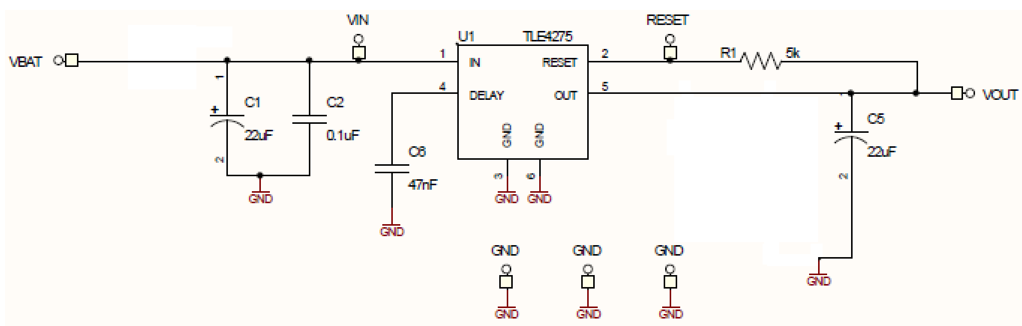
TLE4275-Q1 Low Temperature Stability

MSA Applications

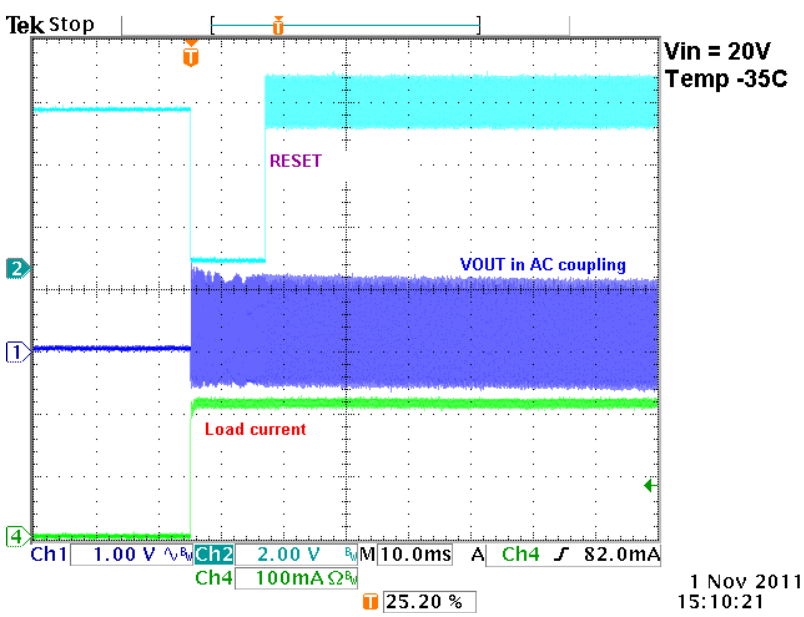
ABSTRACT

Instability at low temperature may occur in linear power supply systems using electrolytic output capacitors. This application note provides a review of the symptoms, cause and prevention. References are also provided for deeper theoretical treatment of linear regulator control stability.

Application Evaluation Circuit

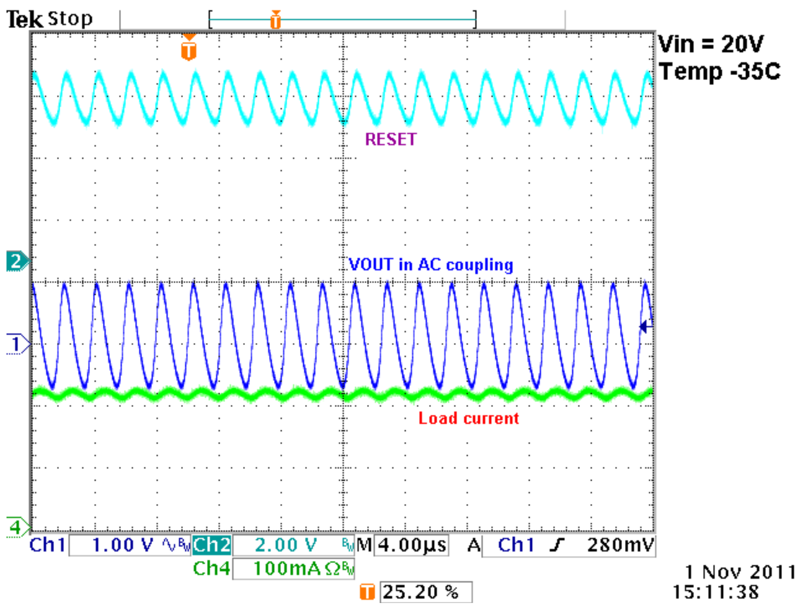


Low Temperature Instability Symptoms



Oscilloscope trace 1 (blue) shows AC coupled output voltage VOUT, trace 2 (aqua) reset pin voltage, trace 4 (green) load current. Note that voltage is not stable as device is enabled; there are large-amplitude, high-frequency oscillations.

Zoom View:

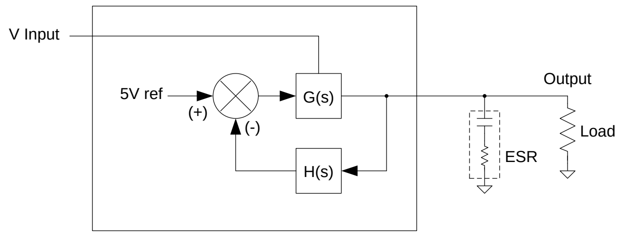


Clearly the voltage does not meet the requirements for stable, well regulated 5V output.

Oscilloscope plots are not shown, but note that at higher temperatures, the circuit does become stable, showing proper regulation and behavior as per specification.

Low Temperature Instability Cause

A linear voltage regulator system can be viewed as a classic control loop, with transfer functions defining the forward and feedback paths. The equations are not solely determined by the regulator chip; the output capacitance and load play a major role and must be accounted for.



For the most common applications, an electrolytic output capacitor is used, and the low temperature stability issue can be traced to an increase in its equivalent series resistance (ESR) at low temperature. The additional resistance introduces changes in the system transfer function which are beyond the limits of stability.

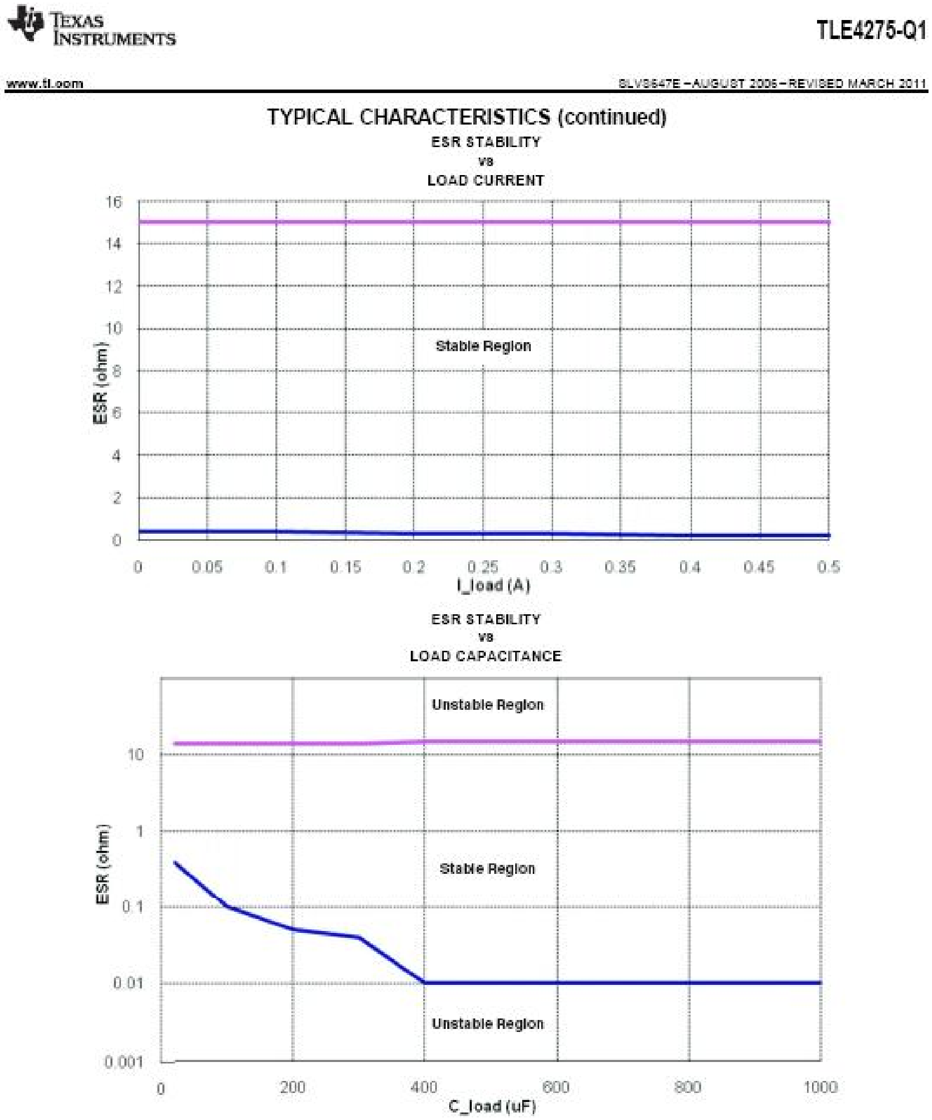
Stability analysis techniques are well known for regulator devices similar to TLE4275-Q1 and are covered by the following Application Notes:

1. *Stability Analysis of Low-Dropout Linear Regulators with a PMOS Pass Element* (SLYT194)
2. *LDO Regulator Stability Using Ceramic Output Capacitors* (SNVA167)
3. *Linear Regulators: Theory of Operation and Compensation* (SNVA020)
4. *ESR, Stability, and the LDO Regulator* (SLVA115)

Additionally, classic textbooks such as Ogata's *Modern Control Engineering,* Sedra & Smith's *Microelectronic Circuits* and Voperian's *Fast Analytical Techniques for Electrical and Electronic Circuits* can provide an in-depth theoretical background.

Low Temperature Instability Prevention

TLE4275-Q1 data sheet provides charts showing the load, capacitance and ESR limits for stable operation.



System designs must ensure their capacitor choice meets the published ESR limits for TLE4275 stability. When ceramic capacitors are used, a series resistor may be required to meet resistance minimum value. As an example, a 22 µF ceramic capacitor with a .33-Ω series resistor will meet stability requirements over full temperature range.

When electrolytic capacitors are used, the most common issue is low temperature ESR rising above maximum limits. Unfortunately, obtaining detailed specifications on electrolytic capacitors at low temperature can be difficult. Systems designers often must rely on empirical testing and experience.

Suggested Electrolytic Capacitor Selection

After testing a number of different capacitor types and values from several vendors, it is suggested to use at least a 68µF output filter capacitor or greater to ensure stability over the full device operating temperature range.

Below are scope shots of response to a pulsed load with system temperature set to -40°C. The first plot used 68 µF, 16V Nichicon UD series electrolytic capacitor. The second used a 68 µF, 16V Panasonic EEE-FT series electrolytic capacitor. Note the stable response to the load.

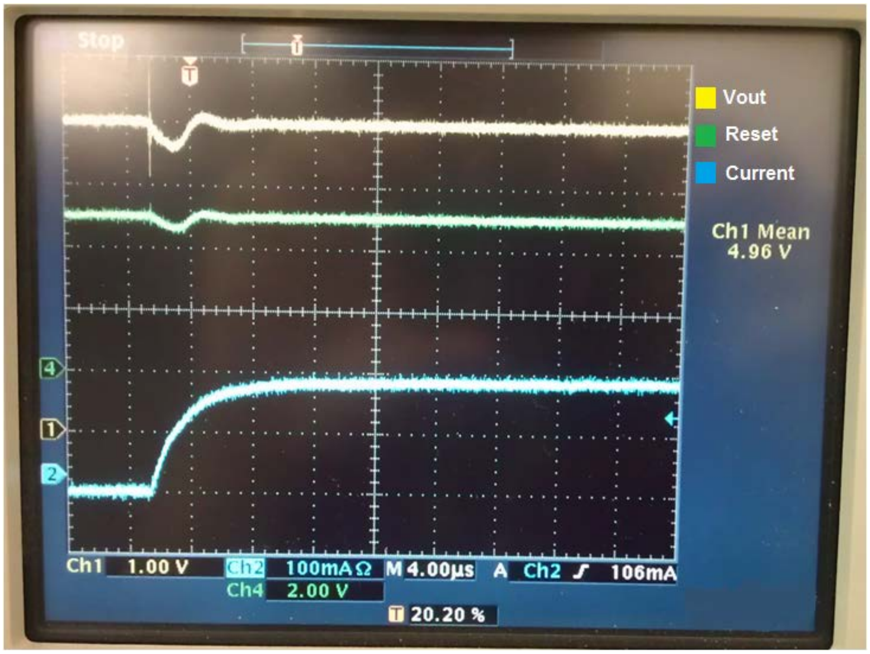


Figure 1. 68µF/16V Nichicon UD Series Cap at V_{IN} = 20V

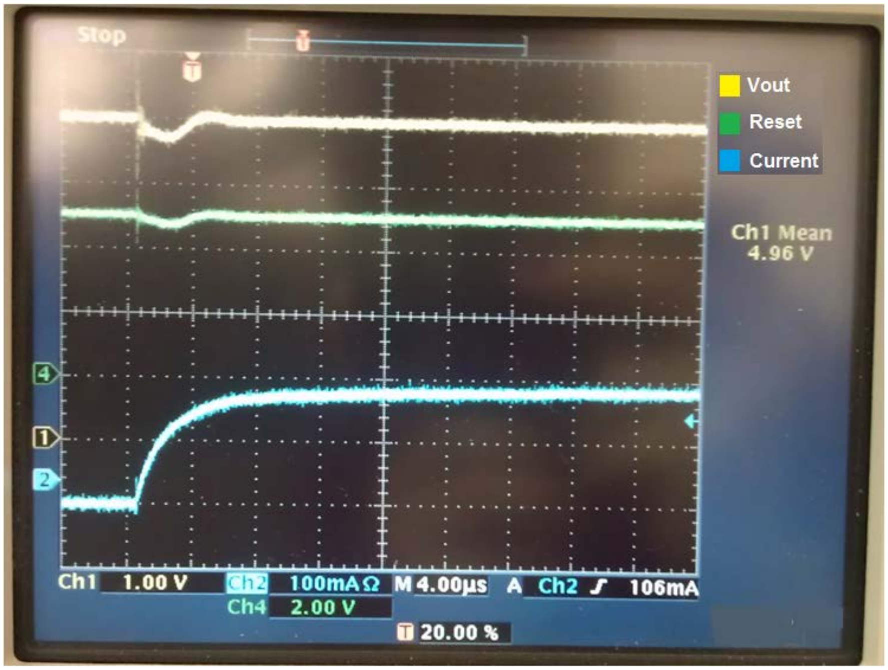


Figure 2. 68µF/16V Panasonic EEE-FT Series Cap at V_{IN} = 20V