

### 4-Channel TFT-LCD Supply

The ISL97522 represents a 4-channel supply control IC for use in large panel TFT-LCD displays. Supporting inputs from 4.5V to 13V, the ISL97522 includes a boost controller to achieve the required  $A_{VDD}$  output voltage. Both  $V_{ON}$  and  $V_{OFF}$  are generated using off-chip charge-pumps which are then post regulated using on-board LDO controllers.

The logic supply is generated using an internal non-synchronous buck controller. This controller runs at 180° out of phase with the  $A_{VDD}$  supply to minimize input noise.

The  $A_{VDD}$ ,  $V_{OFF}$ , and  $V_{ON}$  outputs are automatically sequenced as  $A_{VDD}$ ,  $V_{OFF}$  and  $V_{ON}$ . By using an optional external series transistor with  $A_{VDD}$  (Q1), the start-up sequence can be adjusted to  $V_{OFF}$ ,  $A_{VDD}$  and then  $V_{ON}$ . A  $V_{ON}$  slicing circuit is also included to reduce LCD flicker.

The ISL97522 also incorporates a fault protection circuit that can disable the IC and turn off all outputs when an output short is detected. (Note that to protect  $A_{VDD}$  a single external transistor is required).

### Ordering Information

| PART NUMBER<br>(Note) | PART MARKING | TAPE & REEL  | PACKAGE<br>(Pb-Free) | PKG. DWG. # |
|-----------------------|--------------|--------------|----------------------|-------------|
| ISL97522IRZ-TK        | ISL 97522IRZ | 13" (1k pcs) | 38 Ld QFN            | L38.5x7B    |
| ISL97522IRZ-T         | ISL 97522IRZ | 13" (4k pcs) | 38 Ld QFN            | L38.5x7B    |

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.

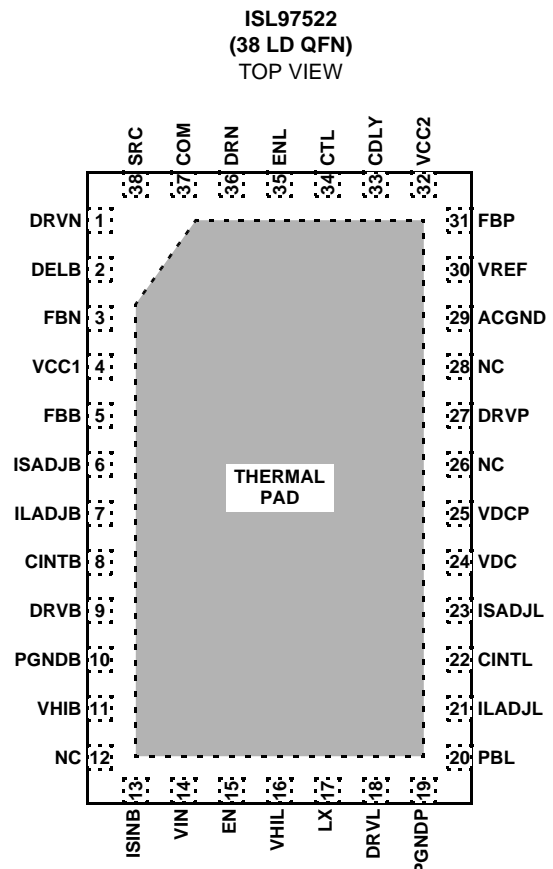
### Features

- 4.5V to 13V input
- Boost controller for  $A_{VDD}$
- Regulated LDOs for  $V_{OFF}$  and  $V_{ON}$
- Buck controller for logic output
- $V_{ON}$  slicing circuit
- Fully fault-protected
- Programmable sequence
- 1MHz switching frequency
- 38 Ld QFN package
- Pb-free plus anneal available (RoHS compliant)

### Applications

- LCD-TVs (up to 50"+)
- LCD monitors (15"+)
- Industrial/medical LCD displays

### Pinout



**Absolute Maximum Ratings** ( $T_A = +25^\circ\text{C}$ )

|  |      |
|--|------|
| Maximum Pin Voltages, all pins except below          | 6.5V |
| V <sub>IN</sub> , EN, ENL, LX, VHIL                  | .25V |
| V <sub>DELB</sub>                                    | .36V |
| V <sub>DRV</sub> , V <sub>SINB</sub> , SRC, COM, DRN | .36V |
| V <sub>DRVN</sub>                                    | -20V |

**Thermal Information**

|                                |   |   |
|--------------------------------|---|---|
| Thermal Resistance             | $\theta_{JA}$ ( $^\circ\text{C}/\text{W}$ ) | $\theta_{JC}$ ( $^\circ\text{C}/\text{W}$ ) |
| 38 Ld QFN Package (Notes 1, 2) | 33  | 4.5   |

**Operating Conditions**

|  |   |
|--|---|
| Input Voltage Range, V <sub>IN</sub>           | 4.5V to 13V                                   |
| Boost Output Voltage Range, A <sub>VDD</sub>   | +15V to +25V                                  |
| V <sub>ON</sub> Output Range, V <sub>ON</sub>  | +15V to +32V                                  |
| V <sub>OFF</sub> Output Range, V <sub>ON</sub> | -15V to -5V                                   |
| Input Capacitance, C <sub>IN</sub>             | .2x10 $\mu\text{F}$                           |
| Boost Inductor, L1                             | 3.3 $\mu\text{H}$ to 10 $\mu\text{H}$         |
| Output Capacitance, C <sub>OUT</sub>           | .4x10 $\mu\text{F}$                           |
| Buck Inductor, L2                              | 3.3 $\mu\text{H}$ to 10 $\mu\text{H}$         |
| Operating Ambient Temperature Range            | -40 $^\circ\text{C}$ to +85 $^\circ\text{C}$  |
| Operating Junction Temperature                 | -40 $^\circ\text{C}$ to +125 $^\circ\text{C}$ |

*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:**

- $\theta_{JA}$  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.
- For  $\theta_{JC}$ , 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:  $T_J = T_C = T_A$*

**Electrical Specifications** V<sub>IN</sub> = 5V, A<sub>VDD</sub> = 15V, V<sub>ON</sub> = 20V, V<sub>OFF</sub> = -9V, V<sub>LOGIC</sub> = 3V, Over Temperature from -40 $^\circ\text{C}$  to +85 $^\circ\text{C}$

| PARAMETER              | DESCRIPTION                    | CONDITION  | MIN   | TYP   | MAX   | UNIT     |
|------------------------|--------------------------------|--|-------|-------|-------|----------|
| <b>GENERAL</b>         |                                |  |       |       |       |          |
| V <sub>IN</sub>        | Input Voltage                  |  | 4.5   |       | 13.2  | V        |
| I <sub>S</sub>         | Sum Quiescent Current into Vin | EN = 0, ENL = 0  |       | 3     |       | mA       |
|                        |                                | EN = ENL = 1, switching  |       | 15    |       | mA       |
| F <sub>OSC</sub>       | Oscillator Frequency           |  | 850   | 1000  | 1100  | kHz      |
| V <sub>REF</sub>       | Reference Voltage              | T <sub>A</sub> = +25 $^\circ\text{C}$  | 1.192 | 1.215 | 1.235 | V        |
|                        |                                |  | 1.190 | 1.215 | 1.237 | V        |
| <b>A<sub>VDD</sub></b> |                                |  |       |       |       |          |
| V <sub>FBB</sub>       | Feedback Reference Voltage     | T <sub>A</sub> = +25 $^\circ\text{C}$  | 1.195 | 1.208 | 1.221 | V        |
|                        |                                |  | 1.193 | 1.208 | 1.223 | V        |
| V <sub>F_FBB</sub>     | FBB Fault Trip Point           | V <sub>FBB</sub> falling   | 0.85  | 0.9   | 0.95  | V        |
| D <sub>MIN</sub>       | Minimum Duty Cycle             |  |       | 19    | 25    | %        |
| D <sub>MAX</sub>       | Maximum Duty Cycle             |  | 80    | 86    |       | %        |
| Eff                    | Boost Efficiency               |  |       | 90    |       | %        |
| I <sub>FBB</sub>       | FBB Input Bias Current         |  |       | 25    |       | nA       |
| R <sub>LINEB</sub>     | Line Regulation                | C <sub>INT</sub> = 2.2nF, V <sub>IN</sub> = 4.5V to 12V, I <sub>O</sub> = 100mA    |       | 0.01  | 0.25  | %/V      |
| R <sub>LOADB</sub>     | Load Regulation                | C <sub>INT</sub> = 2.2nF, V <sub>IN</sub> = 5V, I <sub>AVDD</sub> = 100mA to 350mA |       | 0.03  | 0.25  | %        |
| R <sub>ONB</sub>       | Gate Drive on Resistance       | Pull-up  |       | 3.6   |       | $\Omega$ |
|                        |                                | Pull-down  |       | 1.9   |       | $\Omega$ |

# ISL97522

**Electrical Specifications**  $V_{IN} = 5V$ ,  $A_{VDD} = 15V$ ,  $V_{ON} = 20V$ ,  $V_{OFF} = -9V$ ,  $V_{LOGIC} = 3V$ , Over Temperature from  $-40^{\circ}C$  to  $+85^{\circ}C$

| PARAMETER                           | DESCRIPTION                        | CONDITION  | MIN   | TYP   | MAX   | UNIT     |
|-------------------------------------|------------------------------------|--|-------|-------|-------|----------|
| I <sub>PEAKB</sub>                  | Peak Drive Current                 | Source   |       | 600   |       | mA       |
|                                     |                                    | Sink   |       | 900   |       | mA       |
| I <sub>ISADJB</sub>                 | I <sub>SADJB</sub> Output Current  | R <sub>SADJB</sub> = 30k $\Omega$  | 10    | 15    | 25    | $\mu$ A  |
| I <sub>ILADJB</sub>                 | I <sub>LADJB</sub> Output Current  | R <sub>LADJB</sub> = 30k $\Omega$  | 10    | 17    | 25    | $\mu$ A  |
| <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 $^{\circ}C$  | 1.176 | 1.2   | 1.224 | V        |
|                                     |                                    | I <sub>DRVP</sub> = 0.2mA  | 1.174 | 1.2   | 1.226 | V        |
| V <sub>F_FBP</sub>                  | FBP Fault Trip Point               | V <sub>FBP</sub> falling   | 0.82  | 0.87  | 0.92  | V        |
| I <sub>FBP</sub>                    | FBP Input Bias Current             | V <sub>FBP</sub> = 1.35V   |       | 150   |       | nA       |
| R <sub>LOADP</sub>                  | V <sub>ON</sub> Load Regulation    | I(V <sub>ON</sub> ) = 0mA to 20mA  |       | 0.5   | 0.75  | %        |
| I <sub>DRVP</sub>                   | DRVP Sink Current Max              | V <sub>FBP</sub> = 1.1V, V <sub>DRVP</sub> = 25V   | 2     | 4     |       | mA       |
| I <sub>L_DRVP</sub>                 | DRVP Leakage Current               | V <sub>FBP</sub> = 1.5V, V <sub>DRVP</sub> = 35V   |       | 0.3   | 2     | $\mu$ A  |
| <b>V<sub>OFF</sub> LDO</b>          |                                    |  |       |       |       |          |
| V <sub>FBN</sub>                    | FBN Regulation Voltage             | I <sub>DRVN</sub> = 0.2mA, T <sub>A</sub> = +25 $^{\circ}C$  | 0.186 | 0.213 | 0.24  | V        |
|                                     |                                    | I <sub>DRVN</sub> = 0.2mA  | 0.183 | 0.213 | 0.243 | V        |
| V <sub>F_FBN</sub>                  | FBN Fault Trip Point               | V <sub>FBN</sub> rising  | 0.45  | 0.5   | 0.55  | V        |
| I <sub>FBN</sub>                    | FBN Input Bias Current             | V <sub>FBN</sub> = 0.2V  |       | 40    |       | nA       |
| R <sub>LOADN</sub>                  | V <sub>OFF</sub> Load Regulation   | I(V <sub>OFF</sub> ) = 0mA to 20mA   |       | 0.4   | 0.85  | %        |
| I <sub>DRVN</sub>                   | DRVN Source Current Max            | V <sub>FBN</sub> = 0.3V, V <sub>DRVN</sub> = -6V   | 2     | 4     |       | mA       |
| I <sub>L_DRVN</sub>                 | DRVN Leakage Current               | V <sub>FBN</sub> = 0V, V <sub>DRVN</sub> = -20V  |       | 0.4   | 5     | $\mu$ A  |
| <b>V<sub>LOGIC</sub></b>            |                                    |  |       |       |       |          |
| V <sub>FBL</sub>                    | FBL Regulation Voltage             | T <sub>A</sub> = 25 $^{\circ}C$  | 1.178 | 1.2   | 1.222 | V        |
|                                     |                                    |  | 1.176 | 1.2   | 1.224 | V        |
| D <sub>MIN</sub>                    | Minimum Duty Cycle                 |  |       | 20    |       | %        |
| D <sub>MAX</sub>                    | Maximum Duty Cycle                 |  |       | 85    |       | %        |
| EFF <sub>L</sub>                    | Logic Buck Efficiency              |  |       | 90    |       | %        |
| I <sub>FBL</sub>                    | FBL Input Bias Current             |  |       | 20    |       | nA       |
| I <sub>LINEL</sub>                  | V <sub>LOGIC</sub> Line Regulation | C <sub>INT</sub> = 2.2nF, V <sub>IN</sub> = 5V to 12V  |       | 0.03  | 0.25  | %/V      |
| I <sub>LOADL</sub>                  | V <sub>LOGIC</sub> Load Regulation | C <sub>INT</sub> = 2.2nF, I <sub>LOGIC</sub> = 100mA to 450mA  |       | 0.1   | 0.5   | %        |
| R <sub>ONL</sub>                    | Gate Drive on Resistance           | Pull-up  |       | 3.6   |       | $\Omega$ |
|                                     |                                    | Pull-down  |       | 1.9   |       | $\Omega$ |
| I <sub>PEAKL</sub>                  | Peak Drive Current                 | Source   |       | 600   |       | mA       |
|                                     |                                    | Sink   |       | 900   |       | mA       |
| I <sub>ISADJL</sub>                 | I <sub>SADJB</sub> Output Current  | R <sub>SADJB</sub> = 30k $\Omega$  |       | 15    |       | $\mu$ A  |
| I <sub>ILADJL</sub>                 | I <sub>LADJB</sub> Output Current  | R <sub>LADJB</sub> = 30k $\Omega$  |       | 17    |       | $\mu$ A  |
| <b>V<sub>ON</sub>-SLICE CIRCUIT</b> |                                    |  |       |       |       |          |
| I <sub>LEAKCTL</sub>                | CTL Input Leakage Current          | CTL = A <sub>GND</sub> or V <sub>IN</sub>  | -1    |       | 1     | $\mu$ A  |
| t <sub>Drise</sub>                  | CTL to OUT Rising Prop Delay       | 1k $\Omega$ from DRN to 8V, V <sub>CTL</sub> = 0V to 3V step, no load on OUT, measured from V <sub>CTL</sub> = 1.5V to OUT = 20% |       | 100   |       | ns       |

# ISL97522

**Electrical Specifications**  $V_{IN} = 5V$ ,  $A_{VDD} = 15V$ ,  $V_{ON} = 20V$ ,  $V_{OFF} = -9V$ ,  $V_{LOGIC} = 3V$ , Over Temperature from  $-40^{\circ}C$  to  $+85^{\circ}C$

| PARAMETER              | DESCRIPTION  | CONDITION  | MIN | TYP  | MAX  | UNIT        |
|------------------------|--|--|-----|------|------|-------------|
| $t_{Dfall}$            | CTL to OUT Falling Prop Delay  | 1k $\Omega$ from DRN to 8V, $V_{CTL} = 3V$ to 0V step, no load on OUT, measured from $V_{CTL} = 1.5V$ to OUT = 80% |     | 100  |      | ns          |
| $V_{SRC}$              | SRC Input Voltage Range  |  |     |      | 30   | V           |
| ISRC                   | SRC Input Current  | Start-up sequence not completed  |     | 0.2  | 1.25 | mA          |
|                        |  | Start-up sequence completed  |     | 150  | 250  | $\mu A$     |
| $R_{ONSRC}$            | SRC On Resistance  | Start-up sequence completed  |     | 5    | 14   | $\Omega$    |
| $R_{ONDRN}$            | DRN On Resistance  | Start-up sequence completed  |     | 30   | 60   | $\Omega$    |
| $R_{ONCOM}$            | COM to GND On Resistance   | Start-up sequence not completed  | 400 | 1000 | 1800 | $\Omega$    |
| <b>SEQUENCING</b>      |  |  |     |      |      |             |
| $t_{ON}$               | Turn On Delay  | $C_{DLY} = 0.22\mu F$  |     | 30   |      | ms          |
| $t_{SS}$               | Soft-start Time  | $C_{DLY} = 0.22\mu F$  |     | 2    |      | ms          |
| $t_{DEL1}$             | Delay Between $A_{VDD}$ and $V_{OFF}$                                      | $C_{DLY} = 0.22\mu F$  |     | 10   |      | ms          |
| $t_{DEL2}$             | Delay Between $V_{ON}$ and $V_{OFF}$                                       | $C_{DLY} = 0.22\mu F$  |     | 17   |      | ms          |
| $t_{DEL3}$             | Delay Between $V_{OFF}$ and Delayed $V_{BOOST}$                            | $C_{DLY} = 0.22\mu F$  |     | 10   |      | ms          |
| $I_{DELB\_ON}$         | DELB Pull-Down Current or Resistance when Enabled by the Start-Up Sequence | $V_{DELB} > 0.9V$  | 35  | 50   | 65   | $\mu A$     |
|                        |  | $V_{DELB} < 0.9V$  | 1.2 | 1.6  | 2    | K $\Omega$  |
| $I_{DELB\_OFF}$        | DELB Pull-Down Current or Resistance when Disabled                         | $V_{DELB} < 20V$   |     |      | 500  | nA          |
| <b>FAULT DETECTION</b> |  |  |     |      |      |             |
| $T_{FAULT}$            | Fault Time Out   | $C_{DLY} = 0.22\mu F$  |     | 50   |      | ms          |
| OT                     | Over-temperature Threshold   |  |     | 140  |      | $^{\circ}C$ |
| <b>LOGIC</b>           |  |  |     |      |      |             |
| $V_{HI}$               | Logic High Threshold   |  | 2.2 |      |      | V           |
| $V_{LO}$               | Logic Low Threshold  |  |     |      | 0.8  | V           |
| $I_{LOW}$              | Logic Low Bias Current   |  |     | 0.1  |      | $\mu A$     |
| $I_{HIGH}$             | Logic High Bias Current  |  | 16  | 23   | 30   | $\mu A$     |

Typical Performance Curves

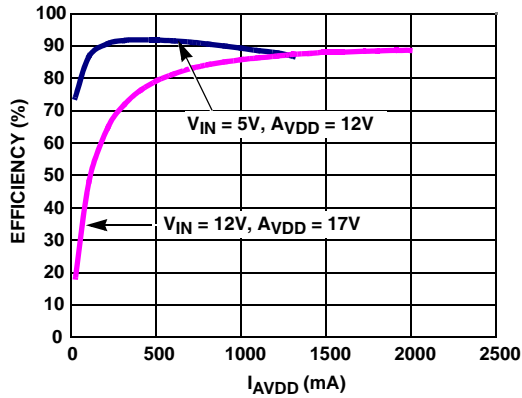


FIGURE 1. BOOST AVDD EFFICIENCY

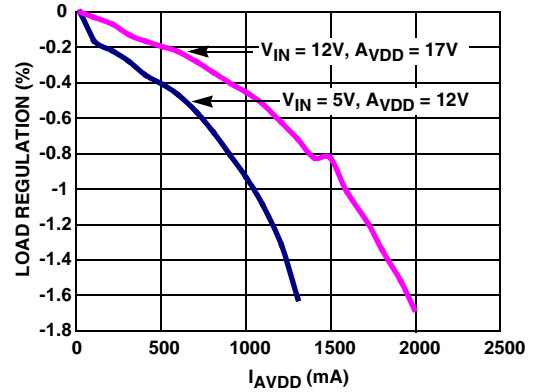


FIGURE 2. BOOST AVDD LOAD REGULATION

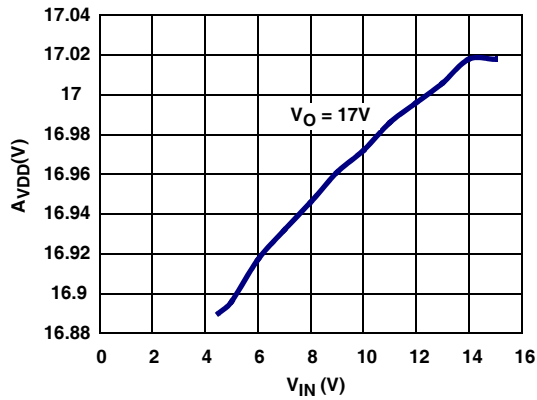


FIGURE 3. BOOST AVDD LINE REGULATION

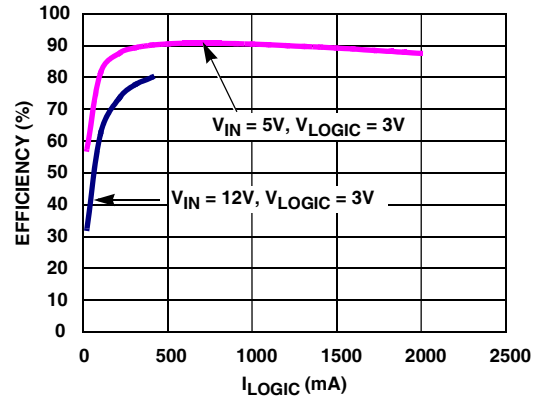


FIGURE 4. BUCK V<sub>LOGIC</sub> EFFICIENCY

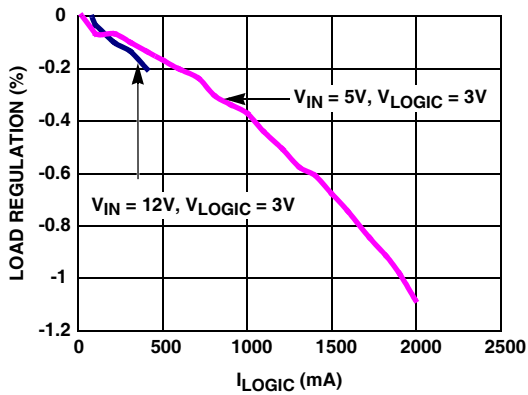


FIGURE 5. BUCK V<sub>LOGIC</sub> LOAD REGULATION

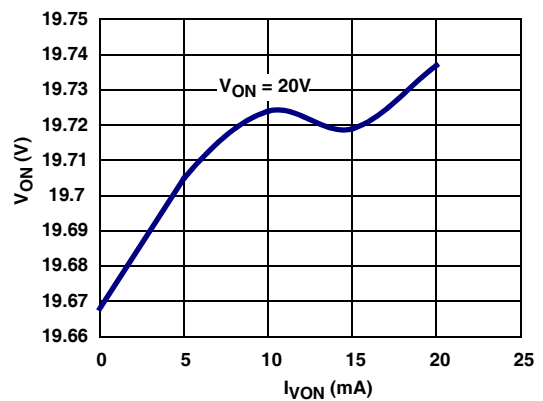


FIGURE 6. V<sub>ON</sub> LOAD REGULATION

Typical Performance Curves (Continued)

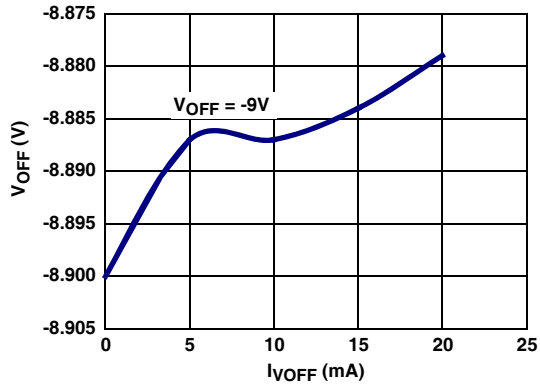


FIGURE 7.  $V_{OFF}$  LOAD REGULATION

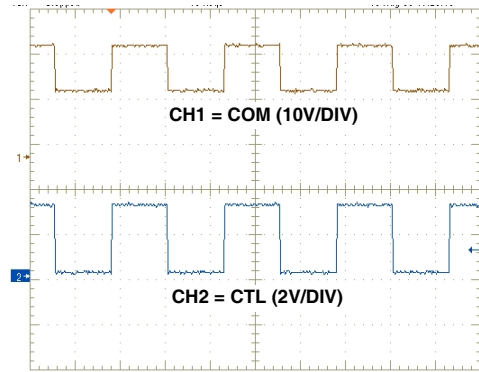


FIGURE 8. 4ms/DIV  $V_{ON}$  SLICE CIRCUIT OPERATION

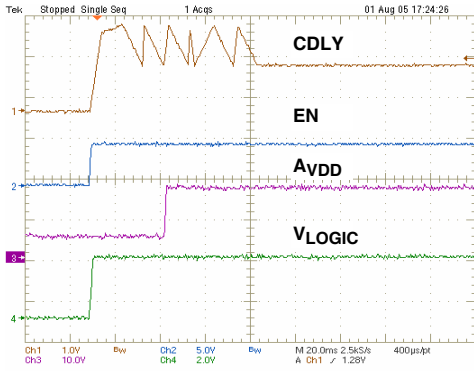


FIGURE 9. START-UP SEQUENCE

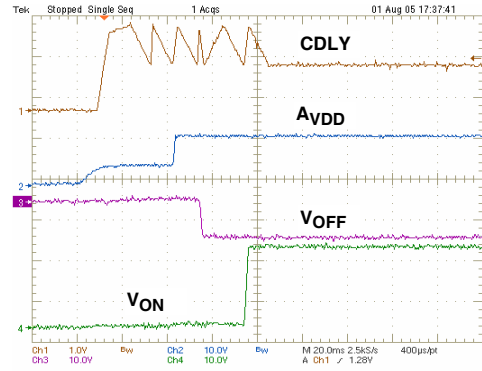


FIGURE 10. START-UP SEQUENCE

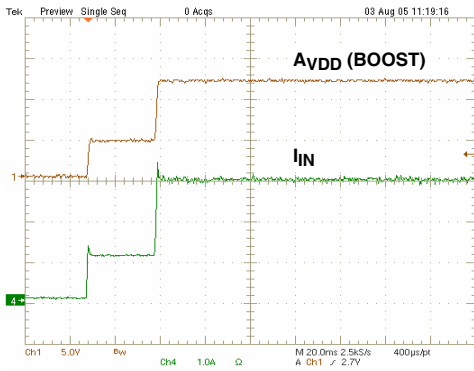


FIGURE 11. IN RUSH CURRENT

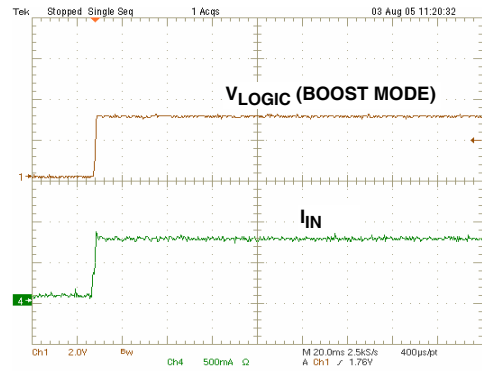


FIGURE 12. IN RUSH CURRENT

Typical Performance Curves (Continued)

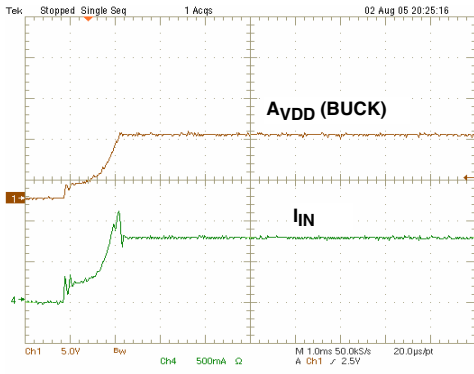


FIGURE 13. IN RUSH CURRENT

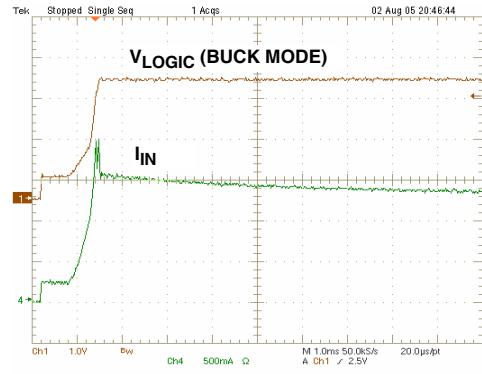


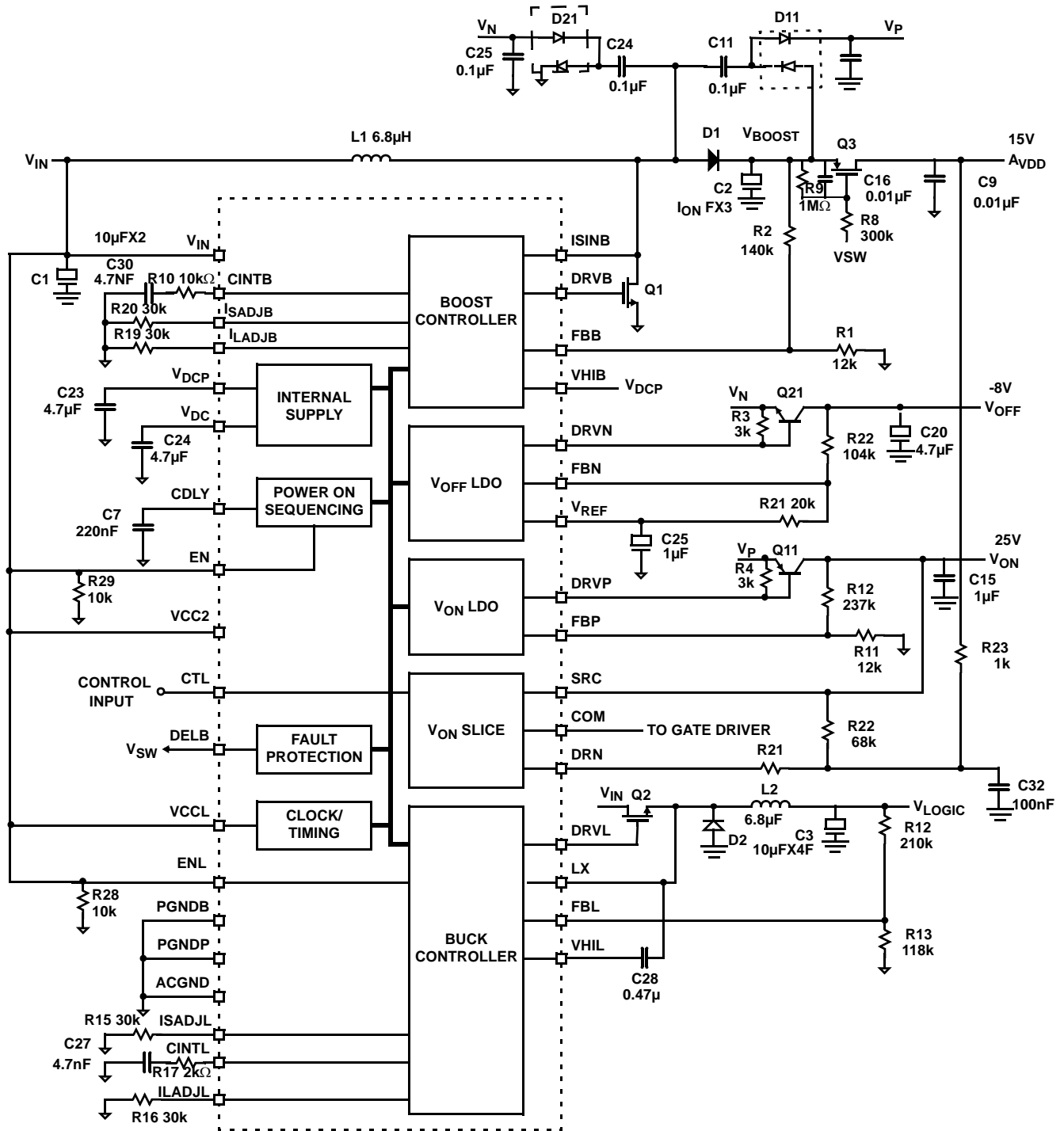
FIGURE 14. IN RUSH CURRENT

**Pin Descriptions**

| PIN # | PIN NAME | PIN DESCRIPTION   |
|-------|----------|---|
| 1     | DRVN     | Negative LDO base drive; open drain of an internal P-Channel MOSFET.  |
| 2     | DELB     | Active low control output for optional delay control for external $A_{VDD}$ P-Channel FET; when fault is detected, this pin goes to high.                 |
| 3     | FBW      | Negative LDO voltage feedback input pin; regulates to 0.2V nominal.   |
| 4     | VCC1     | Supply input, connect to $V_{IN}$ .   |
| 5     | FBB      | $A_{VDD}$ regulator voltage feedback input pin; regulates to 1.2V nominal.  |
| 6     | ISADJB   | Current feedback adjust for $A_{VDD}$ .   |
| 7     | ILADJB   | With a resistor connected from this pin to GND sets the current limit of the external N-channel FET for $A_{VDD}$ .                                       |
| 8     | CINTB    | $A_{VDD}$ integrator output, connect 2.2nF to analog GND.   |
| 9     | DRVB     | Gate driver output for the external N-Channel switch.   |
| 10    | PGNDB    | Power GND for $A_{VDD}$ .   |
| 11    | VHIB     | Internal Drive of Boost controller, Connect to VDCP.  |
| 12    | NC       |   |
| 13    | ISINB    | Sense the drain voltage of the external N-channel FET and connected to the internal current limit comparator.   |
| 14    | VIN      | Main supply input.  |
| 15    | EN       | Enable pin; high enable, low disabled.  |
| 16    | VHIL     | $V_{LOGIC}$ boost strap mode.   |
| 17    | LX       | $V_{LOGIC}$ switch connection.  |
| 18    | DRVL     | Gate driver output for external N-channel switch.   |
| 19    | PGNDP    | Power GND.  |
| 20    | FBL      | $V_{LOGIC}$ regulator voltage feedback pin; regulates to 1.2V nominal.  |
| 21    | ILADJL   | With resistor connected from this pin to GND sets the current limit of the external N-channel FET.  |
| 22    | CINTL    | $V_{LOGIC}$ integrator output, connect 2.2nF to analog GND.   |
| 23    | ISADJL   | Current feedback adjust for $V_{LOGIC}$ .   |
| 24    | VDC      | Positive supply for all internal analog circuits.   |
| 25    | VDCP     | Positive supply for external N-Channel FET gate drives.   |
| 26    | NC       |   |
| 27    | DRVP     | Positive LDO base drive; open drain of an internal N-Channel MOSFET.  |
| 28    | NC       |   |
| 29    | ACGND    | Low noise signal ground.  |
| 30    | VREF     | Bandgap voltage bypass terminal; bypass with a 0.1 $\mu$ F to analog GND; can be used as charge pump reference.   |
| 31    | FBP      | Positive LDO voltage feedback input pin; regulates to 1.2V nominal.   |
| 32    | CC2      | Supply input, connect to $V_{IN}$ .   |
| 33    | CDLY     | With a capacitor connect from this pin to GND, sets the delay time for start-up sequence and fault detection timeout.                                     |
| 34    | CTL      | Input control for switch output.  |
| 35    | ENL      | Enable pin for $V_{LOGIC}$ high enable; low disabled.   |
| 36    | DRN      | Lower reference voltage for switch output.  |
| 37    | COM      | Switch output; when CTL = 1, COM is connected to SRC through a 15 $\Omega$ resistor, when CT = 0, COM is connected to DRN through a 30 $\Omega$ resistor. |
| 38    | SRC      | Upper reference voltage for switch output.  |



Typical Application Diagram



## Applications Information

The ISL97522 provides a multiple output power supply solution for TFT-LCD applications. The system consists of a high efficiency boost controller, two low cost linear-regulator controllers ( $V_{ON}$  and  $V_{OFF}$ ) and a buck regulator ( $V_{LOGIC}$ ).

Table 1 below lists the recommended components.

**TABLE 1. RECOMMENDED COMPONENTS**

| DESIGNATION   | DESCRIPTION   |
|---------------|---|
| C1, C2, C3    | 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<br>457-04) ON SEMI MBRM120ET3                     |
| D11, D12, D21 | 200mA 30V schottky barrier diode (SOT-23)<br>Fairchild BAT54S                                 |
| L1            | 6.8mH 4.6A inductor<br>Coilcraft DO3316P-682ML  |
| Q1,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  |

## $A_{VDD}$ 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  $A_{VDD}$  converter can operate in continuous or discontinuous inductor current mode. The ISL97522 is designed for continuous current mode, but it 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 (in boost mode):

$$\frac{A_{VDD}}{V_{IN}} = \frac{1}{1-D} \quad (\text{EQ. 1})$$

where D is the duty cycle of switching MOSFET.

Figure 15 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 200k $\Omega$  is recommended. The boost converter output voltage is determined by the following equation:

$$A_{VDD} = \frac{R_1 + R_2}{R_1} \times V_{FBB} \quad (\text{EQ. 2})$$

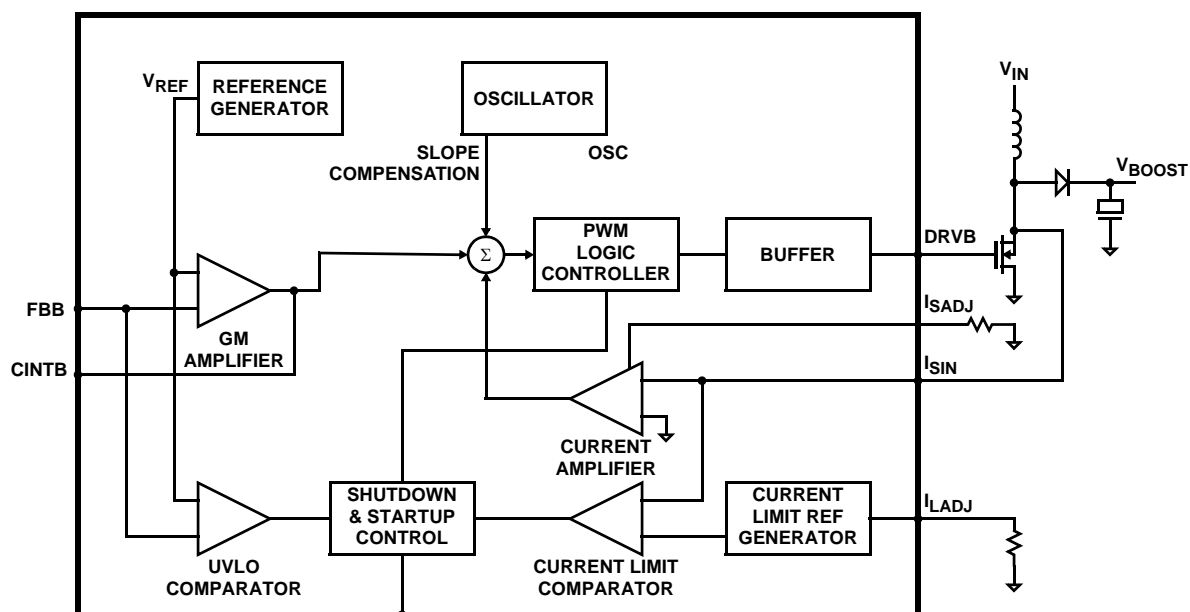


FIGURE 15. FUNCTION DIAGRAM OF THE BOOST CONTROLLER

The internal current limit circuitry is shown in Figure 16. 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 10mA current and any additional current set at  $I_{LADJB}$  pin flowing through an 8kΩ resistor. The voltage reference is based on the following equation:

$$V_{THRESHOLD} = \left( \frac{V_{ILADJB}}{R_1} + 10\mu A \right) \times 8K \quad (EQ. 3)$$

Where  $V_{ILADJB}$  is the voltage at pin  $I_{LADJB}$ .

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

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

$$I_{SAD} = \frac{V_{ISAD}}{R1} \quad (EQ. 4)$$

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.

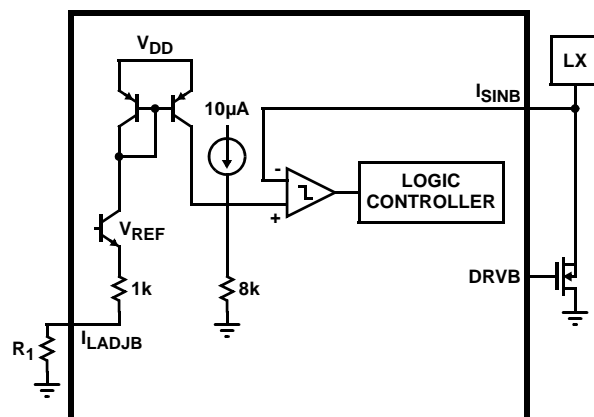


FIGURE 16. CURRENT LIMIT BLOCK DIAGRAM

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

$$I_{OMAX} = \left( \frac{V_{THRESHOLD}}{R_{DS(ON)}} - \frac{\Delta I_L}{2} \right) \times \frac{V_{IN}}{V_O} \quad (EQ. 5)$$

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

$$\Delta I_L = \frac{V_{IN}}{L} \times \frac{D}{f_s} \quad (EQ. 6)$$

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

$$D = \frac{V_O - V_{IN}}{V_O} \quad (\text{EQ. 7})$$

To overcome the variation in external LX driver  $R_{DS(ON)}$ , an input is provided (ILADJ) to accommodate 5 different bands of  $R_{DS(ON)}$  by using 5 different selection resistors. Internally, the ILADJ resistor adjusts two things:

- 1.the current limit;
- 2.the current feedback being used.

This keeps the dc-dc loop stable and the current limit the same over a wide range of external drive FETs.

Alternatively, the current limit can be changed for the same FET by varying the resistor. This would affect the stability of the system somewhat (because the current feedback changes) but be selected appropriately to accommodate the change. The integrator loop should keep the load regulation within limits as long as it doesn't run out of dynamic adjustment range when current feedback gets larger than intended. This could be determined by measuring how close to the upper clamp limit the voltage on the Cint pin voltage gets under maximum load current.

Here are the resistor settings on ILADJ which select the five  $R_{DS(ON)}$  ranges:

1/ 0ohms (Cfb factor 1, "Cfb" are the relative current feedback factors)

2/ 30K (Cfb factor 1/1.8)

3/ 83K (Cfb factor 1/3.3)

4/ 182K (Cfb factor 1/5.7)

5/ >370K (Cfb factor 1/10)

1/ sets maximum internal current feedback and minimum ILimit, used for low Ron fets.

5/ sets minimum internal current feedback and maximum ILimit, used for large Ron fets.

The Current limit factors should be the inverse of the Cfb values.

### 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  $6.8\mu\text{H}$  inductor is recommended. The inductor must be able to handle the following average and peak current:

$$I_{LAVG} = \frac{I_O}{1-D} \quad (\text{EQ. 8})$$

$$I_{LPK} = I_{LAVG} + \frac{\Delta I_L}{2} \quad (\text{EQ. 9})$$

### BOOST 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 Table 2.

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.

$$V_{RIPPLE} = I_{LPK} \times \text{ESR} + \frac{V_O - V_{IN}}{V_O} \times \frac{I_O}{C_{OUT}} \times \frac{1}{f_s} \quad (\text{EQ. 10})$$

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.

### PI mode $C_{INT}$ ( $C_{23}$ ) and $R_{INT}$ ( $R_{10}$ )

The IC is designed to operate with a minimum  $C_{23}$  capacitor of 4.7nF and a minimum  $C_2$  (effective) = 10 $\mu$ F.

Note that, for high voltage  $A_{VDD}$ , the voltage coefficient of ceramic capacitors ( $C_2$ ) reduces their effective capacitance greatly; a 16V 10 $\mu$ F ceramic can drop to around 3 $\mu$ F at 15V.

To improve the transient load response of  $A_{VDD}$  in PI mode, a resistor may be added in series with the  $C_{23}$  capacitor. The larger the resistor the lower the overshoot but at the expense of stability of the converter loop - especially at high currents.

With  $L = 10\mu$ H,  $A_{VDD} = 15$ V,  $C_{23} = 4.7$ nF,  $C_2$  (effective) should have a capacitance of greater than 10 $\mu$ F.  $R_{INT}$  ( $R_7$ ) can have values up to 5k $\Omega$  for  $C_2$  (effective) up to 20 $\mu$ F and up to 10K for  $C_2$  (effective) up to 30 $\mu$ F.

Larger values of  $R_{INT}$  ( $R_7$ ) may be possible if maximum  $A_{VDD}$  load currents less than the current limit are used. To ensure  $A_{VDD}$  stability, the IC should be operated at the maximum desired current and then the transient load response of  $A_{VDD}$  should be used to determine the maximum value of  $R_{INT}$ .

### Operation of the DELB Output Function

An open drain DELB output is provided to allow the boost output voltage, developed at  $C_2$  (see application diagram), to be delayed via an external switch (Q3) to a time after the  $V_{BOOST}$  supply and negative  $V_{OFF}$  charge pump supply have achieved regulation during the start-up sequence shown in Figure 21. This then allows the  $A_{VDD}$  and  $V_{ON}$  supplies to start-up from 0V instead of the normal offset voltage of  $V_{IN} - V_{DIODE}$  ( $D_1$ ) if Q3 were not present.

When DELB is activated by the start-up sequencer, it sinks 50 $\mu$ A allowing a controlled turn-on of Q3 and charge-up of  $C_9$ .  $C_{16}$  can be used to control the turn-on time of Q3 to reduce inrush current into  $C_9$ . The potential divider formed by  $R_9$  and  $R_8$  can be used to limit the  $V_{GS}$  voltage of Q3 if required by the voltage rating of this device. When the voltage at DELB falls to less than 0.6V, the sink current is increased to ~1.2mA to firmly pull DELB to 0V.

The voltage at DELB is monitored by the fault protection circuit so that if the initial 50 $\mu$ A sink current fails to pull DELB below ~0.6V after the start-up sequencing has completed, then a fault condition will be detected and a fault time-out ramp will be initiated on the  $C_{DEL}$  capacitor ( $C_7$ ).

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

The ISL97522 includes two independent linear-regulator controllers, in which one is a positive output voltage ( $V_{ON}$ ), and one is negative. The  $V_{ON}$  and  $V_{OFF}$  linear-regulator

controller function diagrams are shown in Figures 17, and 18, respectively.

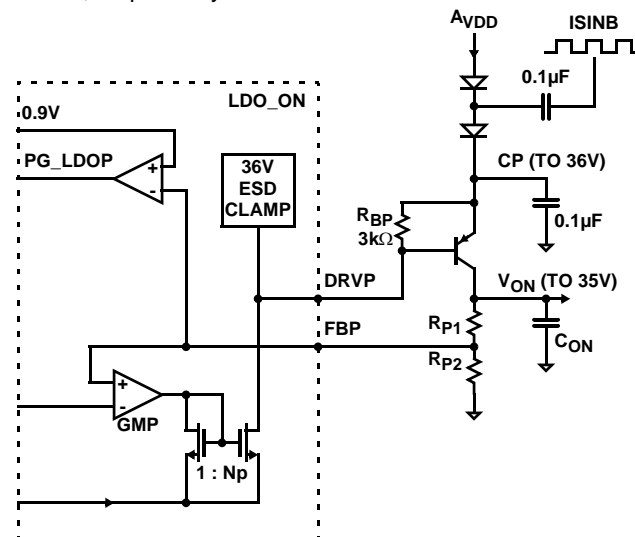


FIGURE 17.  $V_{ON}$  FUNCTION BLOCK DIAGRAM

### Calculation of the Linear Regulator Base-Emitter Resistors ( $R_{BP}$ 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  $V_{ON}$  linear regulator. If a Fairchild MMBT3906 PNP transistor is used as the external pass transistor, Q11 in the application diagram, then for a maximum  $V_{ON}$  operating requirement of 50mA the data sheet indicates  $H_{FE\_min} = 30$ .

The base-emitter saturation voltage is:  $V_{be\_max} = 0.7$ V.

For the ISL97522, the minimum drive current is:

$$I_{DRVP\_min} = 2\text{mA}$$

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

$$R_{BP\_min} = V_{BE\_max} / (I_{DRVP\_min} - I_c / H_{fe\_min}) = 0.7\text{V} / (2\text{mA} - 50\text{mA} / 30) = 2.1\text{k}\Omega$$

This is the minimum value that can be used - so, we now choose a convenient value greater than this minimum value; say 3K $\Omega$ . Larger values may be used to reduce quiescent current, however, regulation may be adversely affected, by supply noise if  $R_{BP}$  is made too high in value.

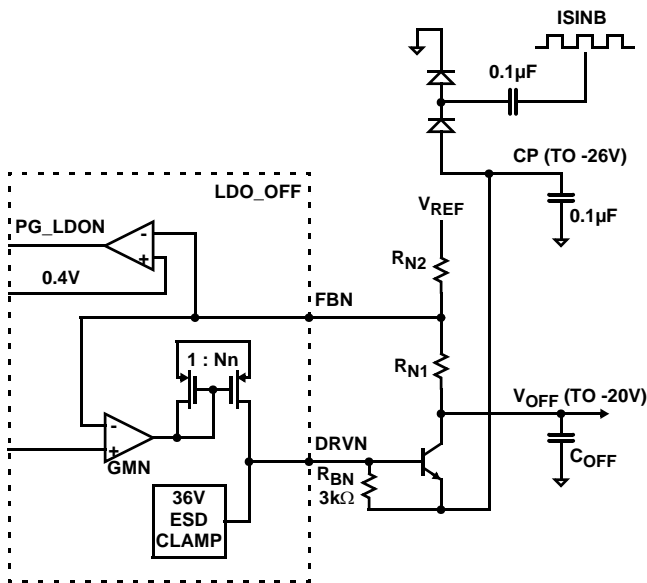


FIGURE 18.  $V_{OFF}$  FUNCTION BLOCK DIAGRAM

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 switch node (LXB) of the  $A_{VDD}$  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 5mA output current, which is sufficient for up to 50mA or more output current under the low dropout condition (forced beta of 10). Typical  $V_{ON}$  voltage supported by the ISL97522 ranges from +15V to +36V. A fault comparator is also included for monitoring the output voltage. The undervoltage threshold is set at 16.7% 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 switch node (LXB) of the  $A_{VDD}$  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 5mA output current, which is sufficient for up to 50mA or more output current under the low dropout condition (forced beta of 10). Typical  $V_{OFF}$  voltage supported by the ISL97522 ranges from -5V to -25V. A fault comparator is also included for monitoring the output voltage. The undervoltage threshold is set at 20% above the 1.0V reference level. Set-Up LDOs Output Voltage.

### Set-Up LDOs Output Voltage

Refer to Typical Application Diagram, the output voltages of  $V_{ON}$ ,  $V_{OFF}$ , and  $V_{LOGIC}$  are determined by Equations 11 and 12:

$$V_{ON} = V_{FBP} \times \left( 1 + \frac{R_{12}}{R_{11}} \right) \quad (\text{EQ. 11})$$

$$V_{OFF} = V_{FBN} + \frac{R_{22}}{R_{21}} \times (V_{FBN} - V_{REF}) \quad (\text{EQ. 12})$$

### Charge Pump

To generate an output voltage higher than  $A_{VDD}$ , 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:

$$N_{\text{POSITIVE}} \geq \frac{V_{\text{OUT}} + V_{\text{CE}} - V_{\text{INPUT}}}{V_{\text{INPUT}} - 2 \times V_{\text{F}}} \quad (\text{EQ. 13})$$

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:

$$N_{\text{NEGATIVE}} \geq \frac{|V_{\text{OUTPUT}}| + V_{\text{CE}}}{V_{\text{INPUT}} - 2 \times V_{\text{F}}} \quad (\text{EQ. 14})$$

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 Equation 15.

$$C_{\text{OUT}} \geq \frac{I_{\text{OUT}}}{2 \times V_{\text{RIPPLE}} \times f_{\text{OSC}}} \quad (\text{EQ. 15})$$

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

### High Charge Pump Output Voltage (>36V) Applications

In the applications where the charge pump output voltage is over 36V, an external npn transistor need to be inserted into between DRVP pin and base of pass transistor Q3 as shown in Figure 19; or the linear regulator can control only one stage charge pump and regulate the final charge pump output as shown in Figure 20.

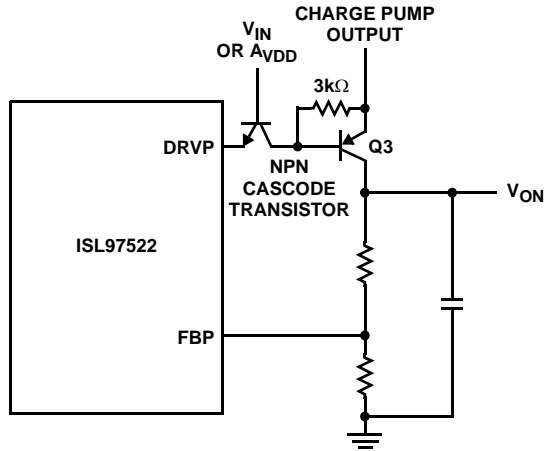


FIGURE 19. CASCODE NPN TRANSISTOR CONFIGURATION FOR HIGH CHARGE PUMP OUTPUT VOLTAGE (>36V)

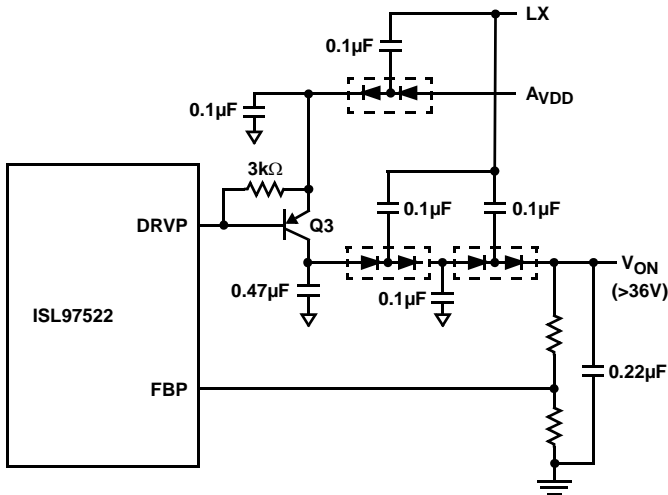


FIGURE 20. THE LINEAR REGULATOR CONTROLS ONE STAGE OF CHARGE PUMP

### Discontinuous/Continuous Boost Operation and its Effect on the Charge Pumps

The ISL97522  $V_{ON}$  and  $V_{OFF}$  architecture uses LX switching edges to drive diode charge pumps from which LDO regulators generate the  $V_{ON}$  and  $V_{OFF}$  supplies. It can be appreciated that should a regular supply of LX switching edges be interrupted, for example during discontinuous operation at light  $A_{VDD}$  boost load currents, then this may affect the performance of  $V_{ON}$  and  $V_{OFF}$  regulation - depending on their exact loading conditions at the time.

To optimize  $V_{ON}/V_{OFF}$  regulation, the boundary of discontinuous/continuous operation of the boost converter can be adjusted, by suitable choice of inductor given  $V_{IN}$ ,  $V_{OUT}$ , switching frequency and the  $A_{VDD}$  current loading, to be in continuous operation.

The following equation gives the boundary between discontinuous and continuous boost operation. For continuous operation (LX switching every clock cycle) we require that:

$$I(A_{VDD\_load}) > D \cdot (1-D) \cdot V_{IN} / (2 \cdot L \cdot F_{OSC})$$

where the duty cycle,  $D = (A_{VDD} - V_{IN}) / A_{VDD}$

For example, with  $V_{IN} = 5V$ ,  $F_{OSC} = 1.0MHz$  and  $A_{VDD} = 12V$  we find continuous operation of the boost converter can be guaranteed for:

$$L = 10\mu H \text{ and } I(A_{VDD}) > 61mA$$

$$L = 6.8\mu H \text{ and } I(A_{VDD}) > 89mA$$

$$L = 3.3\mu H \text{ and } I(A_{VDD}) > 184mA$$

### Buck Converter

The buck converter is the step down converter, which supplies the current to the logic circuit of the LCD system. In the continuous current mode, the relationship between input voltage and output voltage is as following:

$$\frac{V_{LOGIC}}{V_{IN}} = D \quad (\text{EQ. 16})$$

Where  $D$  is the duty cycle of the switching MOSFET. Because  $D$  is always less than 1, the output voltage of buck converter is lower than input voltage.

### The Feedback Resistors

The buck converter output voltage is determined by the following equation:

$$V_{LOGIC} = \frac{R_{12} + R_{13}}{R_{13}} \times V_{FBL} \quad (\text{EQ. 17})$$

Where  $R_{12}$  and  $R_{13}$  are the feedback resistors of buck converter to set the output 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  $300\Omega$  is recommended.

### Buck Converter Input Capacitor

The capacitor should support the maximum AC RMS current which happens when  $D = 0.5$  and maximum output current.

$$I_{acrms}(C_{IN}) = \sqrt{D \cdot (1-D)} \cdot I_O \quad (\text{EQ. 18})$$

Where  $I_O$  is the output current of the buck converter.

### Buck Inductor

An inductor value in the range 3.3-10 $\mu$ H is recommended for the buck converter. Besides the inductance, the DC resistance and the saturation current should also be considered when choosing buck inductor. Low DC resistance can help maintain high efficiency, and the saturation current rating should be at least maximum output current plus half of ripple current.

### Buck MOSFET

The principle to select Buck MOSFET is similar to that of Boost. The voltage of stress of buck converter should be maximum input voltage plus reasonable margin, and the current rating should be over the maximum output current. The  $r_{DS(ON)}$  of this MOSFET should be in the range from 20m $\Omega$  to 50m $\Omega$ .

### Rectifier Diode (Buck Converter)

A Schottky diode is recommended due to fast recovery and low forward voltage. The reverse voltage rating should be higher than the maximum input voltage. The average current should be as the following equation,

$$I_{AVG} = (1 - D) * I_O \quad (\text{EQ. 19})$$

Where  $I_O$  is the output current of buck converter.

### Output Capacitor (Buck Converter)

Four 10 $\mu$ F or two 22 $\mu$ F ceramic capacitors are recommended for this part. The overshoot and undershoot will be reduced with more capacitance, but the recovery time will be longer.

### PI Loop Compensation (Buck Converter)

The buck converter of ISL97522 can be compensated by a RC network connected from CINTL pin to ground. C27 = 4.7nF and R17= 2k RC network is used in the demo board. The larger value resistor can lower the transient overshoot, however, at the expense of stability of the loop.

The stability can be optimized in a similar manner to that described in the section on "PI Loop Compensation (Boost Converter)".

### Bootstrap Capacitor (C28)

This capacitor is used to provide the supply to the high driver circuitry for the buck MOSFET. The bootstrap supply is formed by an internal diode and capacitor combination. A 1 $\mu$ F is recommended for ISL97522. A low value capacitor can lead to overcharging and in turn damage the part.

If the load is too light, the on-time of the low side diode may be insufficient to replenish the bootstrap capacitor voltage. In this case, if  $V_{IN} - V_{BUCK} < 1.5V$ , the internal MOSFET pull-up device may be unable to turn-on until  $V_{LOGIC}$  falls. Hence, there is a minimum load requirement in this case. The

minimum load can be adjusted by the feedback resistors to FBL.

The bootstrap capacitor can only be charged when the higher side MOSFET is off. If the load is too light which can not make the on time of the low side diode be sufficient to replenish the boot strap capacitor, the MOSFET can't turn on. Hence there is minimum load requirement to charge the bootstrap capacitor properly.

### Start-Up Sequence

Figure 21 shows a detailed start-up sequence waveform. For a successful power-up, there should be six peaks at  $V_{CDLY}$ . 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 ( $V_{IN}$ ) exceeds 2.5V, an internal current source starts to charge  $C_{DLY}$  to an upper threshold using a fast ramp followed by a slow ramp. If EN is low at this point, the  $C_{DLY}$  ramp will be delayed until EN goes high.

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

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

During the second ramp, the device checks the status of  $V_{REF}$  and over temperature.

Initially the boost is not enabled so  $V_{BOOST}$  rises to  $V_{IN} - V_{DIODE}$  through the output diode. Hence, there is a step at  $V_{BOOST}$  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  $A_{VDD}$ .

$V_{BOOST}$  soft-starts at the beginning of the third ramp. The soft-start ramp depends on the value of the  $C_{DLY}$  capacitor. For  $C_{DLY}$  of 220nF, the soft-start time is ~2ms.

$V_{OFF}$  turns on at the start of the fourth peak. At the fifth peak, the open drain o/p DELB goes low to turn on the external PMOS Q3 to generate a delayed  $V_{BOOST}$  output.

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

Vlogic's start-up is controlled by ENL. When ENL is L, Vlogic is off, and when ENL is H,  $V_{LOGIC}$  is on.



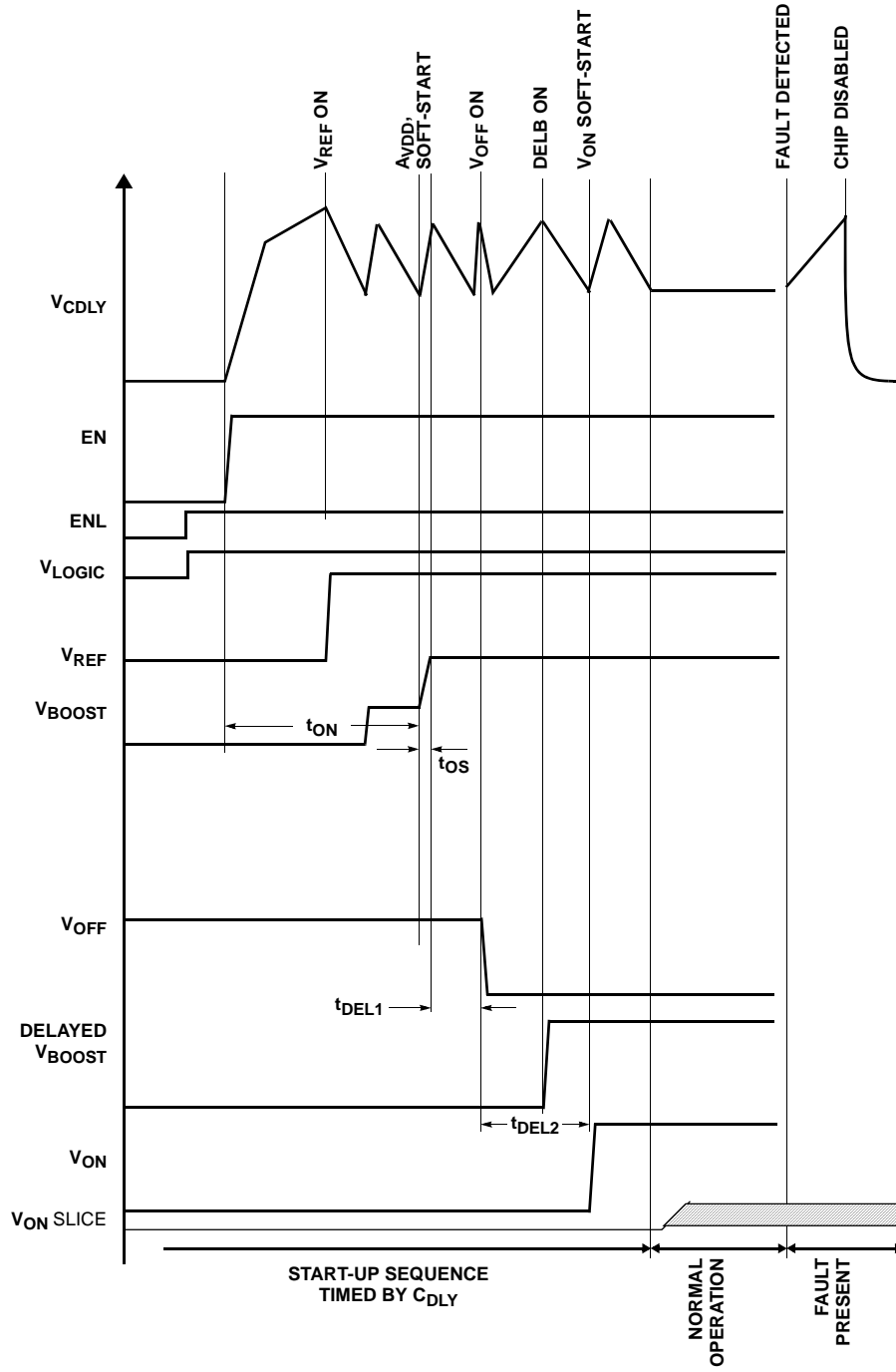


FIGURE 21. ISL97522 START-UP SEQUENCE

### Fault Protection

During the startup sequence, prior to BOOST soft-start,  $V_{REF}$  is checked to be within  $\pm 20\%$  of its final value and the device temperature is checked. If either of these are not within the expected range, the part is disabled until the power is recycled or EN is toggled.

If  $C_{DELAY}$  is shorted low, then the sequence will not start, while if  $C_{DELAY}$  is shorted H, the first down ramp will not occur and the sequence will not complete.

Once the start-up sequence is completed, the chip continuously monitors  $C_{DLY}$ , DELB, FBP, FBL, FBN,  $V_{REF}$  and FBB for faults. During this time, the voltage on the  $C_{DLY}$  capacitor remains at 1.15V until either a fault is detected, or the EN pin is pulled low.

A fault on  $C_{DELAY}$ ,  $V_{REF}$  or temperature will shut down the chip immediately. If a fault on any other output is detected,  $C_{DELAY}$  will ramp up linearly with a 5 $\mu$ A (typical) current to the upper fault threshold (typically 2.4V), at which point the chip is disabled until the power is recycled or EN is toggled. If the fault condition is removed prior to the end of the ramp, the voltage on the  $C_{DLY}$  capacitor returns to 1.15V.

Typical fault thresholds for FBP, FBL, FBN and FBB are included in the tables. DELB fault threshold is typically 0.6V.

$C_{INTB}$  and  $C_{INTL}$  have an internal current-limited clamp to keep the voltage within their normal ranges. If they are shorted low, the regulators will attempt to regulate to 0V.

If any of the regulated outputs ( $AVDD$ ,  $V_{ON}$ ,  $V_{OFF}$  or  $V_{LOGIC}$ ) are driven above their target levels the drive circuitry will switch off until the output returns to its expected value.

If  $AVDD$  and  $V_{LOGIC}$  are excessively loaded, the current limit will prevent damage to the chip. While in current limit, the part acts like a current source and the regulated output will drop. If the output drops below the fault threshold, a ramp will be initiated on  $C_{DELAY}$  and, provided that the fault is sustained, the chip will be disabled on completion of the ramp.

In some circumstances, (depending on ambient temperature and thermal design of the board), continuous operation at current limit may result in the over-temperature threshold being exceeded, which will cause the part to disable immediately.

All I/O also have ESD protection, which in many cases will also provide overvoltage protection, relative to either ground or  $V_{DD}$ . However, these will not generally operate unless abs max ratings are exceeded.

### Component Selection for Start-Up Sequencing and Fault Protection

The  $C_{REF}$  capacitor is typically set at 220nF and is required to stabilize the  $V_{REF}$  output. The range of  $C_{REF}$  is from 22nF to 1 $\mu$ F and should not be more than five times the capacitor on  $C_{DEL}$  to ensure correct start-up operation.

The  $C_{DEL}$  capacitor is typically 220nF and has a usable range from 47nF minimum to several microfarads - only limited by the leakage in the capacitor reaching  $\mu$ A levels.

$C_{DEL}$  should be at least 1/5 of the value of  $C_{REF}$  (See above). Note with 220nF on  $C_{DEL}$  the fault time-out will be typically 50ms and the use of a larger/smaller value will vary this time proportionally (e.g. 1 $\mu$ F will give a fault time-out period of typically 230ms).

### Fault Sequencing

The ISL97522 has an advanced fault detection system which protects the IC from both adjacent pin shorts during operation and shorts on the output supplies.

A high quality layout/design of the PCB, in respect of grounding quality and decoupling is necessary to avoid falsely triggering the fault detection scheme - especially during start-up. The user is directed to the layout guidelines and component selection sections to avoid problems during initial evaluation and prototype PCB generation.

### Over-Temperature Protection

An internal temperature sensor continuously monitors the die temperature. In the event that the die temperature exceeds the thermal trip point of 140°C, the device will shut down.

### 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.

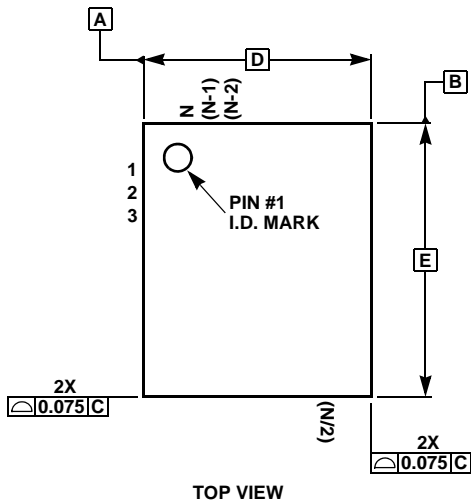
There are some general guidelines for layout:

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  $V_{REF}$ ,  $V_{DC}$  and  $V_{DCP}$  bypass capacitors close to the pins.
3. Minimize the length of traces carrying fast signals and high current.
4. All feedback networks 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 near the main decoupling capacitors.

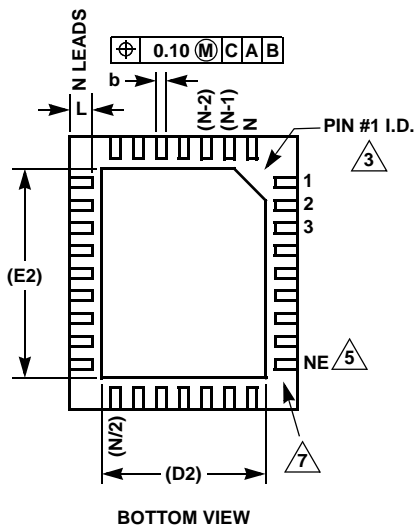
6. The exposed die plate, on the underneath of the package, should be soldered to an equivalent area of metal on the PCB. This contact area should have multiple via connections to the back of the PCB as well as connections to intermediate PCB layers, if available, to maximize thermal dissipation away from the IC.
7. To minimize the thermal resistance of the package when soldered to a multi-layer PCB, the amount of copper track and ground plane area connected to the exposed die plate should be maximized and spread out as far as possible from the IC. The bottom and top PCB areas especially should be maximized to allow thermal dissipation to the surrounding air.
8. A signal ground plane, separate from the power ground plane and connected to the power ground pins only at the exposed die plate, should be used for ground return connections for feedback resistor networks ( $R_1$ ,  $R_{11}$ ,  $R_{41}$ ) and the  $V_{REF}$  capacitor,  $C_{25}$ , the  $C_{DELAY}$  capacitor  $C_7$  and the integrator capacitor  $C_{30}$ ,  $C_{27}$ .
9. Minimize feedback input track lengths to avoid switching noise pick-up.

**Quad Flat No-Lead Plastic Package (QFN)  
Micro Lead Frame Plastic Package (MLFP)**

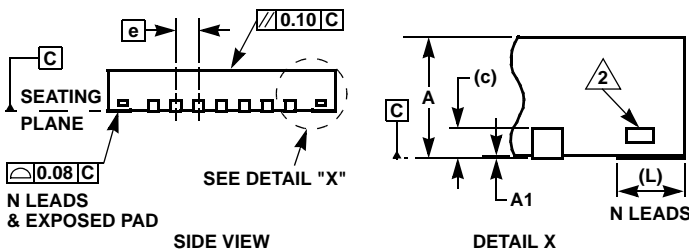
**L38.5x7B** (One of 10 Packages in MDP0046)  
**38 LEAD QUAD FLAT NO-LEAD PLASTIC PACKAGE  
(COMPLIANT TO JEDEC MO-220)**



TOP VIEW



BOTTOM VIEW



SIDE VIEW

DETAIL X

| SYMBOL | MILLIMETERS |         |      | NOTES |
|--------|-------------|---------|------|-------|
|        | MIN         | NOMINAL | MAX  |       |
| A      | 0.80        | 0.90    | 1.00 | -     |
| A1     | 0.00        | 0.02    | 0.05 | -     |
| D      | 5.00 BSC    |         |      | -     |
| D2     | 3.50 REF    |         |      | -     |
| E      | 7.00 BSC    |         |      | -     |
| E2     | 5.50 REF    |         |      | -     |
| L      | 0.35        | 0.40    | 0.45 | -     |
| b      | 0.23        | 0.25    | 0.27 | -     |
| c      | 0.20 REF    |         |      | -     |
| e      | 0.50 BSC    |         |      | -     |
| N      | 38 REF      |         |      | 4     |
| ND     | 7 REF       |         |      | 6     |
| NE     | 12 REF      |         |      | 5     |

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NOTES:

1. Dimensioning and tolerancing per ASME Y14.5M-1994.
2. Tiebar view shown is a non-functional feature.
3. Bottom-side pin #1 I.D. is a diepad chamfer as shown.
4. N is the total number of terminals on the device.
5. NE is the number of terminals on the "E" side of the package (or Y-direction).
6. ND is the number of terminals on the "D" side of the package (or X-direction). ND = (N/2)-NE.
7. Inward end of terminal may be square or circular in shape with radius (b/2) as shown.

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