Application Report

SNVA700–October 2013

Automated Frequency Response Analyzer

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ABSTRACT

This application report discusses a new method of doing stability Analysis testing by using basic lab equipment, while not requiring any specific instruments.

Topic **Page**

1 Introduction

In today's market, there are many expensive instruments available for conducting stability analysis. This Application Report provides a new and easy method to generate Bode plots for stability Analysis by using basic lab instruments. This same technique can be further employed to do a frequency response Analysis of any system.

2 TOP Level Block Diagram

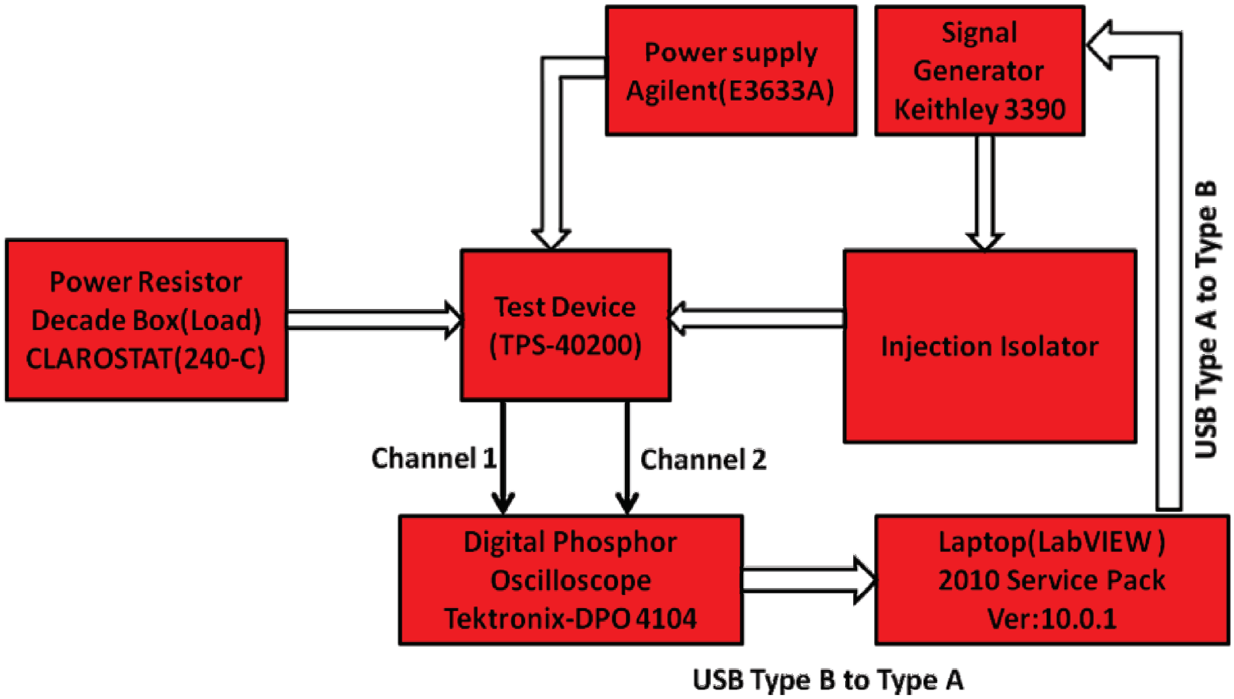

Figure 1. System Level Block Diagram

3 Calculating the Frequency Response

As seen in Figure 2, using the Signal Generator, a single tone is injected into the loop coupling through the Injection Isolator. It is captured using an oscilloscope at both the ends of the 50 Ω resistance. By using drivers on the host computers, data is captured from the oscilloscope and as a result, the frequency response is calculated at the injected frequency.

As demonstrated in Figure 2, the voltage probed at both the nodes of 50 Ω can be given as:

$$V_{OUT}1(f) = V_{OUT}2(f) \times (-A) \times (B) \times [FB2 / (FB1 + FB2)] \quad (1)$$

$$V_{OUT}2(f) = V_{OUT}1(f) - V_{IN} \times (N1 / N2) \quad (2)$$

Here (N1 / N2) = 1, thus we ignore it for further discussion.

From Equation 1 and Equation 2, we have:

$$V_{OUT}2(f) = V_{OUT}2(f) \times (-A) \times (B) \times [FB2 / (FB1 + FB2)] - V_{IN} \quad (3)$$

From Equation 3, we have:

$$V_{OUT}2(f) \times [1 + A \times B \times (FB2 / (FB1 + FB2))] = -V_{IN}(f) \quad (4)$$

From Equation 4, we have:

$$V_{OUT}2(f) = -V_{IN}(f) / [1 + A \times B \times (FB2 / (FB1 + FB2))] \quad (5)$$

From Equation 1 we have:

$$V_{OUT}1(f) = [-VIN(f) \times A \times B\ (FB2 / (FB1 + FB2))] / [(1 + A \times B \times (FB2 / (FB1+FB2))] \quad (6)$$

From Equation 5 and Equation 6, we have:

$$H(f) = V_{OUT}1(f) / V_{OUT}2(f) = A \times B \times (FB2 / (FB1 + FB2)) \quad (7)$$

where A x B x (FB2 / (FB1+FB2)) is the loop gain.

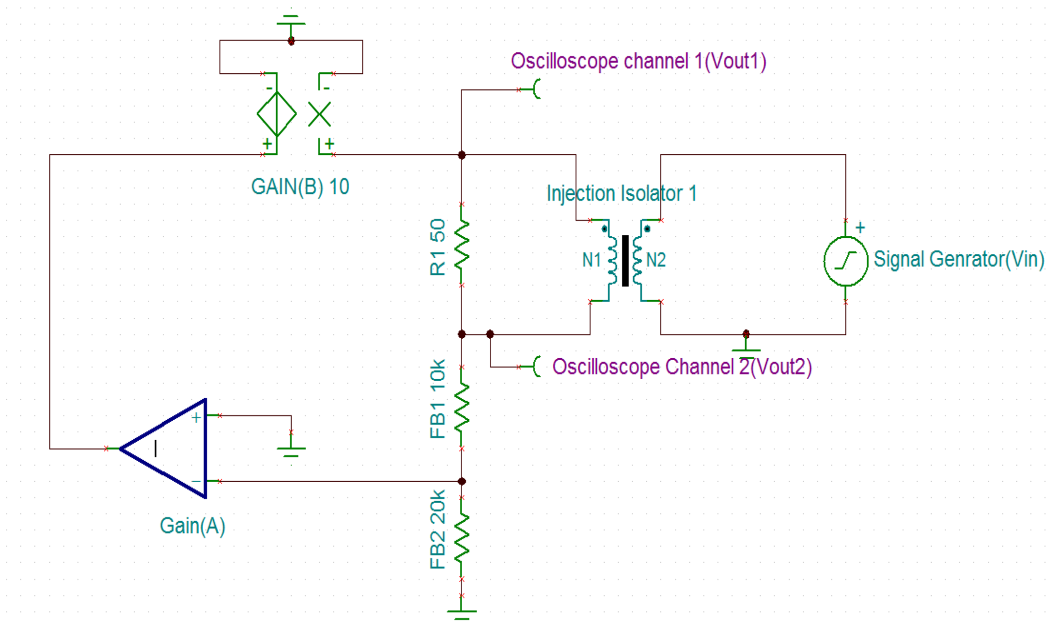

Figure 2. Signal Injection and Capturing

Both the nodes of the 50 ohm resistance (Vout1, Vout2) are captured using channels of the Oscilloscope. Most of the present day Digital Oscilloscopes have capability to transfer captured raw data to the computer. The device specific drivers would be required to capture the raw data from the oscilloscope.

Here, we have used National Instruments' LabVIEW™ to capture the data from the Oscilloscope and to do further processing.

The Flow chart below explains the Signal Flow and processing steps.

4 Signal Flow: Data Capturing Module

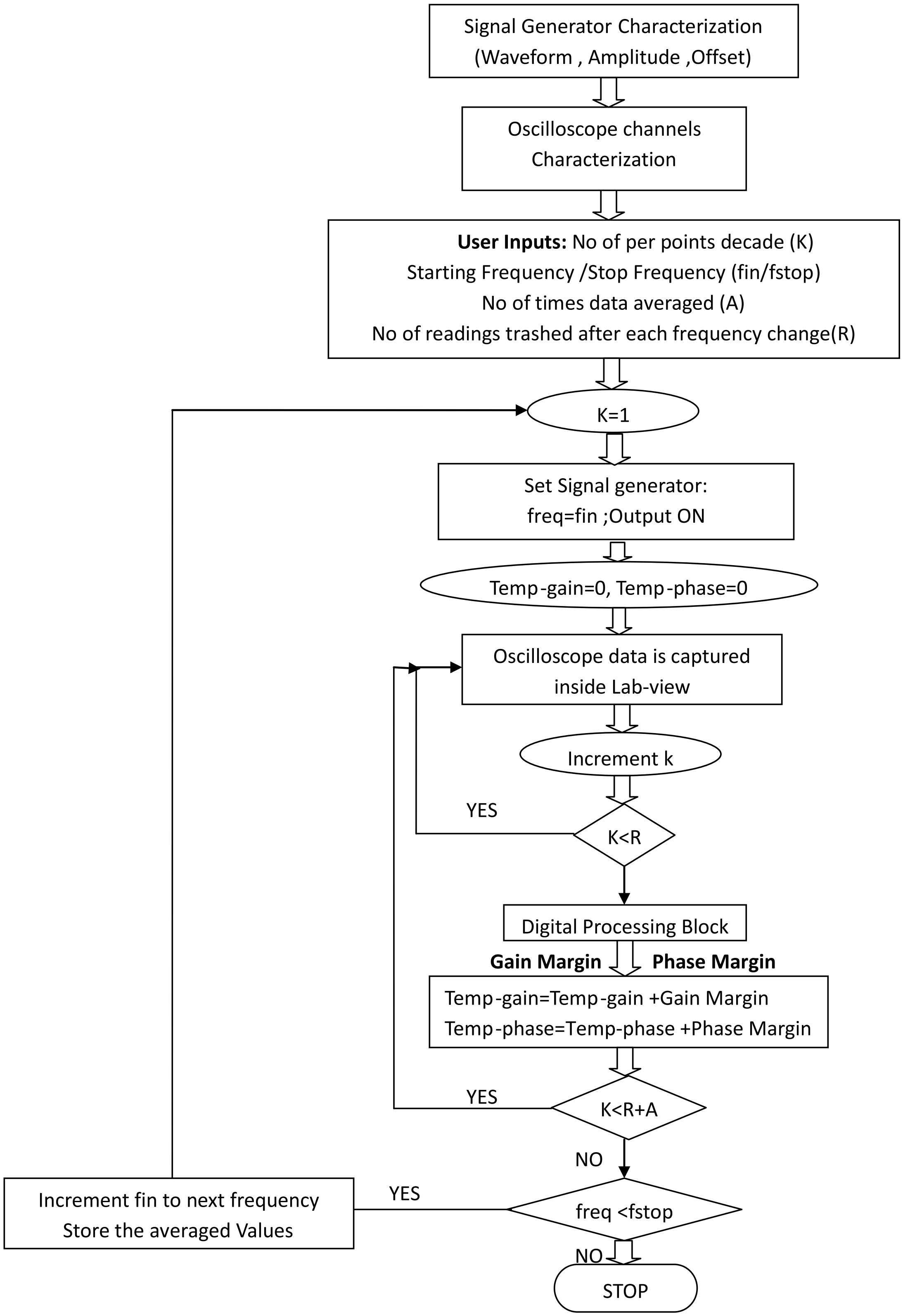

Figure 3. Signal Flow

5 Digital Signal Processing Block

From the above signal flow graph, the digital processing block is explained here.

As demonstrated in Equation 7, the two node voltages $V_{OUT}1(f)$ and $V_{OUT}2(f)$ can be treated as a system in time domain with Input $V_{OUT}1(t)$ and Output $V_{OUT}2(t)$.

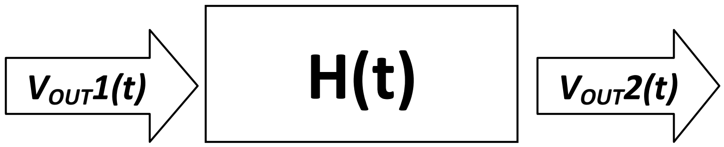

Figure 4.

Where H(t) as derived from Equation 7 can be given in frequency domain as:

H(f) = A x B x [FB2 / (FB1 + FB2)].

H(f) can also be expressed as:

$$H(f) = K(f)e^{i\theta(f)} \quad (8)$$

where:

$$K(f) = \text{modulus}[A \times B \times (FB2 / (FB1 + FB2))] = \text{modulus}[V_{OUT}\,2] / \text{modulus}[V_{OUT}1] \quad (9)$$

and:

$$\theta(f) = \arg[A \times B \times (FB2 / (FB1 + FB2))] = \arg[V_{OUT}2] - \arg[V_{OUT}1] \quad (10)$$

where K(f) is the Magnitude Response and θ(f) is the phase response.

The Digital Processing Block is used to calculate the frequency response as per the two time domain signals $V_{OUT}1(t)$ and $V_{OUT}2(t)$.

To calculate the frequency response *(H(f))* of the system, the FFT of both the signals $V_{OUT}1(t)$ and $V_{OUT}2(t)$ is calculated with a starting frequency of zero hertz and a frequency step size equal to Bin width.

Bin Width = Sampling Frequency / Number of samples taken to calculate FFT (11)

The FFT of the time domain signals will be a vector with both magnitude and phase information present inside it.

As demonstrated in Equation 10, the magnitude and phase of both the signals $V_{OUT}1(f)$ and $V_{OUT}2(f)$ is divided at the respective frequencies and thereby K(f) and θ(f) are calculated. They are both arrays with each array element representing each bin.

The Bin corresponding to the injected frequency gives you Gain Margin and Phase Margin at the desired injected frequency.

From Equation 9 andEquation 10:

Gain Margin G(f) = K(Injected bin) and Phase Margin P(f) = θ(Injected Bin) (12)

where Injected bin = Injected Frequency / Bin Width

6 GUI Made Using LabVIEW™

The data was captured inside the laptop by writing a code in LabVIEW™ using the signal flow Graph given under Heading 4. Online libraries from LabVIEW™ were used and automated setup was made to run for the user entered frequency range.

One needs to input different parameters for signal generator, oscilloscope, and Digital Signal Processing block.

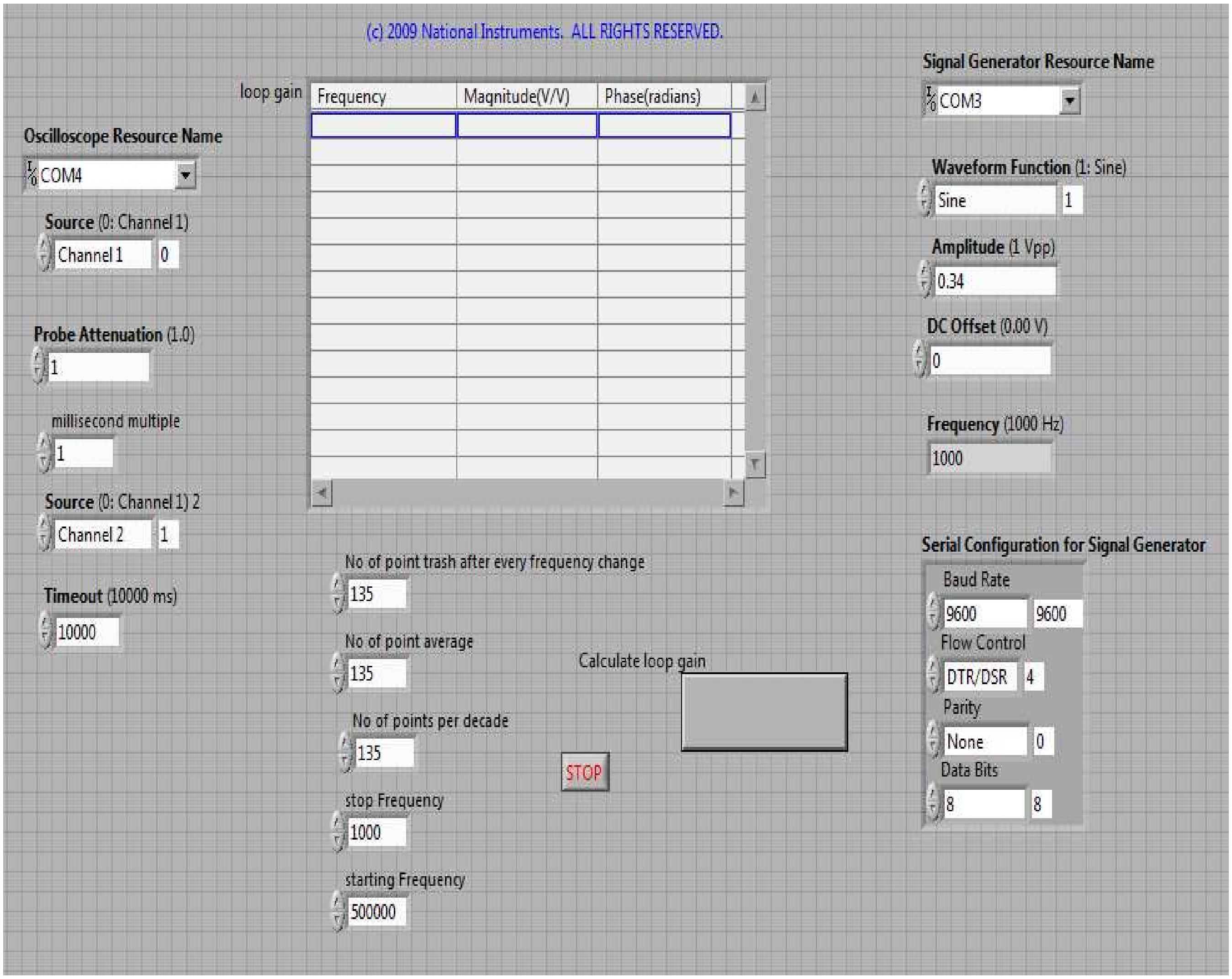

Figure 5. GUI Front Panel Using LabVIEW™

7 Characterization of Oscilloscope Channels

Before running the stability Analysis for a given device, both the channels of Oscilloscope need to be characterized to compensate for inherent sampling phase and gain error present in the channels.

7.1 Experiment Setup

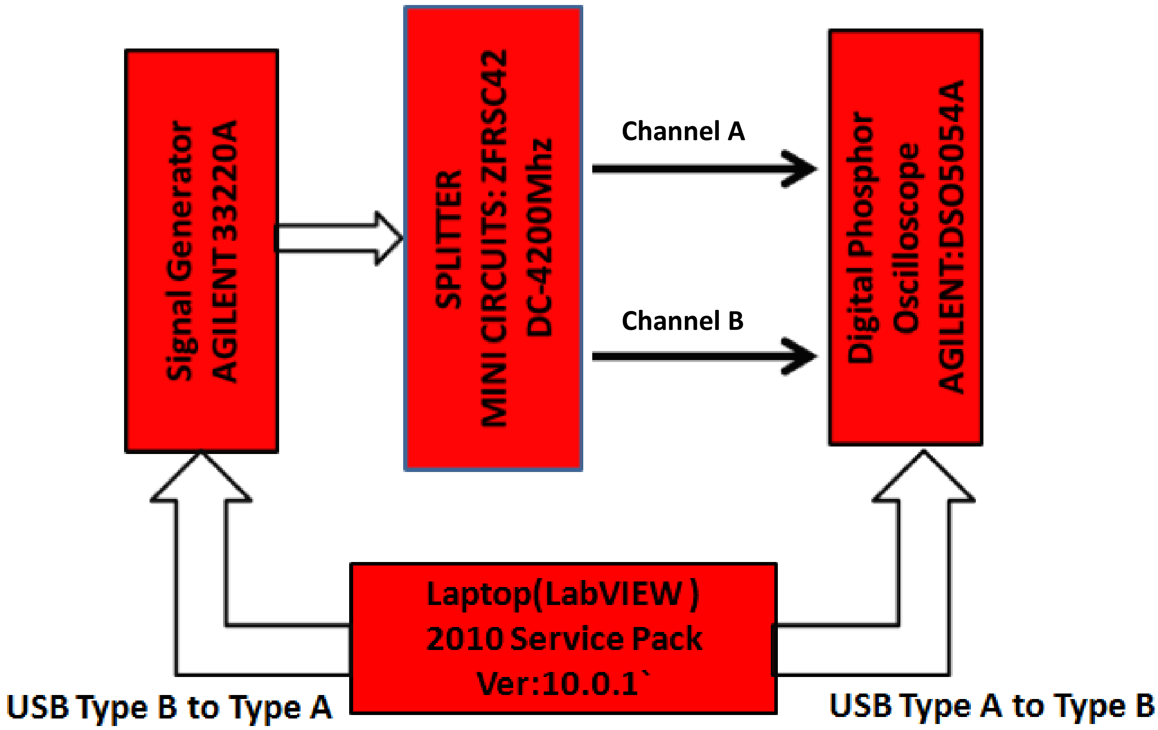

Figure 6. Oscilloscope Characterization (Test Setup)

Test Setup Conditions:

1. Waveform Used: Sine Waveform
2. Amplitude: 300 mV
3. Frequency: 1 KHz to 500 KHz with 20 steps per decade
4. Offset value: 0 V
5. Oscilloscope Channels used: 1 and 4
6. Frequency Resolution used in FFT calculation(Bin width): 1 Hz

7.2 Observed Test Data (Experiment No.1)

GUI mentioned in column5 was used to capture the three parameters.

1. Frequency of the Injected Signal from Signal Generator.
2. Gain Margin =G(f) at the injected frequency as demonstrated in Equation 12
3. Phase Margin=P(f) at the injected frequency as demonstrated in Equation 12

loop gain

Frequency	Magnitude(V/V)	Phase(radians)
1000.000000	0.993686	-0.000247
1500.000000	0.993260	-0.000208
2000.000000	0.993176	-0.000194
2500.000000	0.993153	-0.000183
3000.000000	0.993011	-0.000177
3500.000000	0.992954	-0.000165
4000.000000	0.992838	-0.000135
4500.000000	0.992935	-0.000135
5000.000000	0.992614	-0.000133
5500.000000	0.992708	-0.000132
6000.000000	0.992924	-0.000109
6500.000000	0.993197	-0.000113
7000.000000	0.993059	-9.530545E-5
7500.000000	0.993019	-9.842494E-5
8000.000000	0.993032	-8.874914E-5
8500.000000	0.992952	-7.933237E-5
9000.000000	0.992931	-7.149700E-5
9500.000000	0.993170	-7.991691E-5
10000.000000	0.993127	-7.223340E-5
10000.000000	0.993072	-7.178877E-5
15000.000000	0.993094	-4.236375E-5
20000.000000	0.993158	-4.423788E-5
25000.000000	0.993041	-2.702333E-5
30000.000000	0.993279	-3.306150E-5
35000.000000	0.993172	-4.476817E-5
40000.000000	0.993326	-2.158555E-5
45000.000000	0.993286	-1.584008E-5
50000.000000	0.993240	-3.107281E-5
55000.000000	0.993380	1.049506E-5
60000.000000	0.993450	2.722643E-6
65000.000000	0.993615	1.333673E-5
70000.000000	0.993290	-8.360867E-6
75000.000000	0.993240	9.404218E-6
80000.000000	0.993494	-8.342550E-6
85000.000000	0.993528	7.851100E-6
90000.000000	0.993413	-3.160025E-6
95000.000000	0.993435	4.186047E-5
100000.000000	0.993342	1.703381E-5
100000.000000	0.993579	1.827475E-5
150000.000000	0.993641	0.000107
200000.000000	0.993922	0.001408
250000.000000	0.993604	0.000410
300000.000000	0.991771	-0.000504
350000.000000	0.992693	0.000135
400000.000000	0.992775	-0.005296
450000.000000	0.995206	0.000726

Figure 7. Observed Data (Oscilloscope Characterization)

Figure 7 shows that the maximum phase error observed is 0.000726 at 450 Khz which is equal to 0.0416 degrees. We can neglect this error. Similar is the case with gain error between two channels.

Therefore, the Oscilloscope itself doesn’t introduce any gain and phase errors between both of the channels.

8 Concept Validation: TPS40200

To prove the concept tps40200 was used to calculate the loop stability and hence validate the concept. Test setup used was.

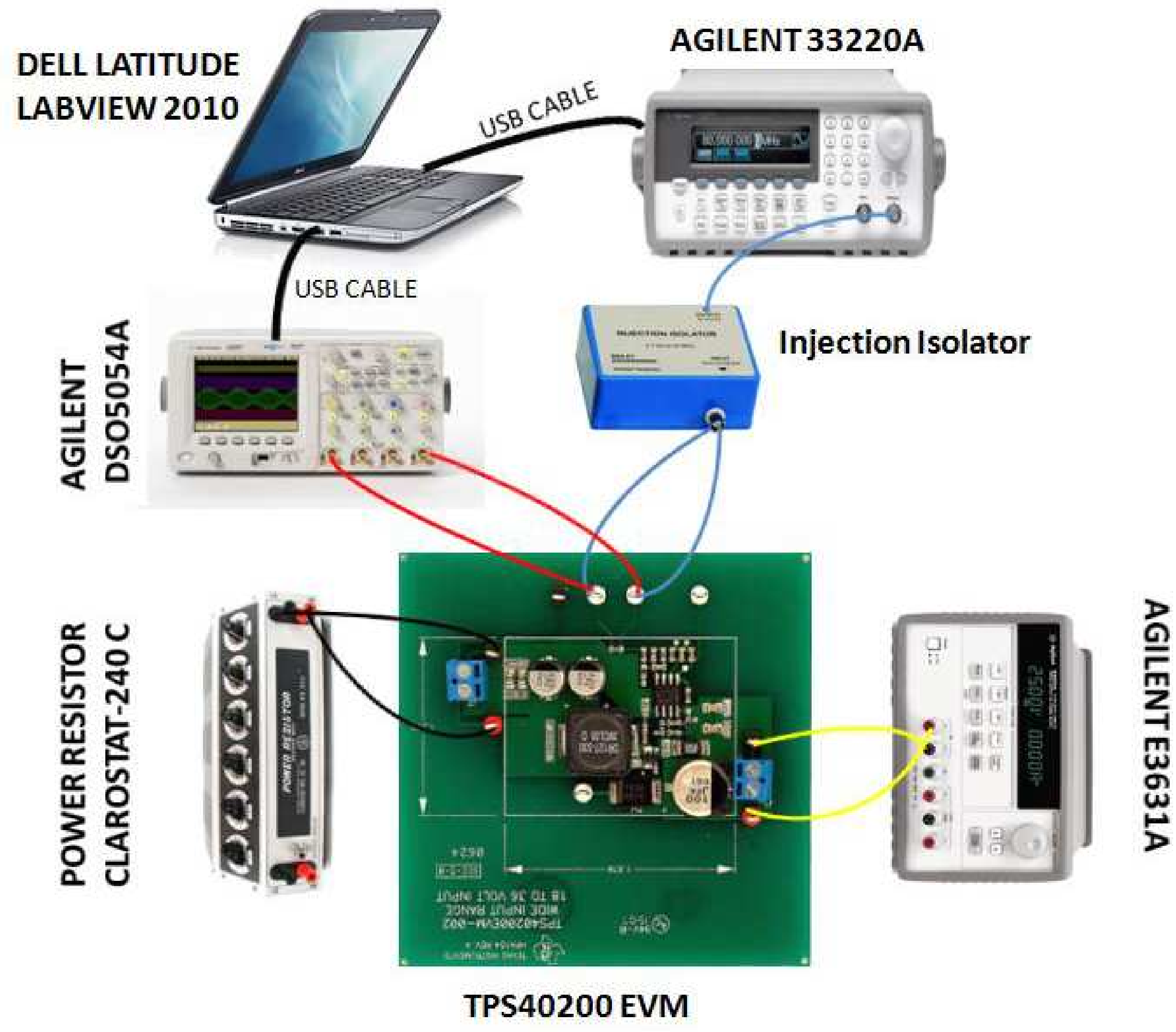

Figure 8. Concept Validation (System Setup)

9 Observed Data Using LabVIEW™

Experiment No.1 was repeated for above system set-up.

loop gain

Frequency	Magnitude(V/V)	Phase(radians)
1000.000000	9.242310	2.017085
1500.000000	7.021692	1.709123
2000.000000	5.036163	1.517099
2500.000000	3.752539	1.416914
3000.000000	2.937901	1.364775
3500.000000	2.400135	1.333388
4000.000000	2.023875	1.311855
4500.000000	1.748717	1.296134
5000.000000	1.538473	1.282314
5500.000000	1.373133	1.269677
6000.000000	1.240207	1.257447
6500.000000	1.129561	1.244952
7000.000000	1.038448	1.233065
7500.000000	0.960130	1.220576
8000.000000	0.892205	1.208085
8500.000000	0.832565	1.195252
9000.000000	0.780208	1.182564
9500.000000	0.734381	1.169651
10000.000000	0.692277	1.156391
10000.000000	0.692534	1.156538
15000.000000	0.434407	1.020942
20000.000000	0.307230	0.887407
25000.000000	0.231194	0.760900
30000.000000	0.180713	0.643143
35000.000000	0.144661	0.533983
40000.000000	0.117826	0.433482
45000.000000	0.097509	0.340286
50000.000000	0.081595	0.253041

Figure 9. Observed Data (TPS40200)

10 Loop Gain Plot

The captured data is finally stored inside an Excel template where the Loop Gain Margin (V/V) and Phase Margin values (radians) are converted into dB and degrees scale respectively. After which they are plotted in the same template.

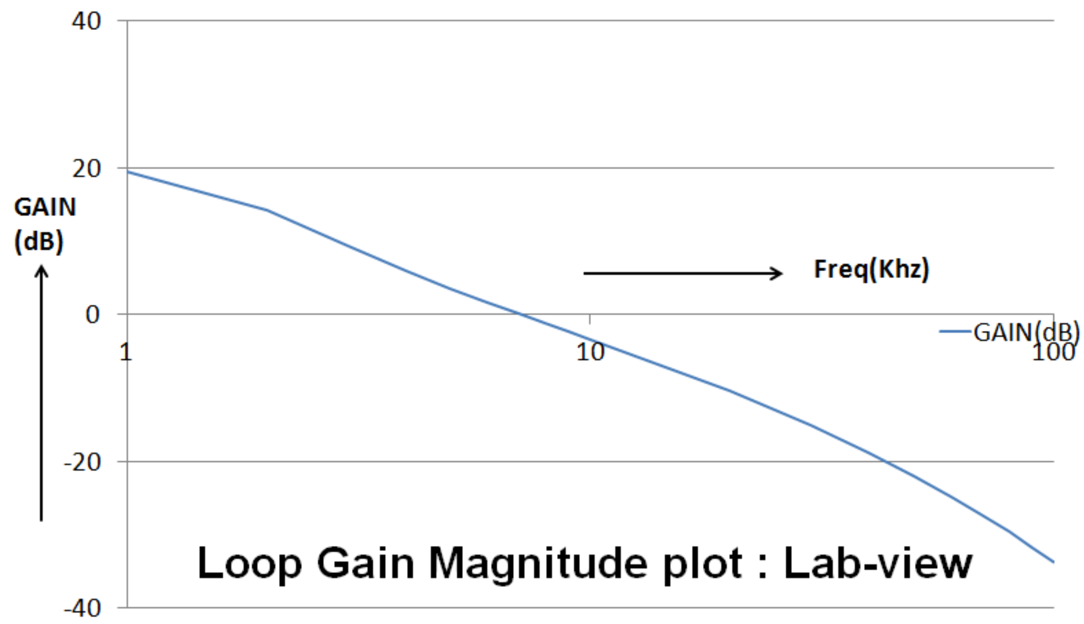

Figure 10. Loop Gain Magnitude Plot: LabVIEW™

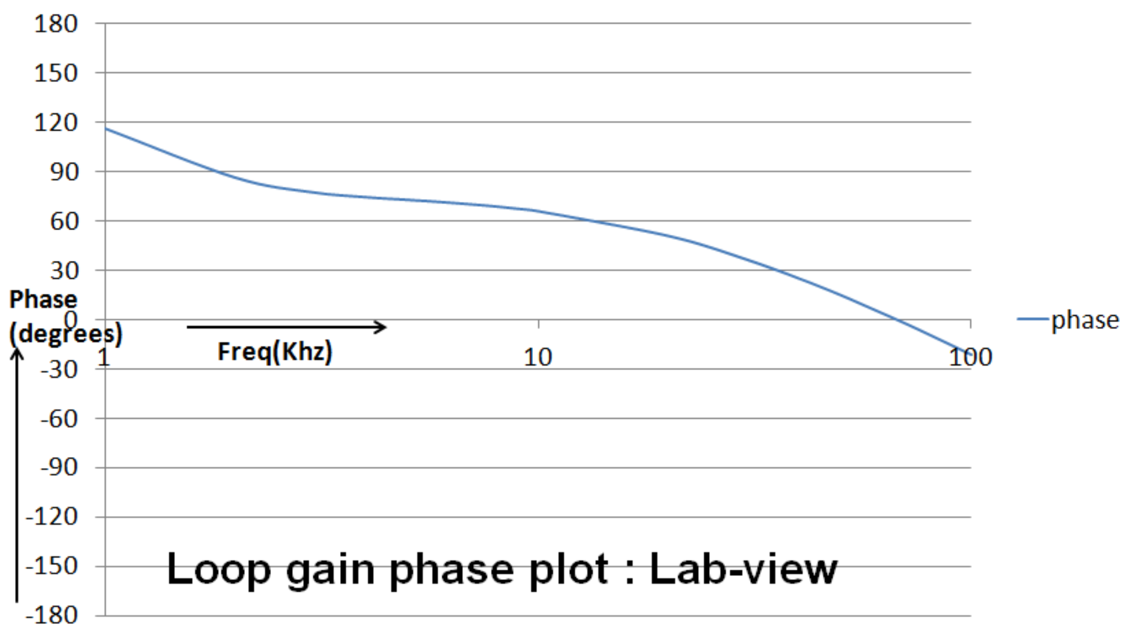

Figure 11. Loop Gain Phase Plot: LabVIEW™

11 TINA-TI Average MODEL for the TPS40200-002 EVM Setup

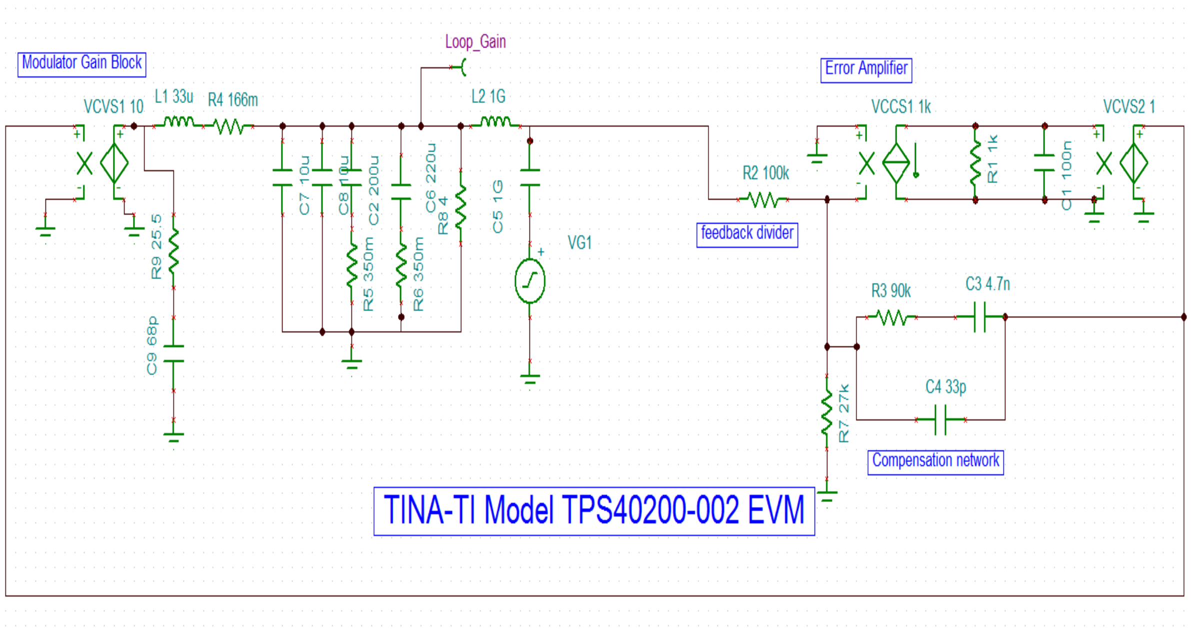

Figure 12. TINA-TI Average Model

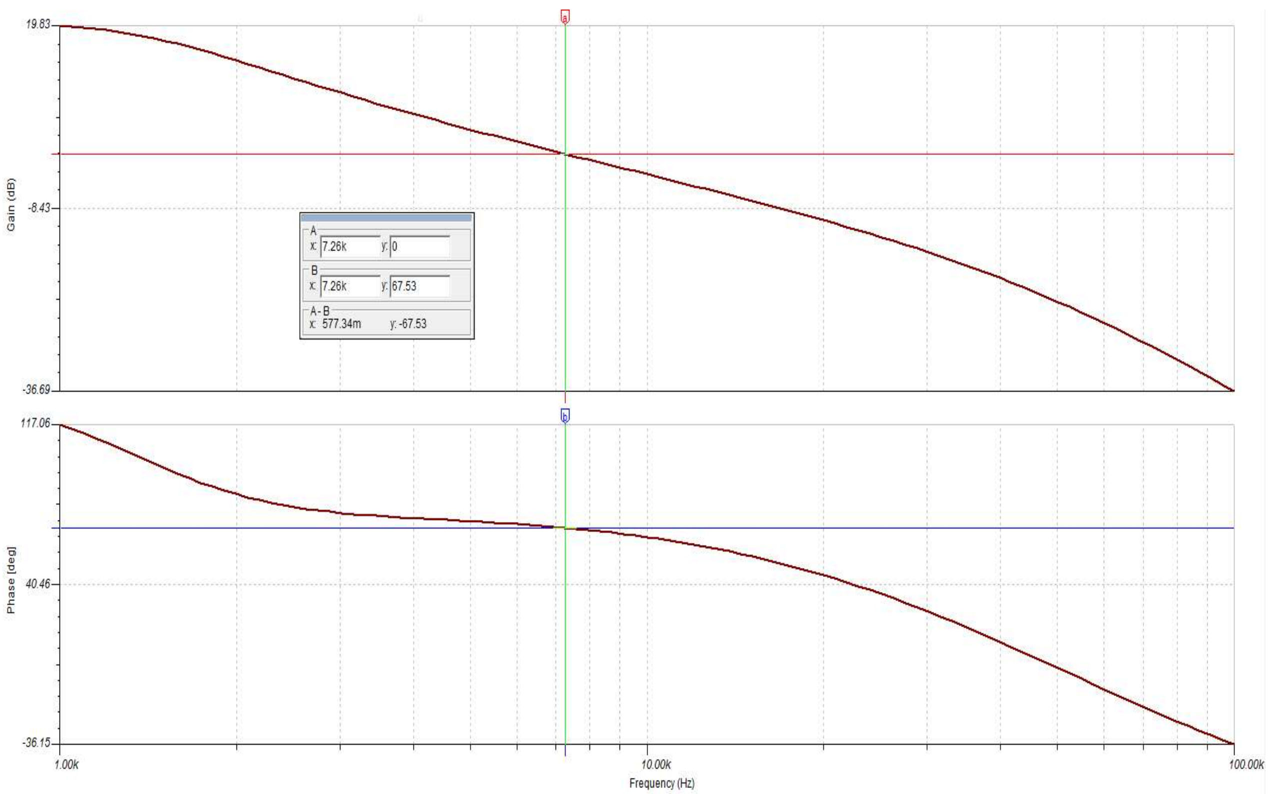

Figure 13. TINA-TI Loop Gain Plot

12 Concept Validation: TPS40210

To validate the concept with a boost EVM TPS40210 was used in the same system setup as Figure 8 with TPS40200 replaced with TPS40210.

13 Observed Data Using LabVIEW™

Experiment No.1 was repeated for above mentioned system set-up.

loop gain

Frequency	Magnitude(V/V)	Phase(radians)
1000	25.75	1.039582
3000	4.61	0.815672
5000	2.26	0.851657
8000	1.233	0.859654
9000	1.078	0.849658
10000	0.9715	0.824668
13000	0.764	0.792681
17000	0.6306	0.718161
20000	0.577	0.648739
25000	0.5282	0.539983
30000	0.5043	0.427428
35000	0.4925	0.320371
40000	0.485	0.218312
45000	0.48	0.113954
55000	0.4735	0.06697
65000	0.47	-0.2479
80000	0.455	-0.5042
100000	0.4085	-0.79468
200000	0.252	-1.61435
300000	0.158	-2.17712

Figure 14. Observed Data Using LabVIEW™

14 Loop Gain Magnitude Plot

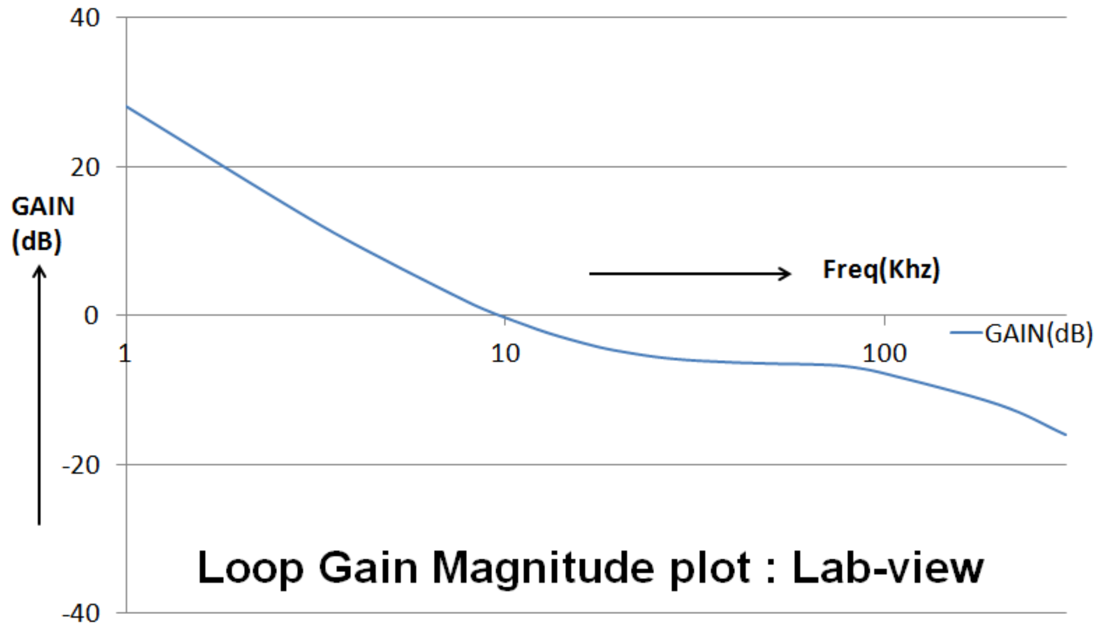

Figure 15. Loop Gain Magnitude Plot: LabVIEW™

15 Loop Gain Phase Plot

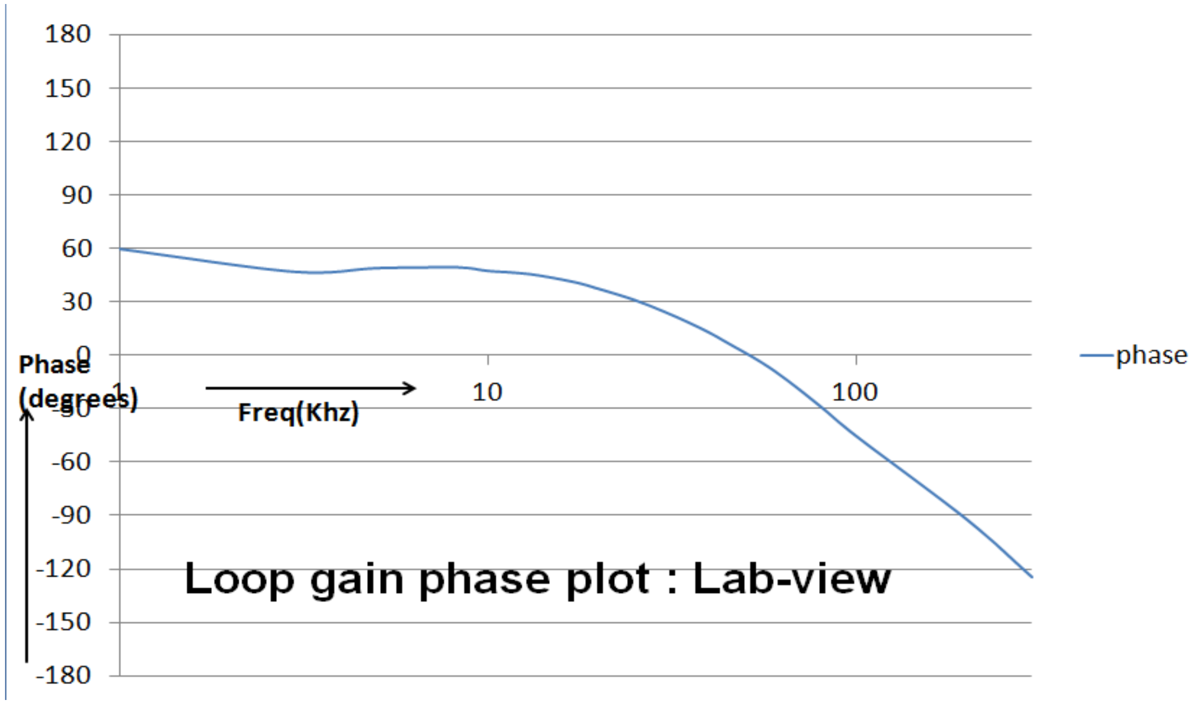

Figure 16. Loop Gain Phase Plot: LabVIEW™

16 Loop Gain Plot under Similar Conditions Given in the TPS40210 User Guide

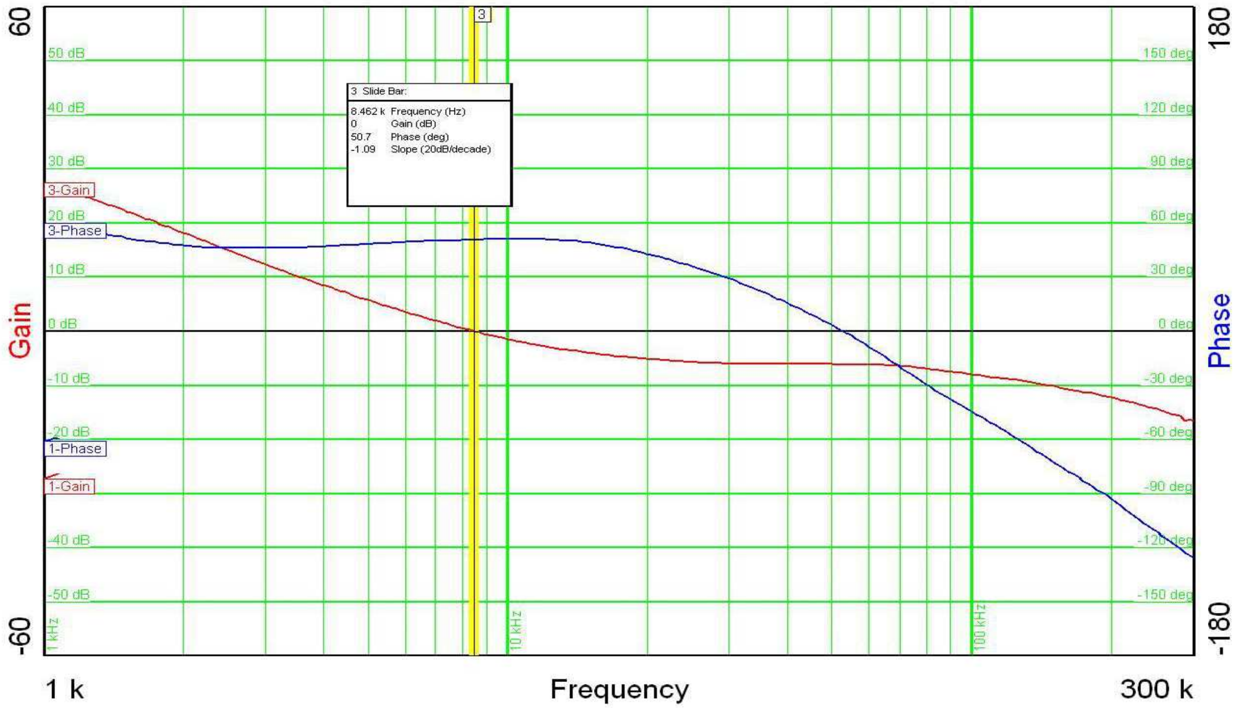

Figure 17. Loop Gain Response Given in User Guide

17 Comparison

Table 1.

	Using Automated Lab Test Set-up	User Guide/TINA-TI
TPS40200 Phase Margin(degrees)	68.4	67.5
TPS40200 Crossover Frequency(Hz)	7.12k	7.26k
TPS40210 Phase Margin(degrees)	48.5	50.7
TPS40210 Crossover Frequency(Hz)	9.2k	8.6k

18 Conclusion

We can conclude that the procedure described above yields results that are close to the expected results. Therefore, the procedure can be used to do stability Analysis testing for different DC-DC converters and LDO’s. The scope of this concept is broad, as it can be used for the PSRR calculation for LDO’s, small signal response calculations for op-amps, and more.

The major advantage found with the above automated system was much less variability. The present test-setup was tested for 1000’s readings and the variability found in the results was less than 0.1%.

Only basic lab equipment was needed for the above Automated Frequency Response Analyzer. Therefore, no individual lab instruments are required for the above characterizations.

This could potentially save a lot of money for the characterizations mentioned above as well as many more, since the individual instruments for these characterizations are quite costly in the market.

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Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

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- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

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This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

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2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。

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EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM’s electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI’s recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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