# Design of Linear Voltage Regulators

Dipl. Ing. Ricardo Erckert

Ingenieurbüro Erckert
Harthauserstraße 36 b
83043 Bad Aibling

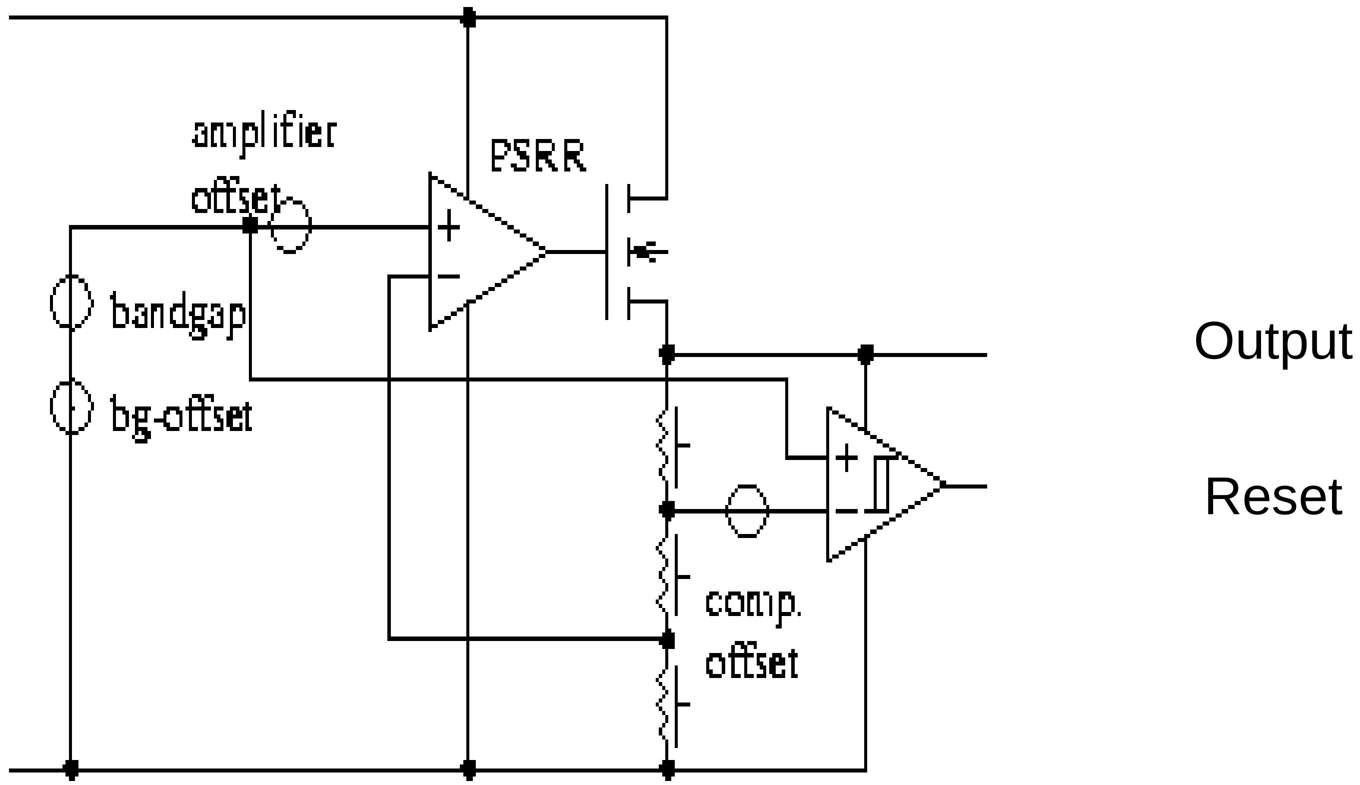
Tel.: 08061 392208
Mobil: 0179 5308708
email: re@erckert−ibe.de

# How do tolerances of voltage regulator and reset generator comply with the application?

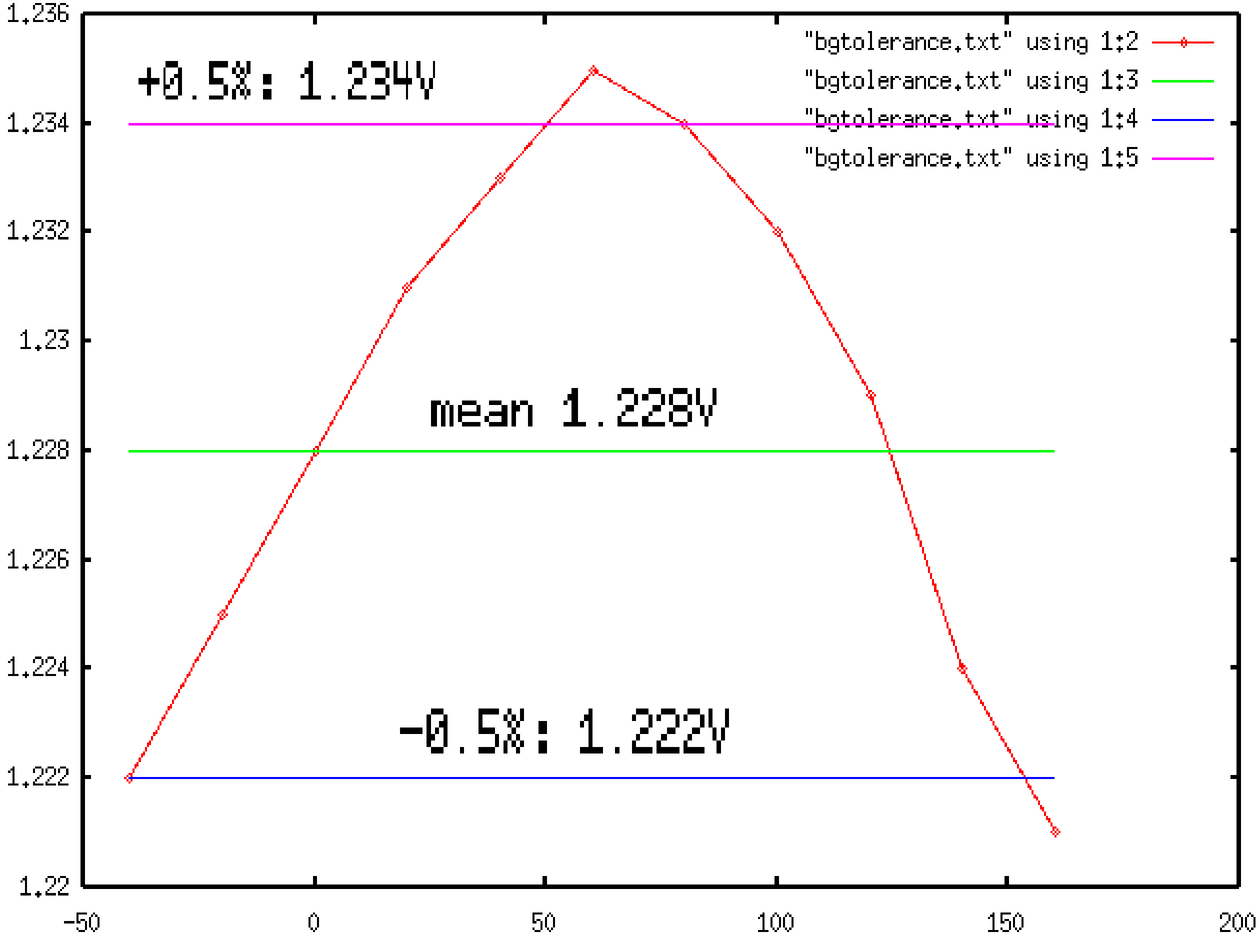
- Your application needs a certain minimum supply voltage.
- The lowest possible reset threshold must be above this application limitation.
- The reset generator has a hysteresis. The worst case upper threshold must be below the lowest possible regulator output voltage.
- The regulator accuracy depends on bandgap tolerance, trimming, load rejection, supply rejection and temperature coefficients
- You need margin for dynamic effects

The following presentation gives you an idea how to set up a reasonable voltage regulator specification

# A typical Voltage Regulator Topology including some Error Sources



# A Good Bandgap's Temperature Behaviour:





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## Load Rejection:

Changing load currents require different output voltages of the regulator driving the power transistor gate. As a rule of thumb the static load rejection calculates as :

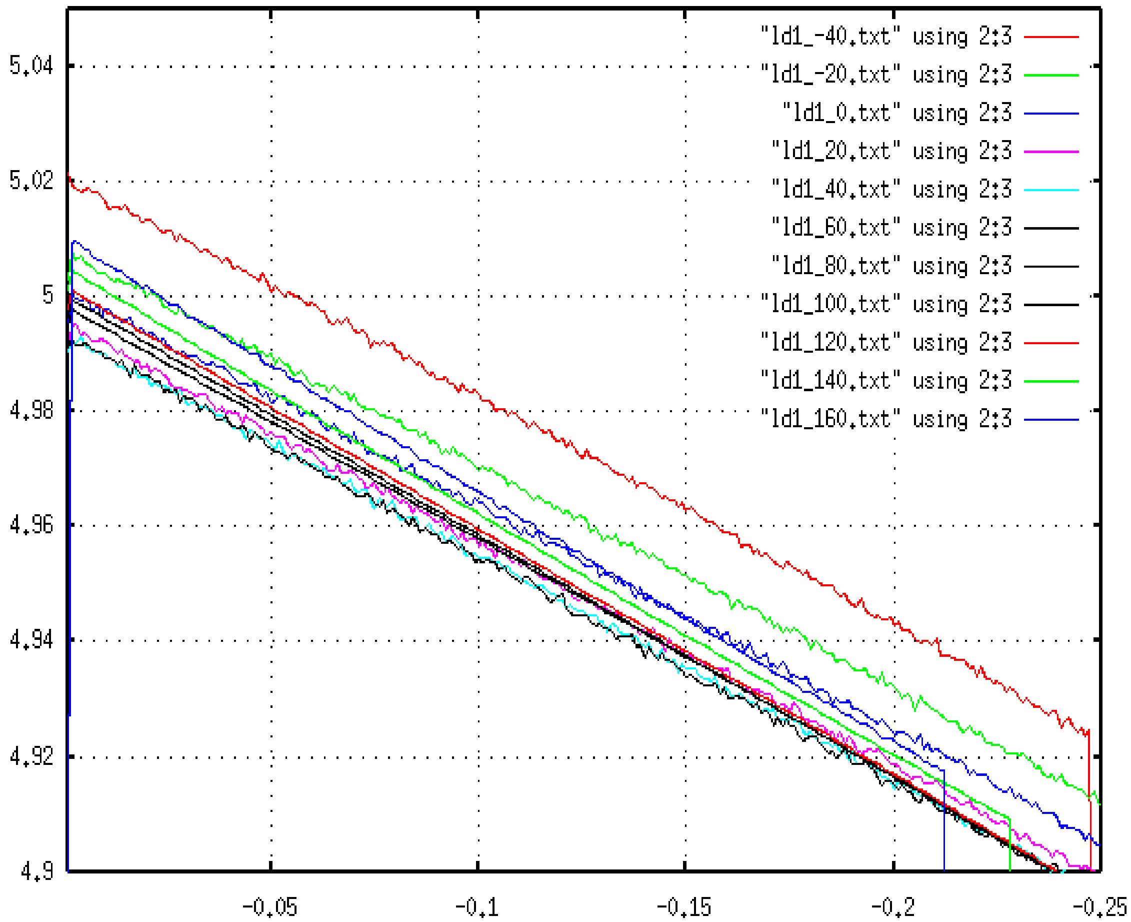
$$\Delta V / \Delta I = 1 /(g_m * gain)$$

Or: If your load current changes by $\Delta I$ your output voltage changes by $\Delta V$

$$\Delta V = \Delta I / (g_m * gain)$$

(Example: $g_m$=0.025A/V, $\Delta I$=0.1A, gain=100 −> $\Delta V$=40mV)

# A Practical Example of Load Rejection





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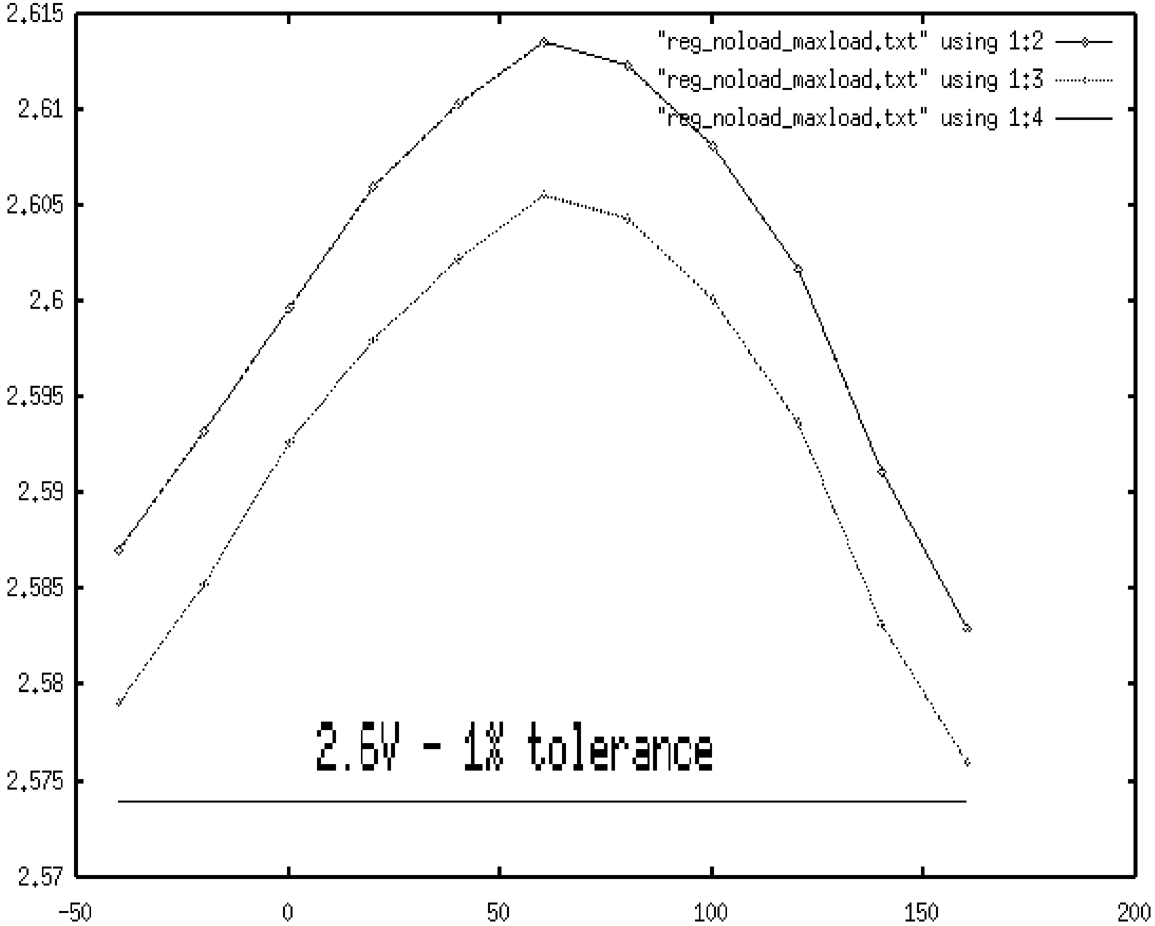
# Regulator w.r.t Temperature at minimum load and maximum load





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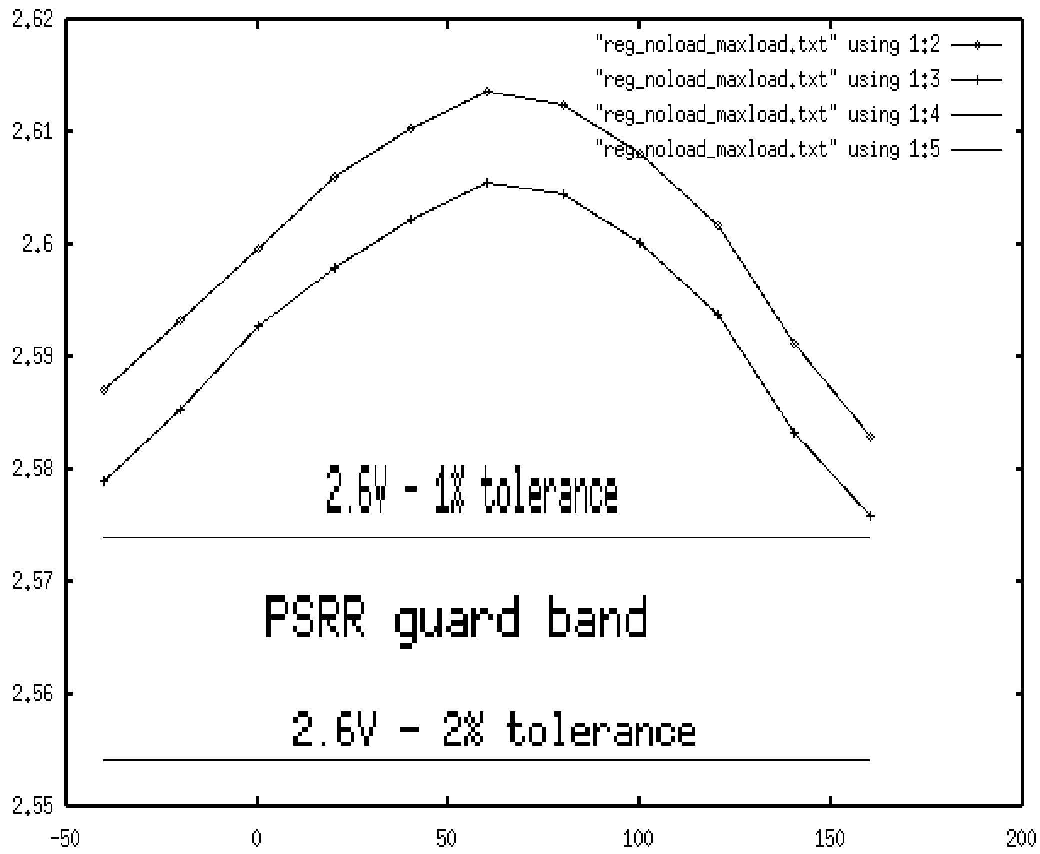
# Supply Rejection

Besides load current supply voltage influences the output voltage of a regulator. Supply rejection depends on early voltages of the transistors used, the amplifier gain and whether cascodes are used. Good regulators have DC supply rejections of 60dB to 70dB. Assuming a 20V supply voltage change 20mV output voltage change must be expected.



# Bandgap Tolerances

Bandgap accuracy analog process (untrimmed): +−4%

Bandgap accuracy digital process (untrimmed): +−6%

Theoretically you can trimm to almost any accuracy you like. But packaging with it's mechanical stress will change your parameters again. Packaging can change your bandgap again by 0.2%. So a least significant trim bit below 0.1% doesn't make sense anymore.

Trimmed bandgap after packaging: +−0.3%

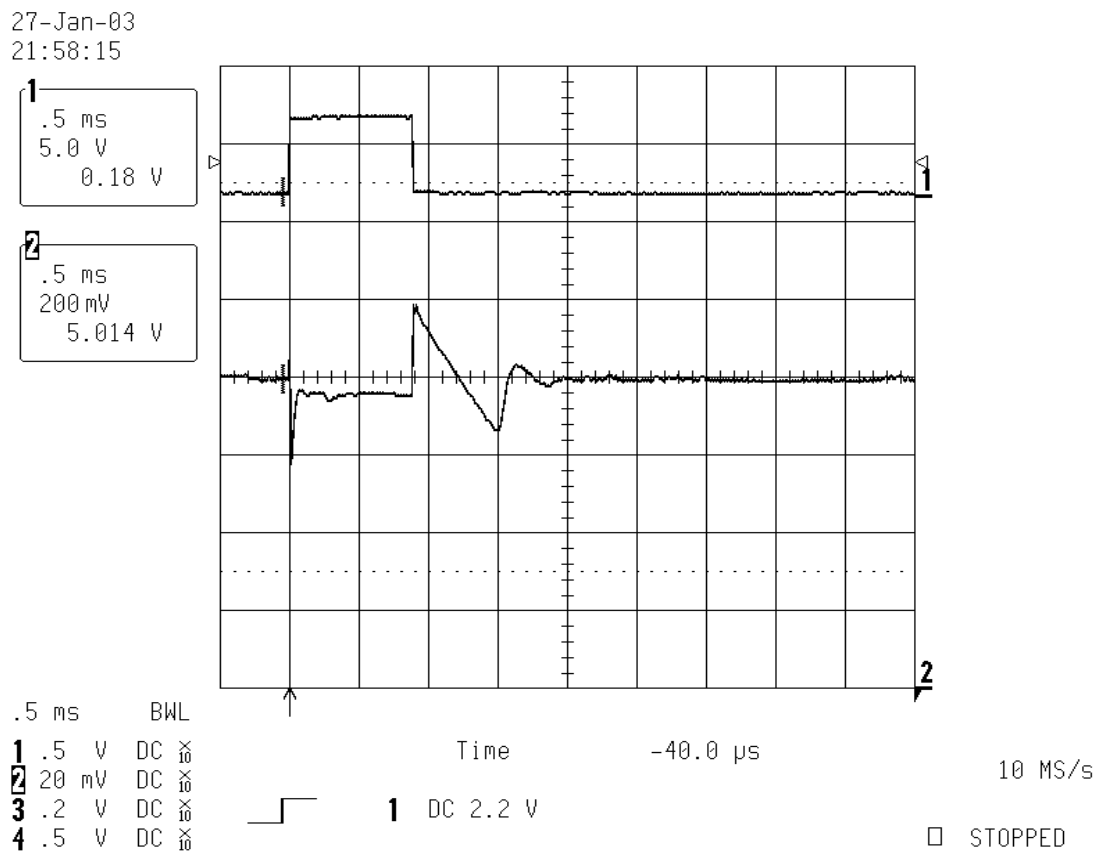
***Conclusion:***

***eventually the regulator tolerance is +1.3% to −2.3%.***
***your can make the typical output voltage without load slightly higher to beautify tolerance to obtain +−2%***

## Dynamic Behaviour

The speed of a regulator amplifier is limited. At sudden load changes the blocking capacitor must supply the load.

Approximate dynamic change of the output voltage:




$$\Delta V = \Delta I * t_{delay} / C$$

(Example: $\Delta I=0.1A$, $t_{delay}=10\mu s$, $C=10\mu F$ –> $\Delta V=0.1V$)

## Reset generator

Reset MUST release below the lowest possible output voltage. This is the upper one of the two hysteresis levels.

Resistors can be matched to +−0.2% −> add 0.2% margin

Comparator offset can be in the range of 20mV −> add 1% margin.

Margin for aprupt load changes and ringing 2%

=> Typical reset release threshold must be below 94.8% of the nominal output voltage (2.46V)

Reset hysteresis should be in the range of 50mV. So typical reset trip point is 92.5% (2.405V) of the nominal output voltage. In case tolerance go the other way worst case trip point is as low as 91.3% of the nominal output voltage (2.37V)

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## What If You Need Higher Accuracy?

1. Operate the regulator at constant load current. This typically brings a +−2% device down to +−1.5% because there is no more error contribution of the load rejection.

2. Supply your regulator from a prestabilized voltage. Together with item 1 you come down to typically +−1%

3. Do You really need the full temperature range? Restricting your application to a smaller temperature swing is helpful.

4. Ceramic packages usually induce less mechanical stress and will in most cases improve accuracy by 0.1% to 0.3%.