**Title:** Safety Board +/- 1V Reference Analysis
**Date:** 4/4/08
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Description: When testing the Safety Boards, it was found that the +/-1 V references were not +/- 1V. This was due to the current draw of the references. Even though it was less than 100 µA, the voltage divider had large enough resistors that the voltage drop was significant. To correct this problem, smaller value resistors should be placed in the voltage divider so that any unexpected or increased loading will have less of an effect on the reference. The +/-1 V references are used on overspeed and overcurrent comparators, therefore extremely tight tolerances are not required. +/- 10% is sufficient, however tighter tolerances are likely possible. The exact value of the reference isn't important as long as the magnitude of the positve and minus refernces are equal. However, a magnitude of around 1V is more flexible vs. using the 2.5V reference directly. This is mainly due to the overcurrent comparators. If 2.5V was used as a reference, the minimum overcurrent would be approximately 11.66 A/V * 2.5V = 29.15A. For overspeed, 2.5V = 1352 arcsec/s, which means 2.5V is acceptable for overspeed. However, to keep flexibility for the overcurrent, 1V will still be used.

UPDATE: Due to the comparators attempting to pull the CPLD down to -15V and the subsequent fix, the voltage references have been changed to less than 0.5V. 0.44V was chosen for convenience.

Original Saftey Board Circuit

Reverse Characteristics
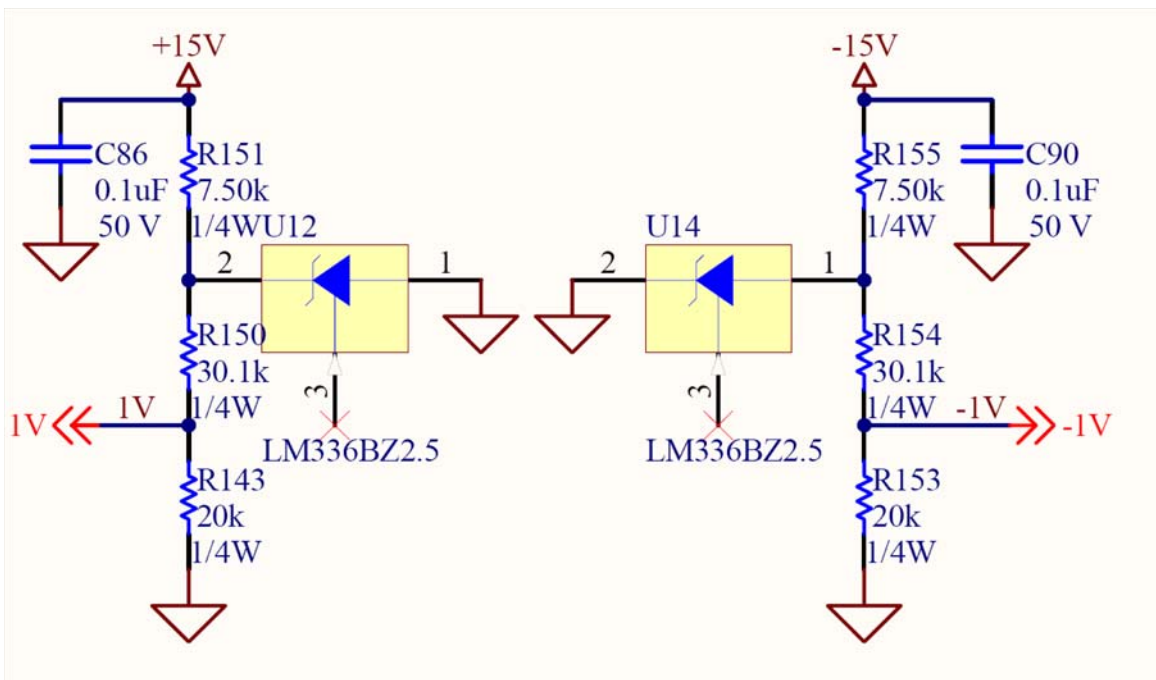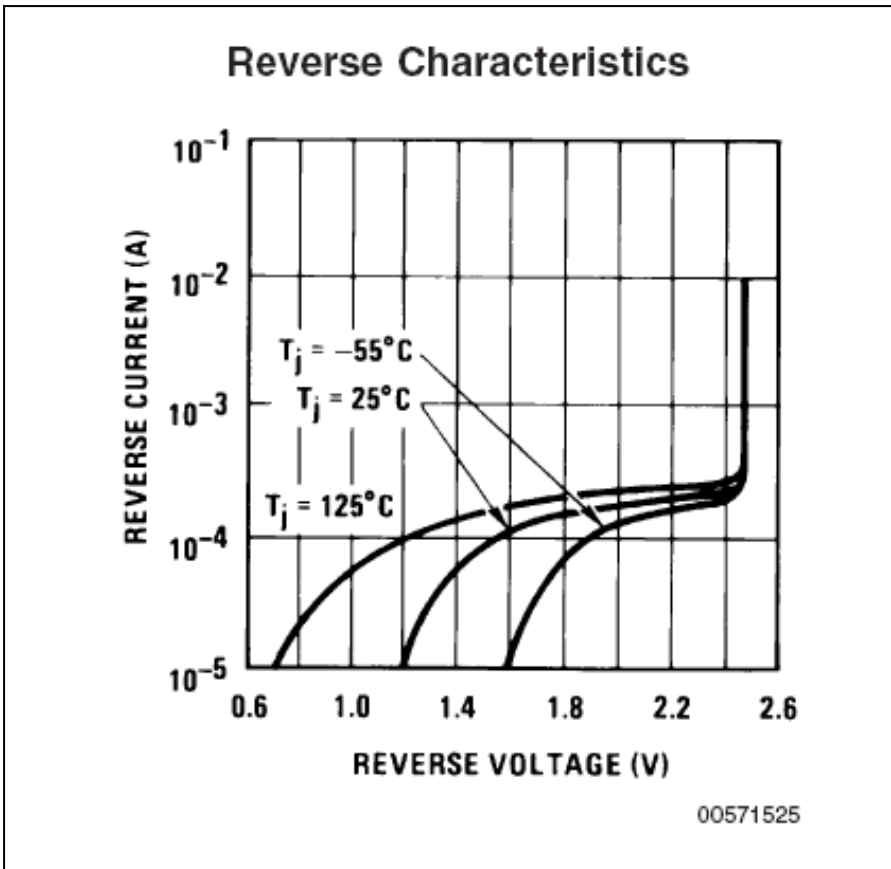
LM336 V-I Curve

Directions

Fill in <mark>yellow highlighted</mark> **regions.**

Values of importance are highlighted in <mark>aqua.</mark>

Variables

$I\_draw\_ref\_max := 100\mu A$ **Current Draw of Reference Loads (comparators)**

$I\_draw\_ref\_min := 1\mu A$ **Current Draw of Reference Loads (comparators)**

$V\_ref\_diode := 2.5V$ **Diode Reference Voltage**

$I\_ref\_diode\_min\_desired := 1mA$ **Desired min diode current draw (see graph above)**

$I\_ref\_diode\_SPEC\_max := 15mA$ **Maximum current SPEC.**

$I\_divider\_desired := 4.5mA$ **Desired approximate divider current draw**

$V\_supply := 15V$ **Supply voltage**

$Vref := 0.44V$ **Final reference voltage**

Analysis section

Calculate the total divider value based on how much current should go through the branch:

$$Divider\_total := \frac{V\_ref\_diode}{I\_divider\_desired}$$

Divider_total = $0.556 \cdot k\Omega$

Assuming an average for the reference current draw and knowing the sum of the divider, the values of the two resistors can be determined:

R150 := 500Ω

R143 := 100Ω

Given

$$\frac{(V\_ref\_diode - Vref)}{R150} - \frac{(I\_draw\_ref\_max + I\_draw\_ref\_min)}{2} - \frac{Vref}{R143} = 0$$

$$R150 + R143 = Divider\_total$$

$$Find(R150, R143) = \begin{pmatrix} 456.867 \\ 98.689 \end{pmatrix} \Omega$$

Select the final, standard values below. The values above are starting points and the final values should be lower.

R150_final := 475Ω

R143_final := 100Ω

VREF results:

Vref_solve := 0

Given

$$\left(\frac{V\_ref\_diode - Vref\_solve}{R150\_final}\right) - \frac{(I\_draw\_ref\_max + I\_draw\_ref\_min)}{2} - \frac{Vref\_solve}{R143\_final} = 0$$

Vref_nom := Find(Vref_solve) = 0.431 V

Given

$$\left(\frac{V\_ref\_diode - Vref\_solve}{R150\_final}\right) - I\_draw\_ref\_min - \frac{Vref\_solve}{R143\_final} = 0$$

Vref_max := Find(Vref_solve) = 0.435 V

Given

$$\left(\frac{V\_ref\_diode - Vref\_solve}{R150\_final}\right) - I\_draw\_ref\_max - \frac{Vref\_solve}{R143\_final} = 0$$

$\text{Vref\_min} := \text{Find}(\text{Vref\_solve}) = 0.427 \text{ V}$

$$\text{R150\_power\_approx} := \frac{(\text{V\_ref\_diode} - \text{Vref})^2}{\text{R150\_final}}$$

$\text{R150\_power\_approx} = 8.934 \cdot \text{mW}$

$$\text{R143\_power\_approx} := \frac{\text{Vref}^2}{\text{R143\_final}}$$

$\text{R143\_power\_approx} = 1.936 \cdot \text{mW}$

Determine the maximum resistor value off the power supply.

$$\text{branch\_current\_max} := \frac{(\text{V\_ref\_diode} - \text{Vref\_min})}{\text{R150\_final}} = 4.365 \cdot \text{mA}$$

$$\text{R151\_max} := \frac{\text{V\_supply} - \text{V\_ref\_diode}}{\text{branch\_current\_max} + \text{I\_ref\_diode\_min\_desired}}$$

$\text{R151\_max} = 2.33 \cdot \text{k}\Omega$

Select a standard value less than the above resistor:

$\text{R151\_final} := 2\text{k}\Omega$

Power disippation:

$$\text{R151\_power} := \frac{\text{V\_supply}^2}{\text{R151\_final}} = 112.5 \cdot \text{mW}$$

$\text{R151\_power} < .250\text{W} = 1$ **"1" equals TRUE, "0" equals FALSE**

The total actual current is:

$$\text{total\_current} := \frac{(\text{V\_supply} - \text{V\_ref\_diode})}{\text{R151\_final}}$$

$\text{total\_current} = 6.25 \cdot \text{mA}$

Check to make sure that the reference diode is conducting current (reverse breakdown = providing a reference) and that it is greater than the desired current:

$\text{actual\_ref\_diode\_current} := \text{total\_current} - \text{branch\_current\_max} = 1.885 \cdot \text{mA}$

$\text{actual\_ref\_diode\_current} > \text{I\_ref\_diode\_min\_desired} = 1$ **"1" equals TRUE, "0" equals FALSE**

Make sure that the current is less than the maximum allowable current for the reference diode:

$\text{actual\_ref\_diode\_current} < \text{I\_ref\_diode\_SPEC\_max} = 1$ **"1" equals TRUE, "0" equals FALSE**

$$\text{actual\_ref\_diode\_current\_max} := \left[\frac{(\text{V\_supply} - \text{V\_ref\_diode})}{\text{R151\_final}} \right] - \frac{(\text{V\_ref\_diode})}{\text{R143\_final} + \text{R150\_final}} = 1.902 \cdot mA$$

$\text{actual\_ref\_diode\_current\_max} < \text{I\_ref\_diode\_SPEC\_max} = 1$ **"1" equals TRUE, "0" equals FALSE**

$$\text{ref\_diode\_current\_margin} := \frac{\text{I\_ref\_diode\_SPEC\_max}}{\text{actual\_ref\_diode\_current\_max}} - 1 = 688.571 \cdot \%$$