TIPS AND TRICKS ON HOW TO VERIFY CONTROL LOOP STABILITY WITH A ROHDE & SCHWARZ OSCILLOSCOPE

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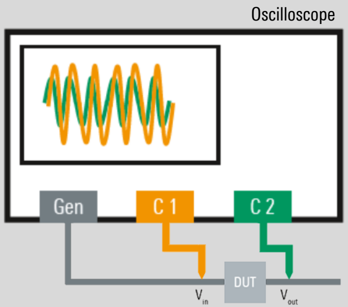
ROHDE&SCHWARZ
Make ideas real

PRIMARY APPLICATIONS

Frequency response

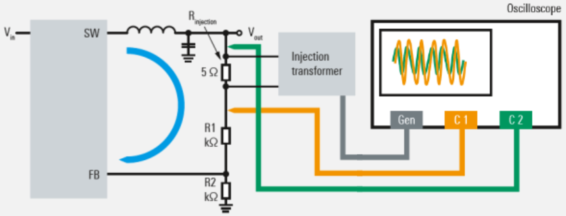
Characterization of passive components



Education for teaching
Low Frequency Filter Response

CLR

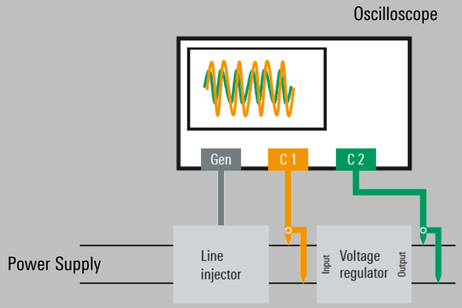
Control loop response stability testing



Power regulator design
Power supply, LDO testing
Amplifier Feedback control

PSRR

Measuring power supply rejection ratio



AC or DC power noise rejection
Product characteristics

OBJECTIVE

- **Reason for Control and Frequency Response Analysis in SMPS**
  - Status Quo of SMPS measurement methods
  - Feedback Principle in SMPS
  - Close Loop in Power Design
  - Linear Time Invariant System and Gain and Phase margin
  - How to select the injection point
- **What is the required equipment to perform Control Loop response measurements**
  - Rohde & Schwarz oscilloscope
  - Injection Transformer – how to choose the right transformer
  - Best probe to perform CLR measurements
- **Measurement Setup**
  - Right probing technique
  - What parameters can have influences on results and how to interpret these
  - How to perform a CLR measurement with a R&S oscilloscope
- **Conclusion**

STATUS QUO OF SMPS MEASUREMENT METHODS

- Load transient test
- Output voltage ripple test
- Input voltage ripple test
- Start-up and shutdown sequences
- Efficiency

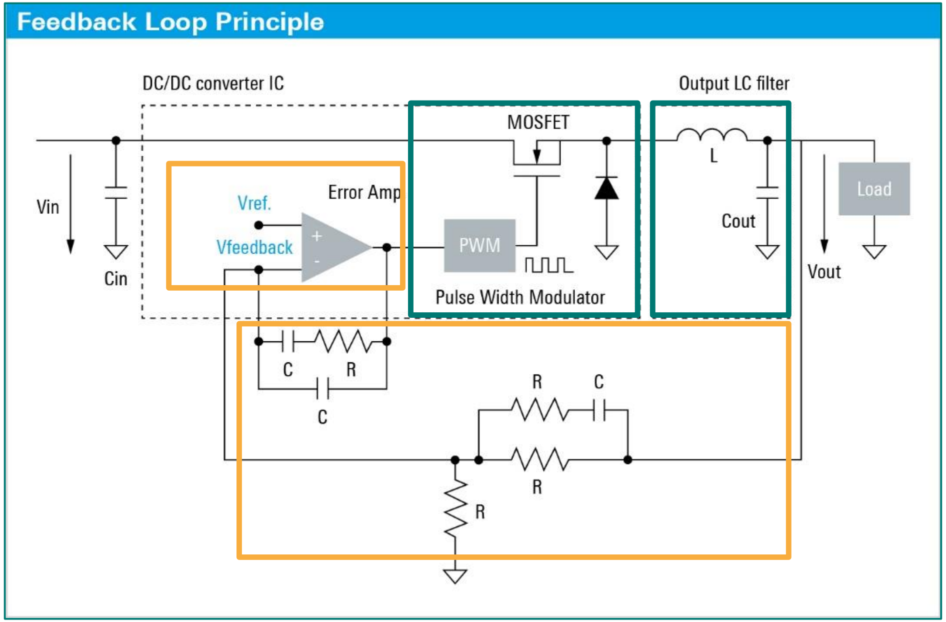
Well Known!

- Closed loop response test
  - This test ensures in addition to the load transient test that the load regulation of the power supply is stable under all circumstances like minimum and maximum output capacitance or temperature variations

An oscilloscope from Rohde & Schwarz is sufficient to perform all relevant tests

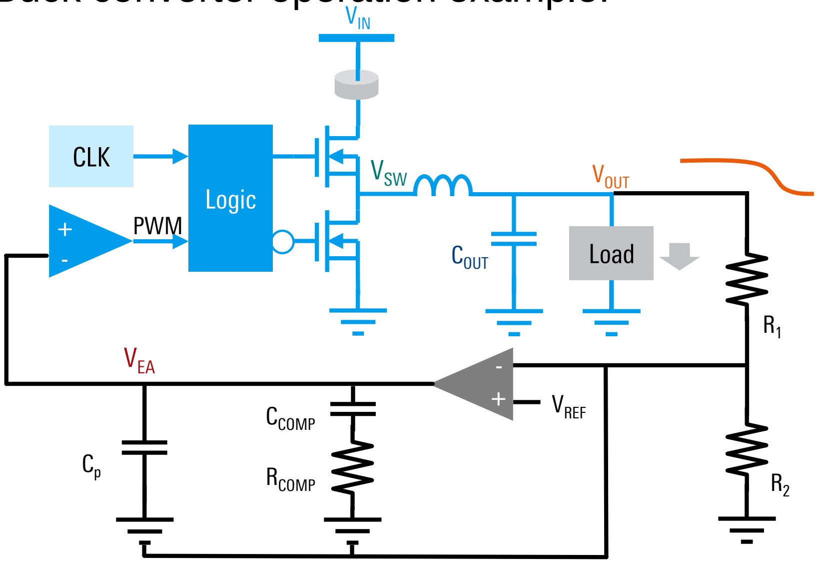
FEEDBACK PRINCIPLE

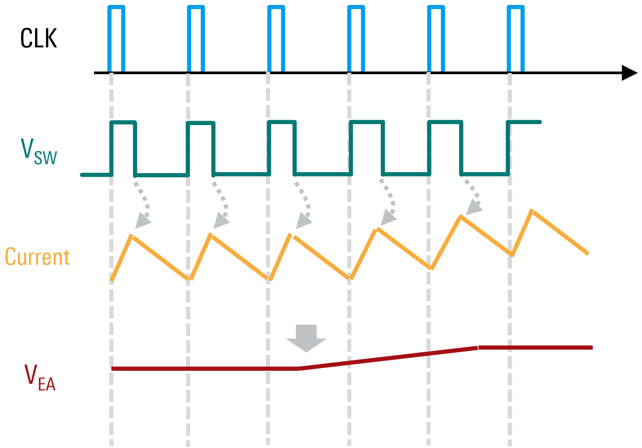
- Modulator with power stage including LC output filter
- Error amplifier and its compensation network



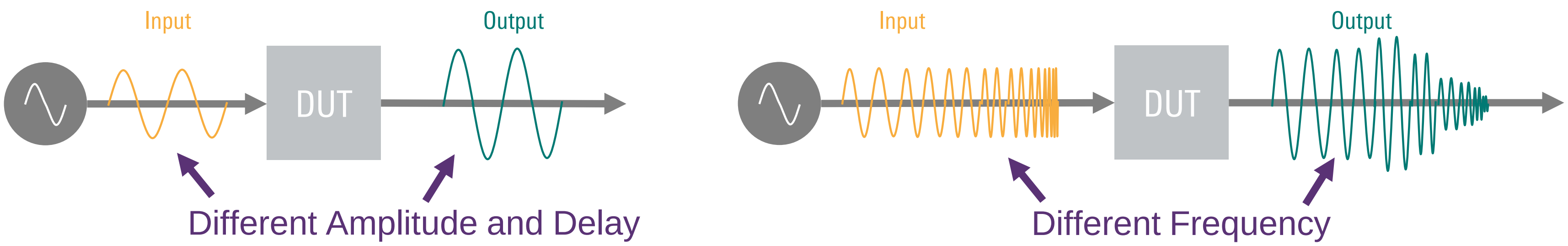
CLOSE LOOP IN POWER DESIGN

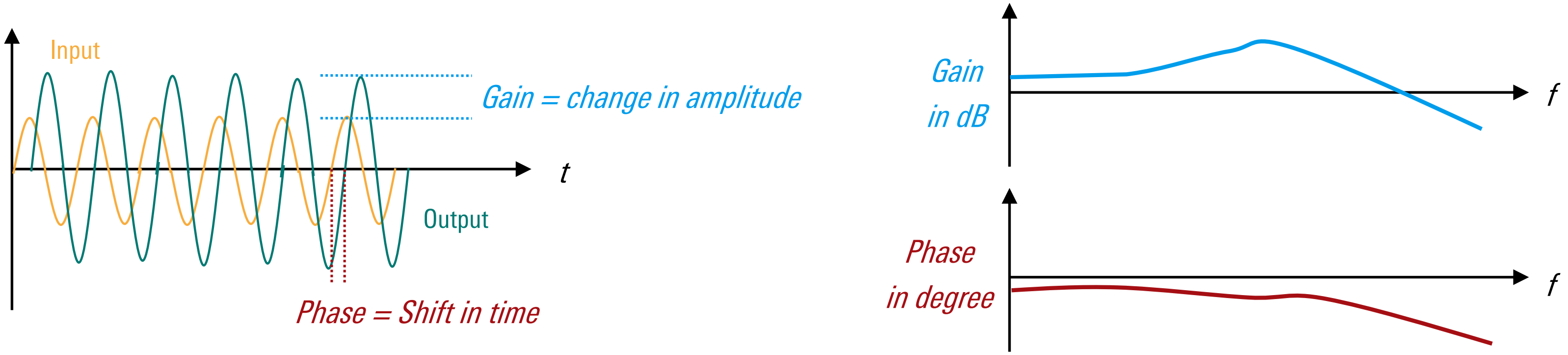
- In power supply, regulator and LDO design, feedback loop help to ensure stable output
- Especially important if load changes rapidly such as CPU, motor, display array, etc
- Buck converter operation example:





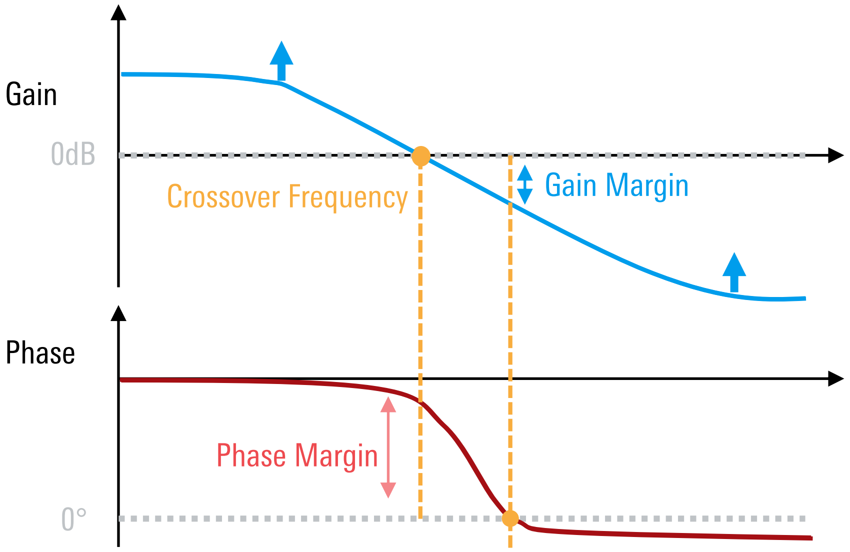
LINEAR TIME INVARIANT SYSTEM





GAIN AND PHASE MARGIN

This is the measurement of how far we are away from the point of non-stability



Crossover Frequency is when Gain plot crosses the 0dB

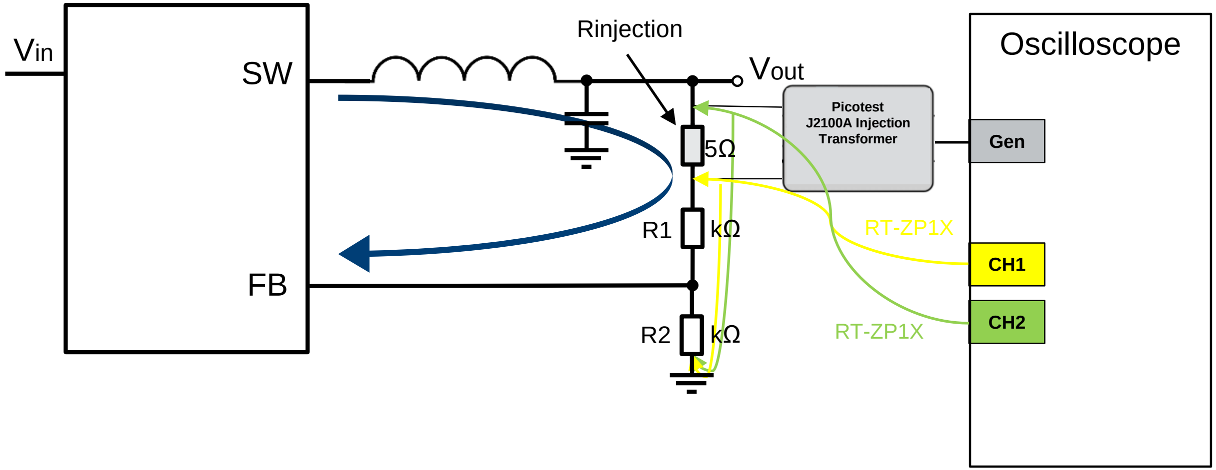
If apply gain on the system, there is no change on the phase (e.g. gain changes with the input voltage variation)

Crossover frequency start to move

The amount of gain we can add before the crossover point reach 0° is known as the Gain Margin.

Similarly phase margin refers to how much phase lag to make 0° at 0dB gain

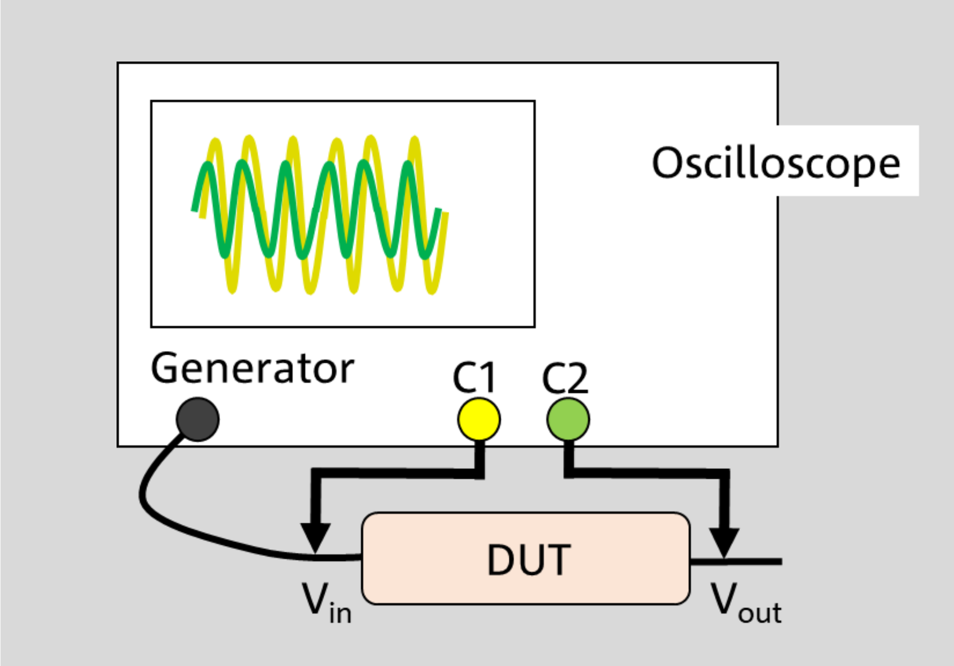
SELECTING THE INJECTION POINT OF AN ERROR SIGNAL



Rules to inject a small signal into the loop:

1. Output impedance of the output stage is much lower compare to the input impedance of the feedback loop
2. Ensure that all relevant components which are part of the loop are included

R&S OSCILLOSCOPE WITH K36
HOW DOES IT WORK?



1. Internal signal generator provides swept stimulus
(enables generator even is user hasn’t purchased generator license)

2. Oscilloscope measures V_{in} and V_{out} amplitudes and phase at each frequency

3. Oscilloscope calculates and plots gain (logarithmically) and phase (linearly)

R&S®K36 FREQUENCY RESPONSE ANALYSIS OPTION

Supported Instruments

RTB2000	RTM3000	RTA4000

► Uses the oscilloscope’s built-in waveform generator

Frequency from 10 Hz up to 25 MHz

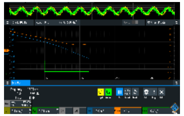
► No separate generator option B6 additionally required

Features & Functionalities

– **Amplitude Profile**
Profile the amplitude of the generator output. Suppress the noise behavior of your DUT when performing a CLR

– **Improve resolution**
Choose the points per decade to setup and modify the resolution of your plot (up to 500 points per decade)

– **Parallel Display of time domain (unique)**
See the timing correlation of input and output channels



– **Markers support & Result Table**
Use markers to get single sample values & the table to get a list the measure samples. Eaysily save your results

WIDEBAND INJECTION TRANSFORMER

How to choose the right injection transformer:

- ► Isolation → Voltages up to 400V at e.g. PFC circuits
- ► Bandwidth → Has to match your task, so f_{start} and f_{stop} are critical
- ► Gain flatness → Could at frequency dependent missmatches and thus cause unwanted reflections
- ► Primary to secondary capacitance → Dominates coupling and thus system response
- ► Saturation → Influences losses and measured system response

Our Recommondation for Control Loop Response (CLR)

- ► **Picotest J2100A Injection** Transformer (1 Hz – 5 MHz)
- ► **Picotest J2101A Injection** Transformer (10 Hz – 45 MHz)

BEST PROBE TO PERFORM CLR-MEASUREMENTS

- 10:1 probe
- RT-ZP05S/RT-ZP10

\+ Supplied standard with oscilloscope

\+ Provides up to 500 MHz bandwidth

\+ Magnifies DC offset range by 10x

\- Limits vertical sensitivity by 10x

\- **Magnifies oscilloscope‘s noise floor by 10x**

- 1:1 probe
- RT-ZP1X

\+ Optimizes vertical sensitivity

\+ Minimizes oscilloscope noise floor

\- Limits bandwidth up to 38 MHz

\- Limits DC offset

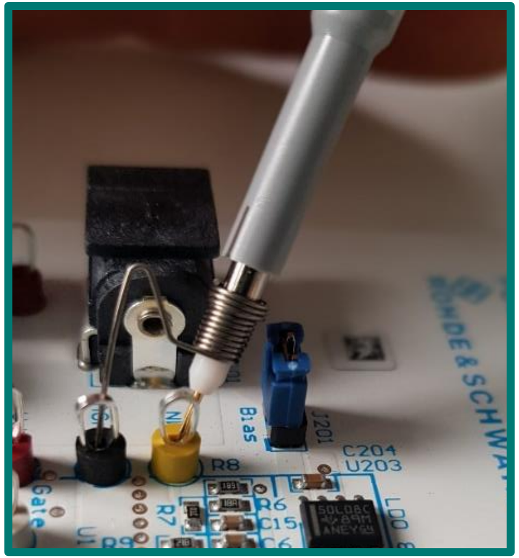
\- ~ 220 € probe extra

PROBING TECHNIQUE

- $\mathrm{SNR} = \frac{V_{in}}{Attenuation * V_{noise}}$

- Standard ground lead of probe can act as an antenna amplify unwanted switching noise

→ **Reduce length of the ground connection to minimize noise**



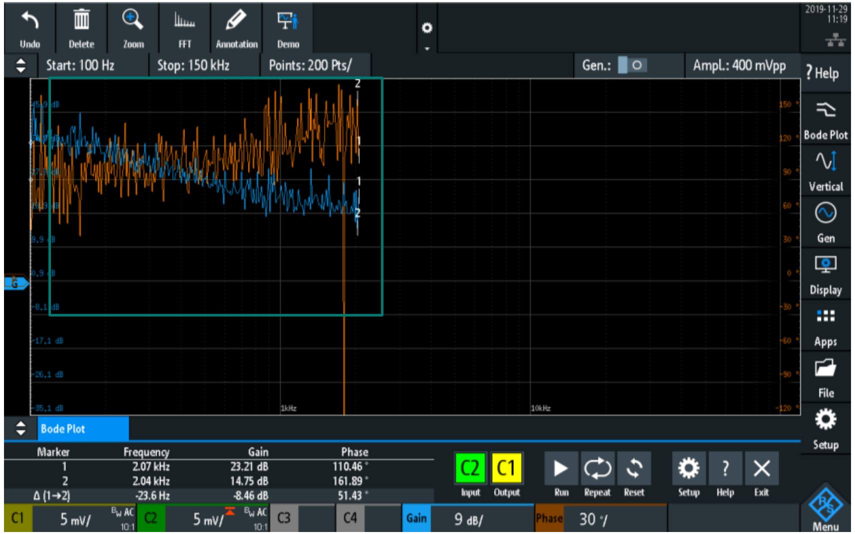
MEASUREMENT IMPACTS (PROBING)

Poor Probing

- Probe with 10:1 attenuation
- Use of standard ground reference leads

Optimized Probing

- Use a probe with 1:1 attenuation
- Minimized ground reference leads



MEASUREMENT IMPACTS (PROFILING)

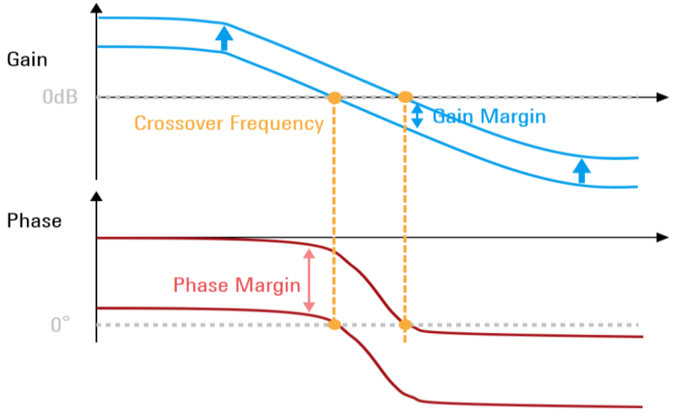
Constant Injection Level

- Low injection level used (100 mV)
- System needs higher signal level below the cross over freq

Profiled Injection Level

- Higher injection level (750mV) in the lower frequency range
- Lower injection level in the higher frequency range

TYPICAL CLR MEASUREMENT
INTERPRET RESULTS



Results of our system

Fco = 15kHz

PM = 64°

GM = -15dB

- Higher 0 dB cross-over frequency = Faster response to load changes
- Higher phase margin (>45°) at 0 dB cross-over frequency = Higher stability
- Lower gain at higher frequencies = Better noise immunity (output ripple)

→ Designer must optimize response speed and stability for their applications

CONTROL AND SETTINGS

CONCLUSION

RTB2000, RTM3000 & RTA4000 oscilloscope

- Rivals performance of a dedicated solution

- Lower price & easier to use than a network analyzer

- See the timing correlation of input and output channels

- Faster & more dynamic range than any other oscilloscope based solution

- All in One test solution – oscilloscopes are the primary measurement tools for engineers to characterize their power supply designs

FIND OUT MORE

rohde-schwarz.com

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Make ideas real