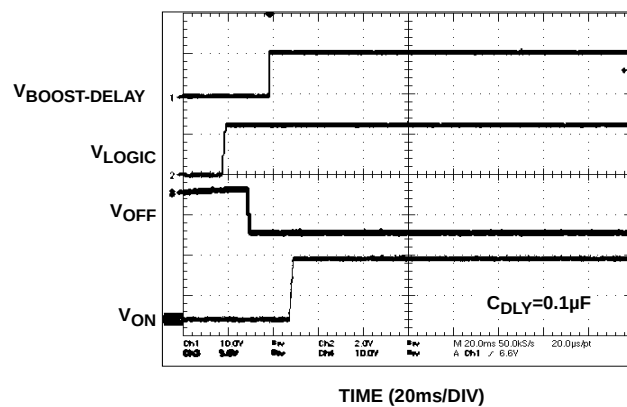


FIGURE 12. EL7520 START-UP SEQUENCE

Typical Performance Curves (Continued)

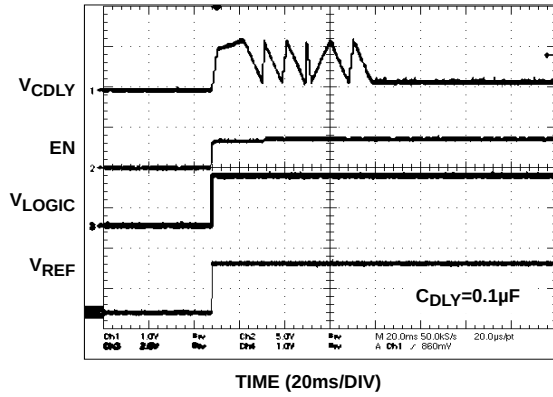


FIGURE 13. EL7520A START-UP SEQUENCE

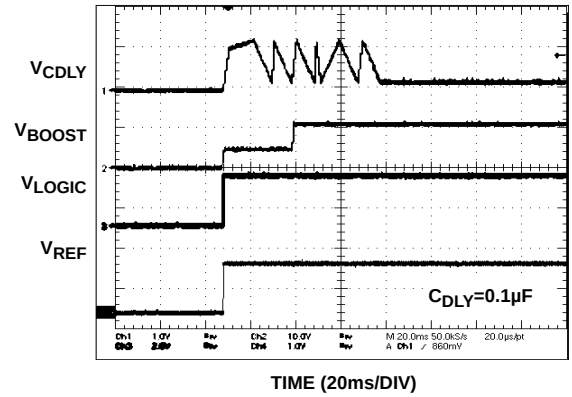


FIGURE 14. EL7520A START-UP SEQUENCE

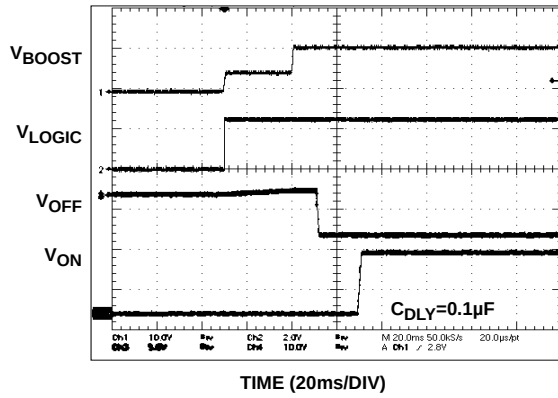


FIGURE 15. EL7520A START-UP SEQUENCE

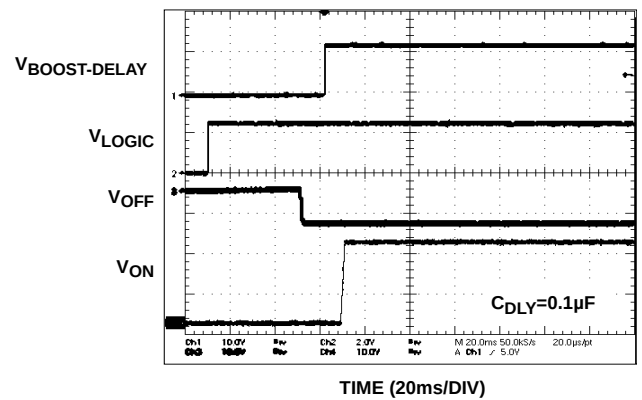


FIGURE 16. EL7520A START-UP SEQUENCE

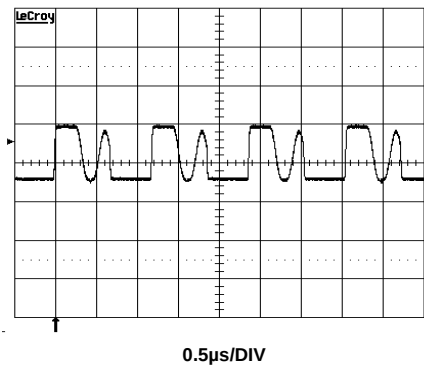


FIGURE 17. LX WAVEFORM-DISCONTINUOUS MODE

Typical Performance Curves (Continued)

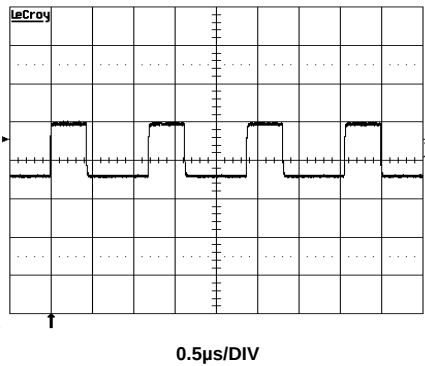


FIGURE 18. LX WAVEFORM-CONTINUOUS MODE

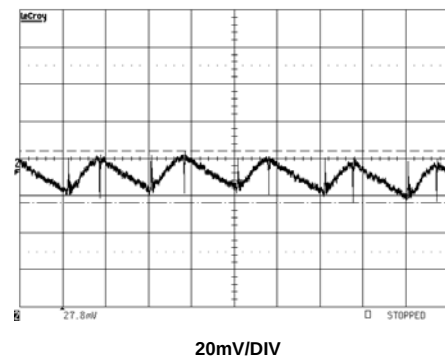


FIGURE 19.  $V_{BOOST}$  OUTPUT VOLTAGE RIPPLE

CH1= $V_{BOOST}$ , 100mV/DIV  
CH4=LOAD CURRENT, 200mA/DIV

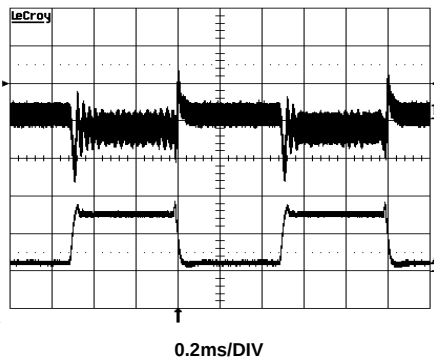


FIGURE 20.  $V_{BOOST}$  TRANSIENT RESPONSE

CH1= $V_{LOGIC}$ , 20mV/DIV  
CH4=LOAD CURRENT, 100mA/DIV

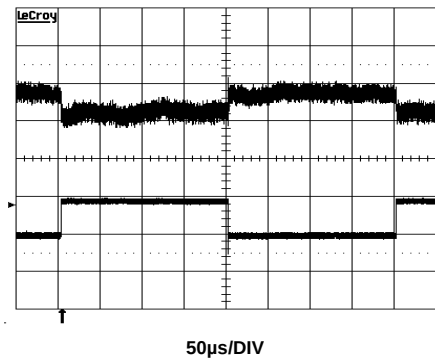


FIGURE 21.  $V_{LOGIC}$  TRANSIENT RESPONSE

CH1= $V_{ON}$ , 100mV/DIV  
CH4=LOAD CURRENT, 50mA/DIV

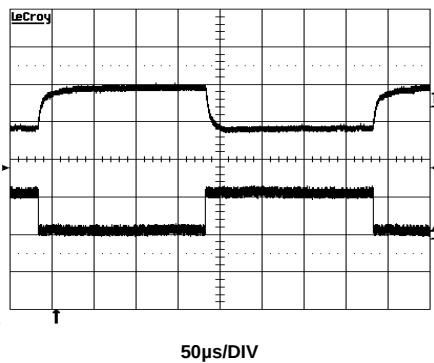


FIGURE 22.  $V_{ON}$  TRANSIENT RESPONSE

CH1= $V_{OFF}$ , 50mV/DIV  
CH4=LOAD CURRENT, 50mA/DIV

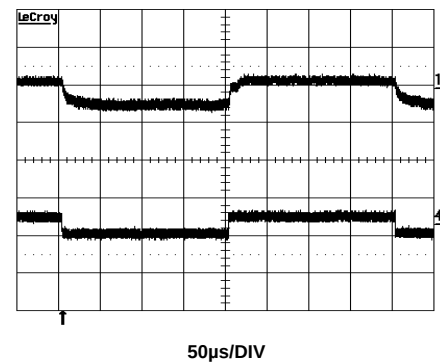
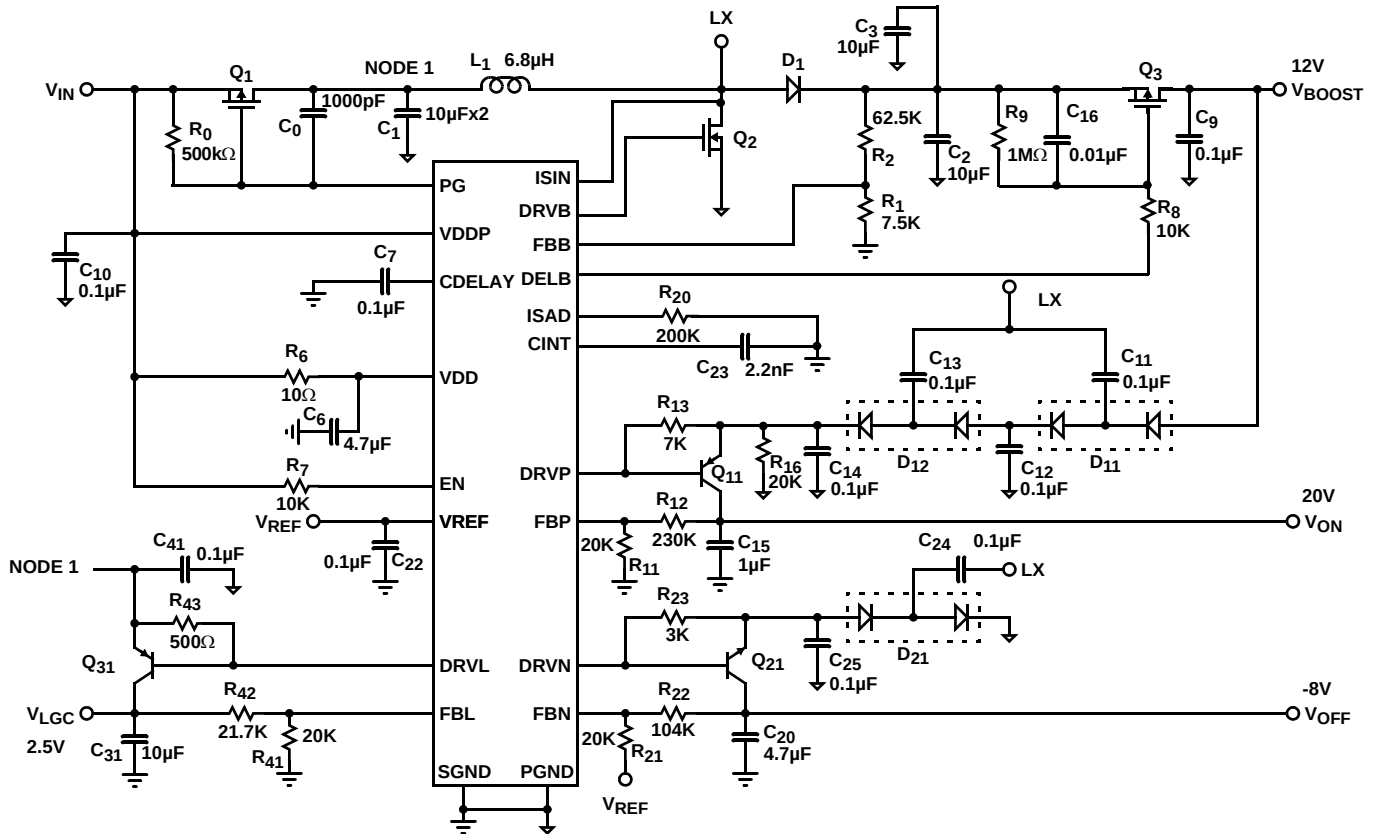


FIGURE 23.  $V_{OFF}$  TRANSIENT RESPONSE

**Pin Descriptions**

| PIN NUMBER | PIN NAME | FUNCTION DESCRIPTION                                                                                                                              |
|------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 1          | CDLY     | With a capacitor connected from this pin to GND sets the delay time for start-up sequence and sets the fault timeout time                         |
| 2          | DRVB     | Gate driver output for the external N channel switch; the pulse voltage follows the input voltage                                                 |
| 3          | PGND     | Power GND                                                                                                                                         |
| 4          | ISAD     | With a resistor connected from this pin to GND sets the current limit of the external N channel FET                                               |
| 5          | ISIN     | Sense the drain voltage of the external N channel FET and connected to the internal current limit comparator                                      |
| 6          | DELB     | Active low control output for optional delay control for external $V_{\text{BOOST}}$ P channel FET; when fault is detected, this pin goes to high |
| 7          | SGND     | Low noise signal ground                                                                                                                           |
| 8          | FBB      | Boost regulator voltage feedback input pin; regulates to 1.2V nominal                                                                             |
| 9          | CINT     | $V_{\text{BOOST}}$ integrator output, connect 2.2nF to analog GND for PI mode or connect to $V_{\text{REF}}$ for P mode operation                 |
| 10         | VREF     | Bandgap voltage bypass terminal; bypass with a 0.1 $\mu$ F to analog GND; can be used as charge pump reference                                    |
| 11         | FBN      | Negative LDO voltage feedback input pin; regulates to 0.2V nominal                                                                                |
| 12         | DRVN     | Negative LDO base drive; open drain of an internal P channel MOSFET                                                                               |
| 13         | FBL      | Logic LDO voltage feedback input pin; regulates to 1.2V nominal                                                                                   |
| 14         | DRVL     | Logic LDO base drive; open drain of an internal N channel MOSFET                                                                                  |
| 15         | FBP      | Positive LDO voltage feedback input pin; regulates to 1.2V nominal                                                                                |
| 16         | DRVP     | Positive LDO base drive; open drain of an internal N channel MOSFET                                                                               |
| 17         | EN       | Enable pin for the chip; high enable; low disabled                                                                                                |
| 18         | VDD      | Positive supply for all internal circuitry except DRVB                                                                                            |
| 19         | VDDP     | Positive supply for external N channel FET gate drive (DRVB)                                                                                      |
| 20         | PG       | Output gate drive of the external fault protection P channel FET; when chip is disabled or when a fault has been detected, this pin is high       |

## Typical Application



## Applications Information

The EL7520 and EL7520A provide a multiple output power supply solution for TFT-LCD applications. The system consists of a high efficiency boost controller and three low cost linear-regulator controllers ( $V_{ON}$ ,  $V_{OFF}$  and  $V_{LOGIC}$ ).

The block diagram of the whole part is shown in Figure 24. Table 1 lists the recommended components.

TABLE 1. RECOMMENDED COMPONENTS

| DESIGNATION     | DESCRIPTION                                                            |
|-----------------|------------------------------------------------------------------------|
| C1, C2, C3, C31 | 10 $\mu$ F, 16V, X7R ceramic capacitor (1206)<br>TDK C3216X7R1C106M    |
| C20             | 4.7 $\mu$ F, 16V X5R ceramic capacitor (1206)<br>TDK C3216X5R1A475K    |
| C15             | 1 $\mu$ F, 25V X7R ceramic capacitor (1206)<br>TDK C3216X7R1E105K      |
| D1              | 1A 20V low leakage schottky rectifier (CASE 457-04) ON SEMI MBRM120ET3 |
| D11, D12, D21   | 200mA 30V schottky barrier diode (SOT-23)<br>Fairchild BAT54S          |
| L1              | 6.8mH 1.3A inductor<br>TDK SLF6025T-6R8M1R3-PF                         |

TABLE 1. RECOMMENDED COMPONENTS (Continued)

| DESIGNATION | DESCRIPTION                                                                                   |
|-------------|-----------------------------------------------------------------------------------------------|
| Q1          | -2.4 -20V P-channel 1.8V specified<br>PowerTrench MOSFET (SuperSOT-3)<br>Fairchild FDN304P    |
| Q2          | 6.3A 30V single N-channel logic level<br>PowerTrench MOSFET (SOT-23)<br>Fairchild FDC655AN    |
| Q3          | -2A -30V single P-channel logic level<br>PowerTrench MOSFET (SuperSOT-3)<br>Fairchild FDN360P |
| Q11         | 200mA 40V PNP amplifier (SOT-23)<br>Fairchild MMBT3906                                        |
| Q21         | 200mA 40V NPN amplifier (SOT-23)<br>Fairchild MMBT3904                                        |
| Q31         | 1A 30V PNP low saturation amplifier (SOT-23)<br>Fairchild FMMT549                             |

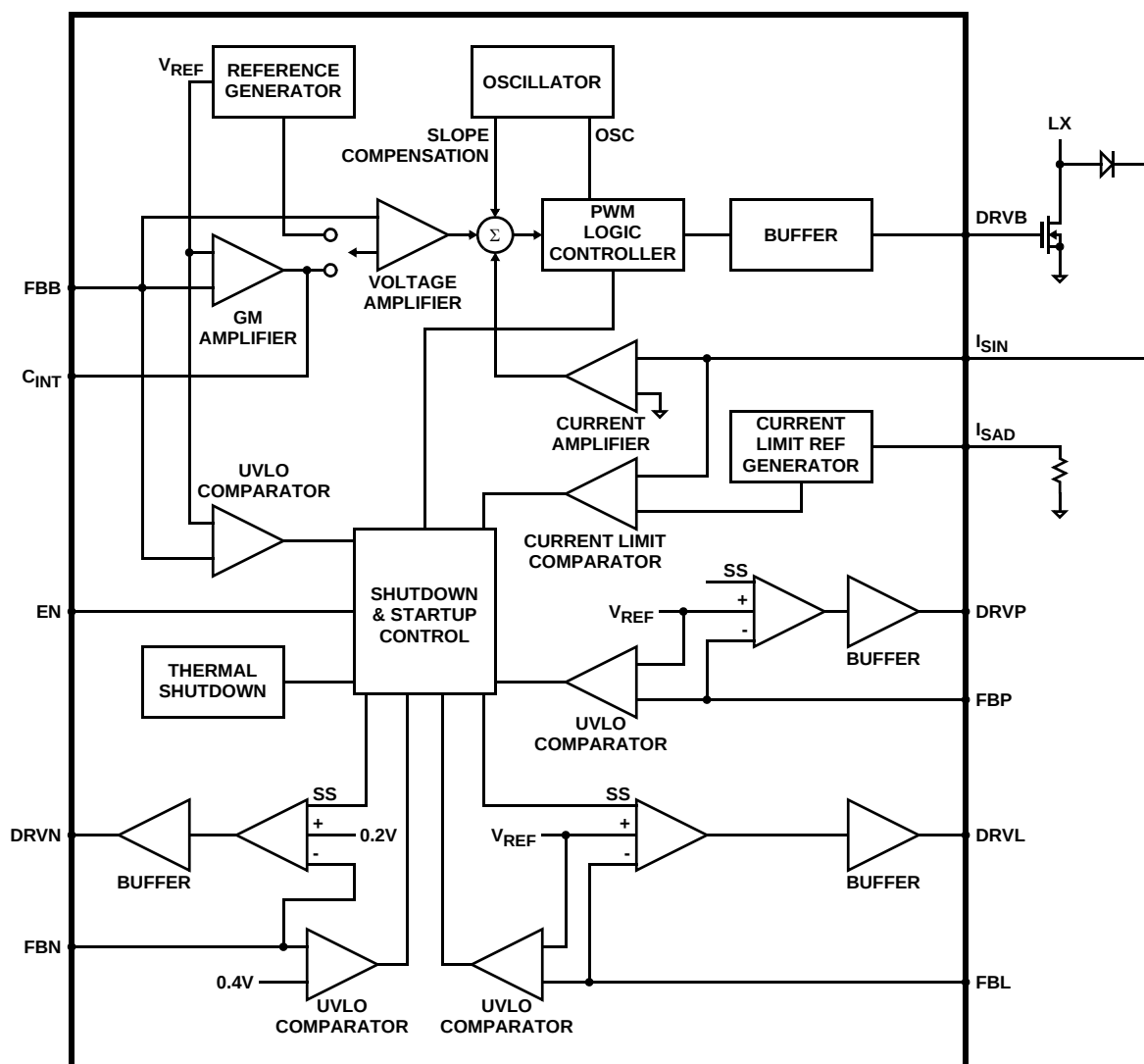


FIGURE 24. BLOCK DIAGRAM

### Boost Converter

The main boost converter is a current mode PWM controller operating at a fixed frequency. The 1MHz switching frequency enables the use of low profile inductor and multilayer ceramic capacitors, which results in a compact, low-cost power system for LCD panel design.

The boost converter can operate in continuous or discontinuous inductor current mode. The EL7520 and EL7520A are designed for continuous current mode, but they can also operate in discontinuous current mode at light load. In continuous current mode, current flows continuously in the inductor during the entire switching cycle in steady state operation. The voltage conversion ratio in continuous current mode is given by:

$$\frac{V_{\text{BOOST}}}{V_{\text{IN}}} = \frac{1}{1-D}$$

Where D is the duty cycle of switching MOSFET.

Figure 25 shows the function diagram of the boost controller. It uses a summing amplifier architecture consisting of GM stages for voltage feedback, current feedback and slope compensation. A comparator looks at the peak inductor current cycle by cycle and terminates the PWM cycle if the current limit is reached.

An external resistor divider is required to divide the output voltage down to the nominal reference voltage. Current drawn by the resistor network should be limited to maintain the overall converter efficiency. The maximum value of the resistor network is limited by the feedback input bias current and the potential for noise being coupled into the feedback pin. A resistor network in the order of 60kΩ is recommended. The boost converter output voltage is determined by the following equation:

$$V_{\text{BOOST}} = \frac{R_1 + R_2}{R_1} \times V_{\text{REF}}$$

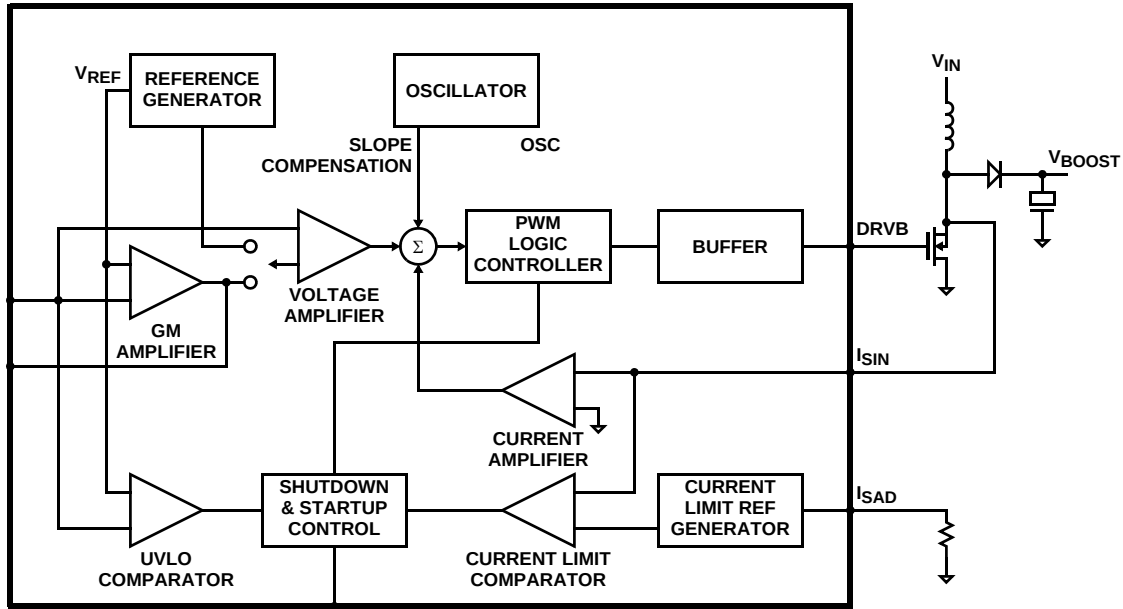


FIGURE 25. FUNCTION DIAGRAM OF THE BOOST CONTROLLER

The internal current limit circuitry is shown in Figure 26. The circuit senses the voltage across the  $R_{DS(ON)}$  when the MOSFET is on; then compare it to the internal voltage reference to realize the current limit. The internal voltage reference is generated by a  $10\mu A$  current and any additional current set at  $I_{SAD}$  pin flowing through an  $8k\Omega$  resistor. The voltage reference is based on the following equation:

$$V_{THRESHOLD} = \left( \frac{V_{ISAD}}{R_1} + 10\mu A \right) \times 8K$$

Where  $V_{ISAD}$  is the voltage at pin  $I_{SAD}$ .

$$V_{ISAD} = V_{REF} - V_{BE} - 1K \times I_{SAD}$$

$$I_{SAD} = \frac{V_{ISAD}}{R_1}$$

Where  $V_{BE} \approx 0.7V$

The external resistor  $R_1$  should be chosen in the order of  $100K$  to generate  $\mu A$  of current.

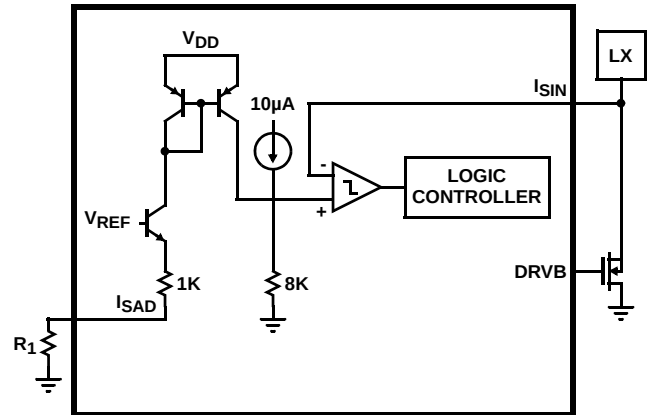


FIGURE 26. CURRENT LIMIT BLOCK DIAGRAM

Hence the maximum output current is determined by the following equation:

$$I_{OMAX} = \left( \frac{V_{THRESHOLD}}{R_{DS(ON)}} - \frac{\Delta I_L}{2} \right) \times \frac{V_{IN}}{V_O}$$

Where  $\Delta I_L$  is the peak to peak inductor ripple current, and is set by:

$$\Delta I_L = \frac{V_{IN}}{L} \times \frac{D}{f_s}$$

$f_s$  is the switching frequency;  $D$  is the duty cycle.

$$D = \frac{V_O - V_{IN}}{V_O}$$

### Input Capacitor

The input capacitor is used to supply the current to the converter. It is recommended that  $C_{IN}$  be larger than  $10\mu\text{F}$ . The reflected ripple voltage will be smaller with larger  $C_{IN}$ . The voltage rating of input capacitor should be larger than maximum input voltage.

### Boost Inductor

A  $3.3\mu\text{H}$  inductor is recommended due to the fixed internal slope compensation. The inductor must be able to handle the following average and peak current:

$$I_{LAVG} = \frac{I_O}{1-D}$$

$$I_{LPK} = I_{LAVG} + \frac{\Delta I_L}{2}$$

### Switching MOSFET

Due to the parasitic inductance of the trace, the MOSFET will experience spikes higher than the output voltage when the MOSFET turns off. Thus, a MOSFET with enough voltage margin is needed.

The  $R_{DS(ON)}$  of the MOSFET is critical for power dissipation and current limit. A MOSFET with low  $R_{DS(ON)}$  is desired to get high efficiency and output current, but very low  $R_{DS(ON)}$  will reduce the loop stability. A MOSFET with  $20\text{m}\Omega$  to  $50\text{m}\Omega$   $R_{DS(ON)}$  is recommended. Some recommended MOSFETs are shown in following table.

TABLE 2. RECOMMENDED MOSFETs

| PART NUMBER | MANUFACTURER            | FEATURE                                    |
|-------------|-------------------------|--------------------------------------------|
| FDC655AN    | Fairchild Semiconductor | 6.3A, 30V, $R_{DS(ON)} = 23\text{m}\Omega$ |
| FDS4488     | Fairchild Semiconductor | 7.9A, 30V, $R_{DS(ON)} = 22\text{m}\Omega$ |
| Si7844DP    | Vishay                  | 10A, 30V, $R_{DS(ON)} = 22\text{m}\Omega$  |
| SI6928DQ    | Vishay                  | 20A, 30V, $R_{DS(ON)} = 30\text{m}\Omega$  |

### Rectifier Diode

A high-speed diode is desired due to the high switching frequency. Schottky diodes are recommended because of their fast recovery time and low forward voltage. The rectifier diode must meet the output current and peak inductor current requirements.

### Output Capacitor

The output capacitor supplies the load directly and reduces the ripple voltage at the output. Output ripple voltage consists of two components: the voltage drop due to the inductor ripple current flowing through the ESR of output capacitor, and the charging and discharging of the output capacitor.

$$V_{RIPPLE} = I_{LPK} \times ESR + \frac{V_O - V_{IN}}{V_O} \times \frac{I_O}{C_{OUT}} \times \frac{1}{f_S}$$

For low ESR ceramic capacitors, the output ripple is dominated by the charging and discharging of the output capacitor. The voltage rating of the output capacitor should be greater than the maximum output voltage.

### Compensation

The EL7520 and EL7520A can operate in either P mode or PI mode. Connecting  $C_{INT}$  pin directly to  $V_{IN}$  will enable P mode. For better load regulation, use PI mode with a  $2.2\text{nF}$  capacitor between  $C_{INT}$  and ground.

### Linear-Regulator Controllers ( $V_{ON}$ , $V_{LOGIC}$ , and $V_{OFF}$ )

The EL7520, EL7520A include three independent linear-regulator controllers, in which two are positive output voltage ( $V_{ON}$  and  $V_{LOGIC}$ ), and one is negative. The  $V_{ON}$ ,  $V_{OFF}$ , and  $V_{LOGIC}$  linear-regulator controller functional diagrams, applications circuits are shown in Figures 27, 28, and 29 respectively.

### Calculation of the Linear Regulator Base-Emitter Resistors ( $R_{BL}$ , $R_{BP}$ and $R_{BN}$ )

For the pass transistor of the linear regulator, low frequency gain ( $H_{fe}$ ) and unity gain freq. ( $f_T$ ) are usually specified in the datasheet. The pass transistor adds a pole to the loop transfer function at  $f_p = f_T/H_{fe}$ . Therefore, in order to maintain phase margin at low frequency, the best choice for a pass device is often a high frequency low gain switching transistor. Further improvement can be obtained by adding a base-emitter resistor  $R_{BE}$  ( $R_{BP}$ ,  $R_{BL}$ ,  $R_{BN}$  in the Functional Block Diagram), which increase the pole frequency to:  $f_p = f_T \cdot (1 + H_{fe} \cdot r_e / R_{BE}) / H_{fe}$ , where  $r_e = KT/qI_C$ . So choose the lowest value  $R_{BE}$  in the design as long as there is still enough base current ( $I_B$ ) to support the maximum output current ( $I_C$ ).

We will take as an example the  $V_{LOGIC}$  linear regulator. If a Fairchild FMPT549 PNP transistor is used as the external pass transistor, Q31 in the application diagram, then for a maximum  $V_{LOGIC}$  operating requirement of  $500\text{mA}$  the data sheet indicates  $H_{fe\_min} = 100$ .

The base-emitter saturation voltage is:  $V_{be\_max} = 1.25\text{V}$  (note this is normally a  $V_{be} \sim 0.7\text{V}$ , however, for the Q5 transistor an internal Darlington arrangement is used to increase its current gain, giving a 'base-emitter' voltage of  $2 \times V_{BE}$ ).

(Note that using a high current Darlington PNP transistor for Q5 requires that  $V_{IN} > V_{LOGIC} + 2V$ . Should a lower input voltage be required, then an ordinary high gain PNP transistor should be selected for Q5 so as to allow a lower collector-emitter saturation voltage).

For the EL7520, EL7520A, the minimum drive current is:  $I_{DRV\_min} = 8\text{mA}$

The minimum base-emitter resistor,  $R_{BL}$ , can now be calculated as:

$$R_{BL\_min} = V_{BE\_max} / (I_{DRVL\_min} - I_c / H_{fe\_min}) = 1.25V / (8mA - 500mA / 100) = 417\Omega$$

This is the minimum value that can be used - so, we now choose a convenient value greater than this minimum value; say  $500\Omega$ . Larger values may be used to reduce quiescent current, however, regulation may be adversely affected, by supply noise if  $R_{BL}$  is made too high in value.

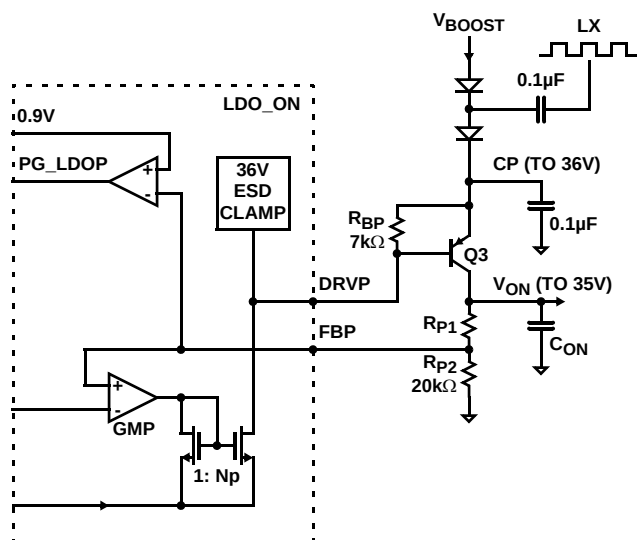


FIGURE 27.  $V_{ON}$  FUNCTIONAL BLOCK DIAGRAM

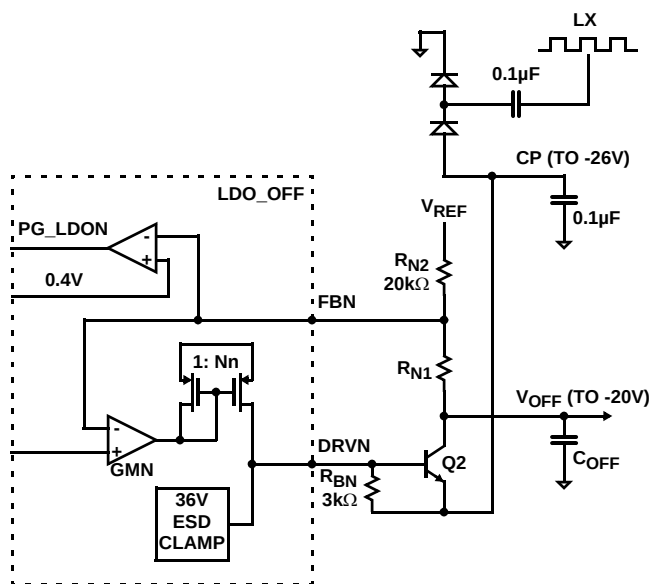


FIGURE 28.  $V_{OFF}$  FUNCTIONAL BLOCK DIAGRAM

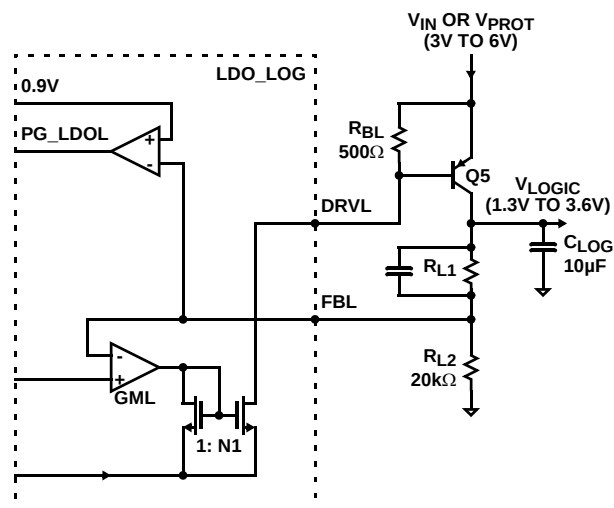


FIGURE 29.  $V_{LOGIC}$  FUNCTIONAL BLOCK DIAGRAM

The  $V_{ON}$  power supply is used to power the positive supply of the row driver in the LCD panel. The DC/DC consists of an external diode-capacitor charge pump powered from the inductor (LX) of the boost converter, followed by a low dropout linear regulator (LDO\_ON). The LDO\_ON regulator uses an external PNP transistor as the pass element. The onboard LDO controller is a wide band (>10MHz) transconductance amplifier capable of 4mA drive current, which is sufficient for up to 40mA or more output current under the low dropout condition (forced beta of 10). Typical  $V_{ON}$  voltage supported by EL7520, EL7520A range from +15V to +36V. A fault comparator is also included for monitoring the output voltage. The under-voltage threshold is set at 25% below the 1.2V reference.

The  $V_{OFF}$  power supply is used to power the negative supply of the row driver in the LCD panel. The DC/DC consists of an external diode-capacitor charge pump powered from the inductor (LX) of the boost converter, followed by a low dropout linear regulator (LDO\_OFF). The LDO\_OFF regulator uses an external NPN transistor as the pass element. The onboard LDO controller is a wide band (>10MHz) transconductance amplifier capable of 4mA drive current, which is sufficient for up to 40mA or more output current under the low dropout condition (forced beta of 10). Typical  $V_{OFF}$  voltage supported by EL7520, EL7520A range from -5V to -20V. A fault comparator is also included for monitoring the output voltage. The undervoltage threshold is set at 200mV above the 0.2V reference level.

The  $V_{LOGIC}$  power supply is used to power the logic circuitry within the LCD panel. The DC/DC may be powered directly from the low voltage input, 3.3V or 5.0V, or it may be powered through the fault protection switch. The LDO\_LOGIC regulator uses an external PNP transistor as the pass element. The onboard LDO controller is a wide band (>10MHz) transconductance amplifier capable of 16mA drive current, which is sufficient for up to 160mA or more output current

under the low dropout condition (forced beta of 10). Typical  $V_{\text{LOGIC}}$  voltage supported by EL7520, EL7520A range from +1.3V to  $V_{\text{DD}}-0.2\text{V}$ . A fault comparator is also included for monitoring the output voltage. The undervoltage threshold is set at 25% below the 1.2V reference.

### Set-Up LDOs Output Voltage

Refer to Typical Application Diagram, the output voltages of  $V_{\text{ON}}$ ,  $V_{\text{OFF}}$ , and  $V_{\text{LOGIC}}$  are determined by the following equations:

$$V_{\text{ON}} = V_{\text{REF}} \times \left( 1 + \frac{R_{12}}{R_{11}} \right)$$

$$V_{\text{OFF}} = V_{\text{REFN}} + \frac{R_{22}}{R_{21}} \times (V_{\text{REFN}} - V_{\text{REF}})$$

$$V_{\text{LOGIC}} = V_{\text{REF}} \times \left( 1 + \frac{R_{42}}{R_{41}} \right)$$

Where  $V_{\text{REF}} = 1.2\text{V}$ ,  $V_{\text{REFN}} = 0.2\text{V}$ .

### Charge Pump

To generate an output voltage higher than  $V_{\text{BOOST}}$ , single or multi stages of charge pumps are needed. The number of stage is determined by the input and output voltage. For positive charge pump stages:

$$N_{\text{POSITIVE}} \geq \frac{V_{\text{OUT}} + V_{\text{CE}} - V_{\text{INPUT}}}{V_{\text{INPUT}} - 2 \times V_{\text{F}}}$$

where  $V_{\text{CE}}$  is the dropout voltage of the pass component of the linear regulator. It ranges from 0.3V to 1V depending on the transistor.  $V_{\text{F}}$  is the forward-voltage of the charge pump rectifier diode.

The number of negative charge pump stages is given by:

$$N_{\text{NEGATIVE}} \geq \frac{|V_{\text{OUTPUT}}| + V_{\text{CE}}}{V_{\text{INPUT}} - 2 \times V_{\text{F}}}$$

To achieve high efficiency and low material cost, the lowest number of charge pump stages, which can meet the above requirements, is always preferred.

### Charge Pump Output Capacitors

A ceramic capacitor with low ESR is recommended. With ceramic capacitors, the output ripple voltage is dominated by the capacitance value. The capacitance value can be chosen by the following equation:

$$C_{\text{OUT}} \geq \frac{I_{\text{OUT}}}{2 \times V_{\text{RIPPLE}} \times f_{\text{OSC}}}$$

Where  $f_{\text{SOC}}$  is the switching frequency.

### Start-Up Sequence

Figures 30 and 31 show detailed start-up sequence waveforms, EL7520 and EL7520A, respectively. For a successful power-up, there should be six peaks at  $V_{\text{CDLY}}$ . When a fault is detected, the device will latch off until either EN is toggled or the input supply is recycled.

If EN is L, the device is powered down. If EN is H, and the input voltage ( $V_{\text{DD}}$ ) exceeds 2.5V, an internal current source starts to charge  $C_{\text{DLY}}$  to an upper threshold using a fast ramp followed by a slow ramp. If EN is low at this point, the  $C_{\text{DLY}}$  ramp will be delayed until EN goes high.

The first four ramps on  $C_{\text{DLY}}$  (two up, two down) are used to initialize the fault protection switch and to check whether there is a fault condition on  $C_{\text{DLY}}$  or  $V_{\text{REF}}$ . If a fault is detected, the outputs and the input protection will turn off and the chip will power down. For EL7520A,  $V_{\text{REF}}$  will stay on.

If no fault is found,  $C_{\text{DLY}}$  continues ramping up and down until the sequence is completed.

During the second ramp, the device checks the status of  $V_{\text{REF}}$  and over temperature. At the peak of the second ramp, PG output goes low and enables the input protection PMOS Q1. Q1 is a controlled FET used to prevent in-rush current into  $V_{\text{BOOST}}$  before  $V_{\text{BOOST}}$  is enabled internally. Its rate of turn on is controlled by  $C_0$ . When a fault is detected, Q1 will turn off and disconnect the inductor from  $V_{\text{IN}}$ .

With the input protection FET on, NODE1 (See Typical Application Diagram) will rise to  $-V_{\text{IN}}$ . Initially the boost is not enabled so  $V_{\text{BOOST}}$  rises to  $V_{\text{IN}} - V_{\text{DIODE}}$  through the output diode. Hence, there is a step at  $V_{\text{BOOST}}$  during this part of the start-up sequence. If this step is not desirable, an external PMOS FET can be used to delay the output until the boost is enabled internally. The delayed output appears at  $A_{\text{VDD}}$ .

For EL7520,  $V_{\text{BOOST}}$  and  $V_{\text{LOGIC}}$  soft-start at the beginning of the third ramp. The soft-start ramp depends on the value of the  $C_{\text{DLY}}$  capacitor. For  $C_{\text{DLY}}$  of 220nF, the soft-start time is ~2ms. EL7520A is the same as EL7520 except that  $V_{\text{REF}}$  and  $V_{\text{LOGIC}}$  turn on once input voltage exceeds 2.5V.

$V_{\text{OFF}}$  turns on at the start of the fourth peak. At the fifth peak, DELB gate goes low to turn on the external PMOS Q4 to generate a delayed  $V_{\text{BOOST}}$  output.

$V_{\text{ON}}$  is enabled at the beginning of the sixth ramp.  $A_{\text{VDD}}$ , PG,  $V_{\text{OFF}}$ , DELB and  $V_{\text{ON}}$  are checked at end of this ramp.

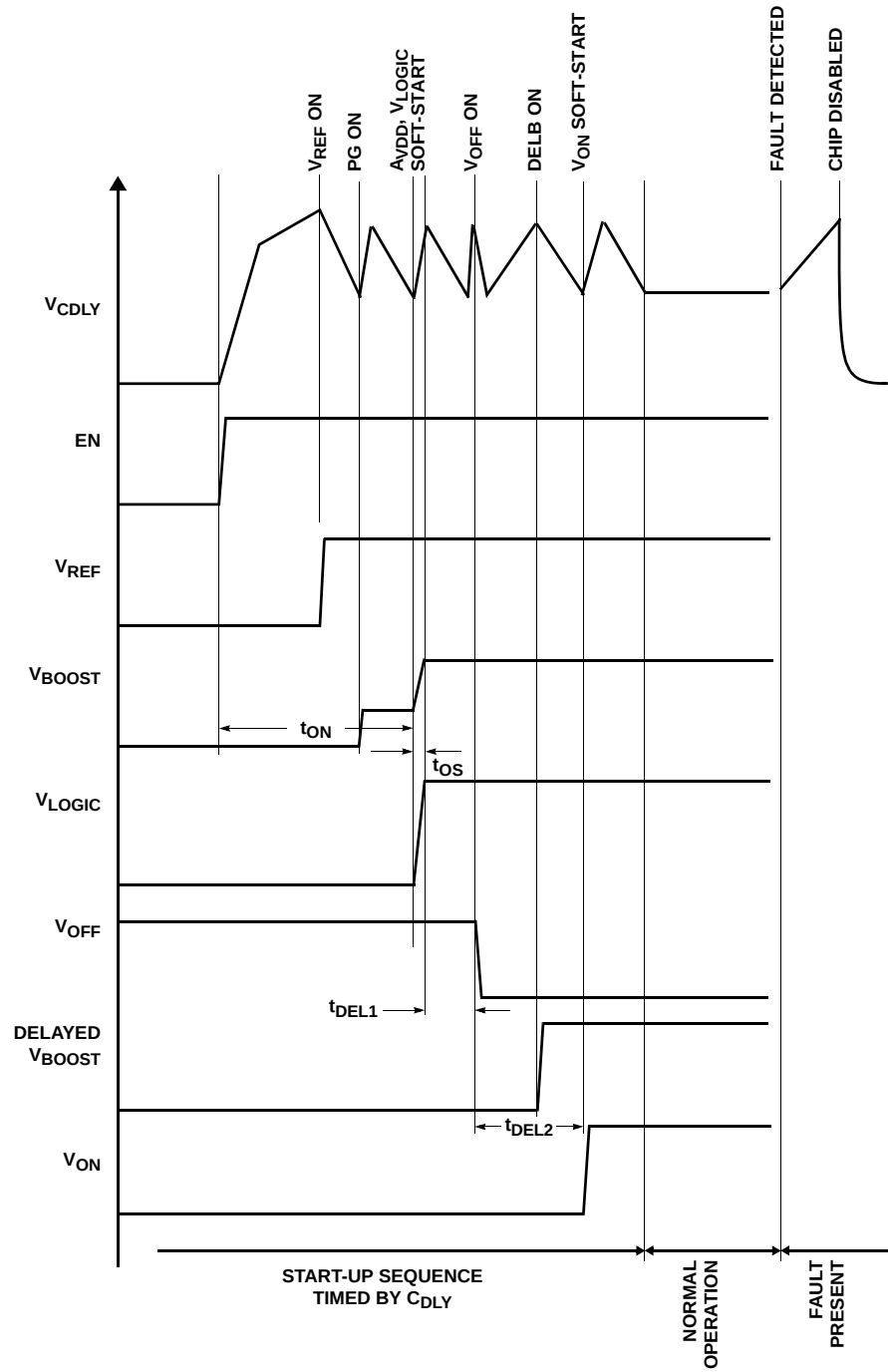


FIGURE 30. EL7520 START-UP SEQUENCE

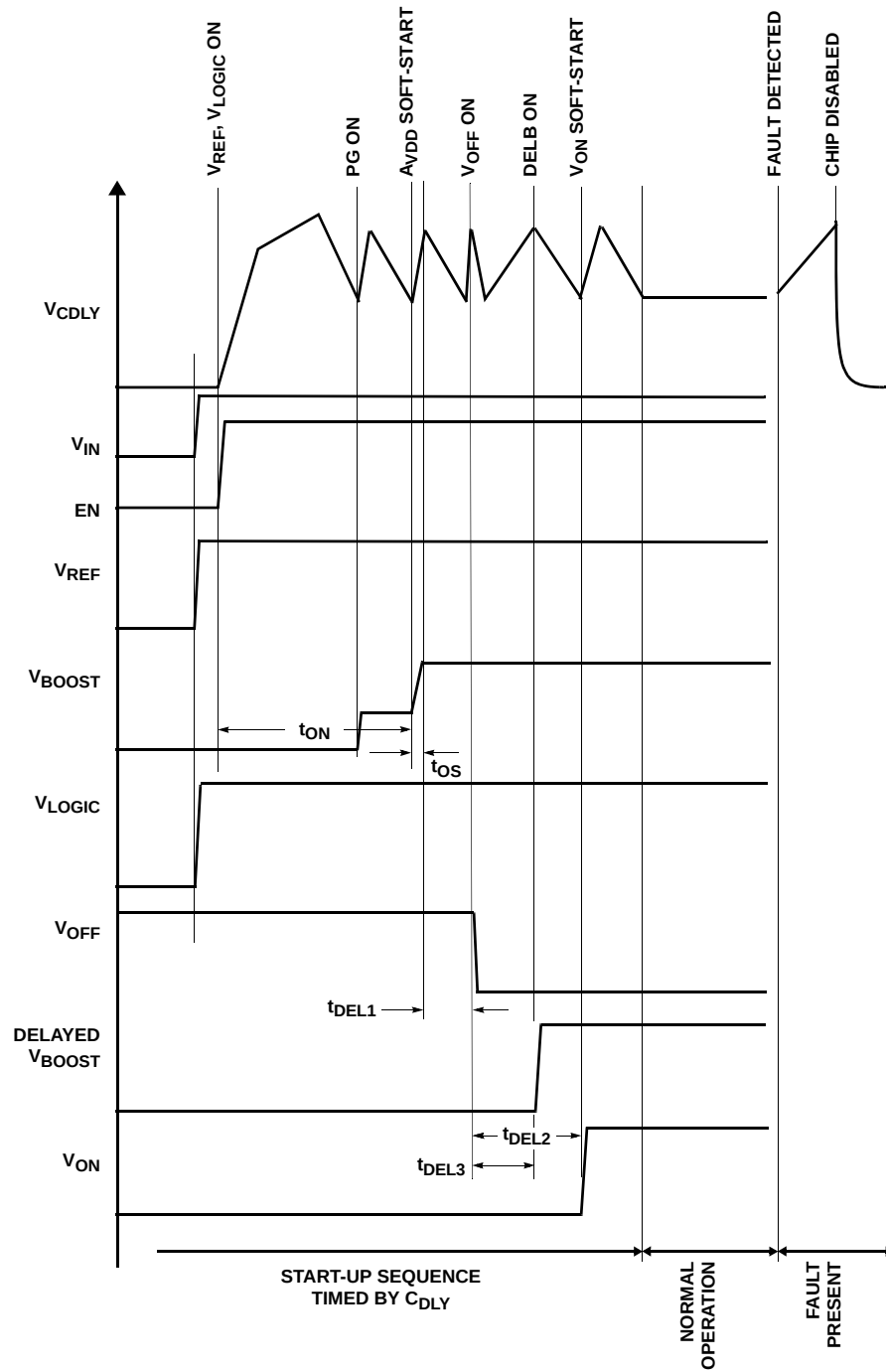


FIGURE 31. EL7520A START-UP SEQUENCE

**Over-Temperature Protection**

An internal temperature sensor continuously monitor the die temperature. In the event that the die temperature exceeds the thermal trip point, the device will shut down. The upper and lower trigger points are typically set to 130°C and -90°C respectively.

**Layout Recommendation**

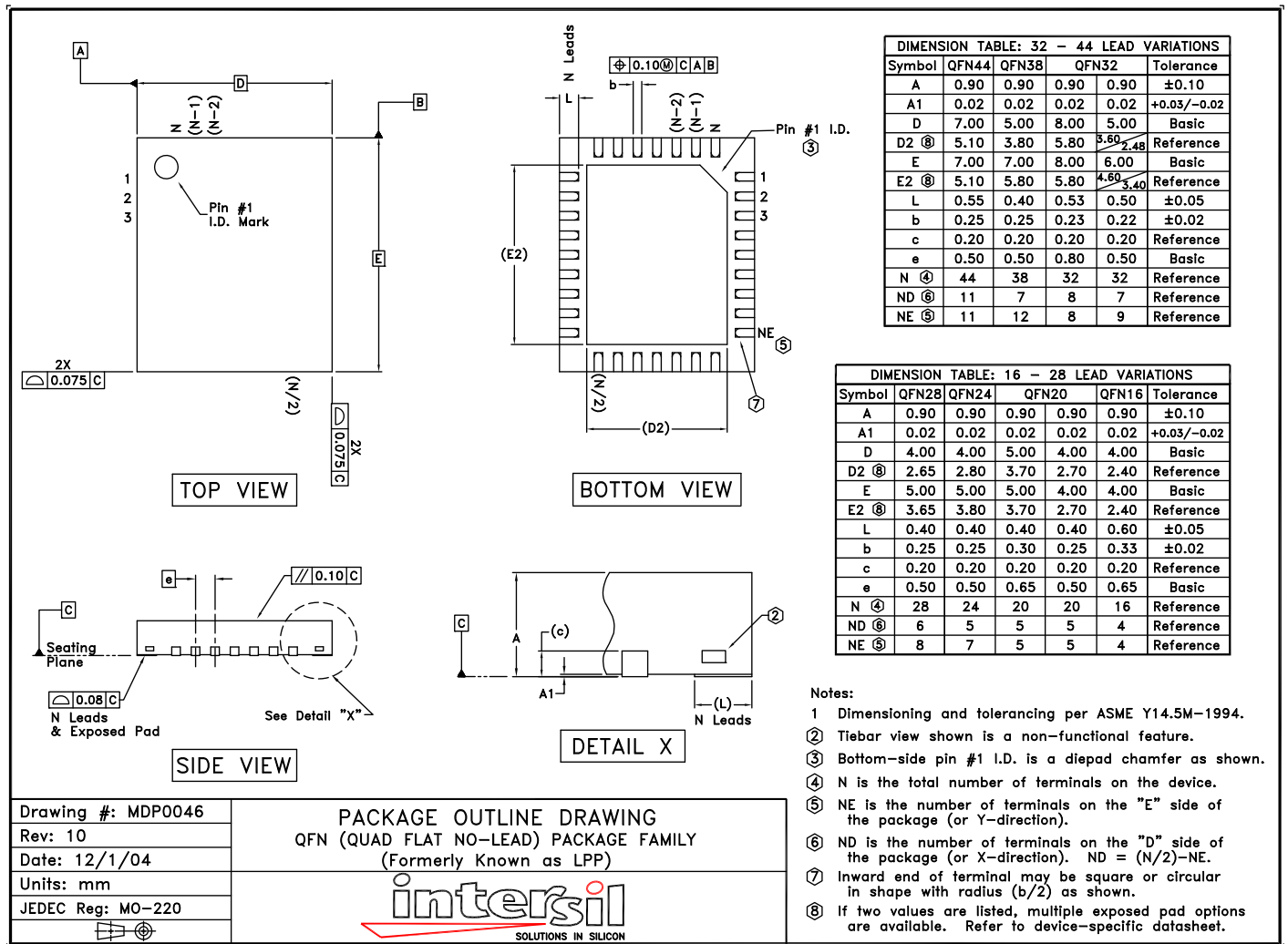
The device's performance including efficiency, output noise, transient response and control loop stability is dramatically affected by the PCB layout. PCB layout is critical, especially at high switching frequency.

There are some general guidelines for layout:

1. Place the external power components (the input capacitors, output capacitors, boost inductor and output diodes, etc.) in close proximity to the device. Traces to these components should be kept as short and wide as possible to minimize parasitic inductance and resistance.
2. Place  $V_{REF}$  and  $V_{DD}$  bypass capacitors close to the pins.
3. Reduce the loop with large AC amplitudes and fast slew rate.
4. The feedback network should sense the output voltage directly from the point of load, and be as far away from LX node as possible.
5. The power ground (PGND) and signal ground (SGND) pins should be connected at only one point.

A demo board is available to illustrate the proper layout implementation.

## QFN Package Outline Drawing



NOTE: The package drawing shown here may not be the latest version. To check the latest revision, please refer to the Intersil website at <http://www.intersil.com/design/packages/index.asp>

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