Venable Instruments Application Note

Measuring a Modulator (Plant) Transfer Function – Open Loop Method

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This Venable Instruments Application Note is excerpted from Venable's 'Software Manual' that includes software, hardware and application information. By excerpting the following content, the information that follows is more accessible to the user.

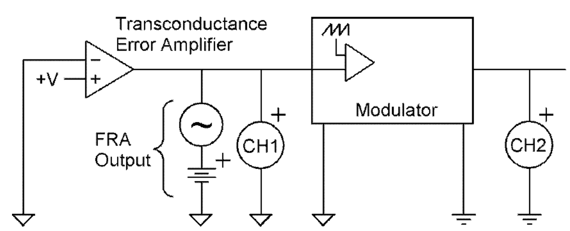
Two versions of the Software Manual exist, each being software centric. Venable supports both Version 5 and Version 6 of Venable's Stability Analysis Software. Version 5 is for legacy Frequency Response Analyzers and Version 6 is for FRAs manufactured after 2019. The Version 5 Software Manual can be found here, and the Version 6 Software Manual here.

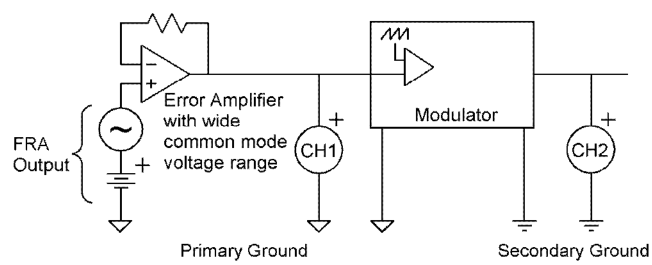
Measuring a Modulator (Plant) Transfer Function – Open Loop Method

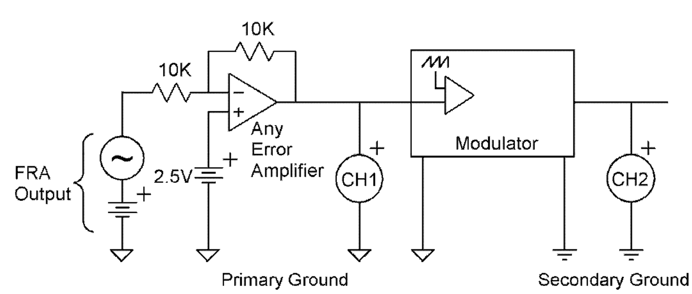
We use the words “Modulator”, “Plant”, and “Control-to-output transfer function” synonymously. These terms refer to the gain from the output of the error amplifier to the output of the system. This gain block typically has a fixed low-frequency gain. High frequency gain falls off at a -1 (-20 dB/decade) or -2 (-40 dB/decade) slope depending on the characteristics of the circuit. Because the gain at low frequency (including DC) is fixed, it is possible to use a DC voltage to bias the operating point to achieve a desired system output. By superimposing a small AC voltage on the DC bias voltage, the operating point of the modulator can be varied. The transfer function of this gain block can then be measured by connecting frequency selective voltmeters (the inputs of the Frequency Response Analyzer) to the input and output of the circuit and sweeping the modulation frequency across the desired frequency range. The output of Venable Analyzers are designed to deliver DC and swept frequency AC voltage simultaneously. The inputs are designed to measure voltage at the frequency of the output and reject all other frequencies and DC.

Here is the step-by-step procedure for measuring the control-to-output transfer function:

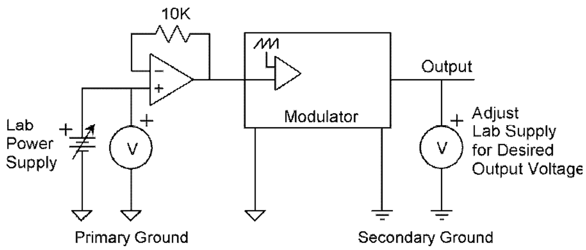
1. The first step is to set up the circuit to be controlled by the output of the FRA. There are three ways to do this. If the error amplifier is a high output impedance transconductance amplifier, the output can be biased high and the output of the FRA used directly to control the operating point. If the error amplifier has a conventional low impedance output but has an input common-mode range at least equal to the voltage swing needed in the output to control the system, the error amplifier can be wired as a buffer follower. If the error amplifier has a conventional low impedance output and a relatively narrow input common-mode voltage range that does not encompass the entire output voltage swing required, the error amplifier can be wired as a gain stage and there is complete freedom of operating point. If in doubt, this third method will work in any situation. The three methods are shown in the nearby figures.



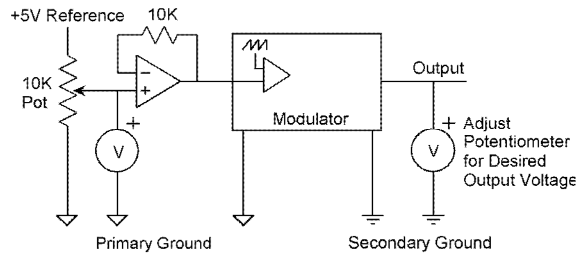




2. The next step is to adjust the DC voltage for the desired output of the system. This can always be done if the system has a fixed gain at low frequency. It may be simpler to use a DC lab power supply or a pot across the +5 V reference voltage from the PWM chip to set the bias voltage initially since they are easy to adjust.



Adjusting operating point with laboratory power supply.



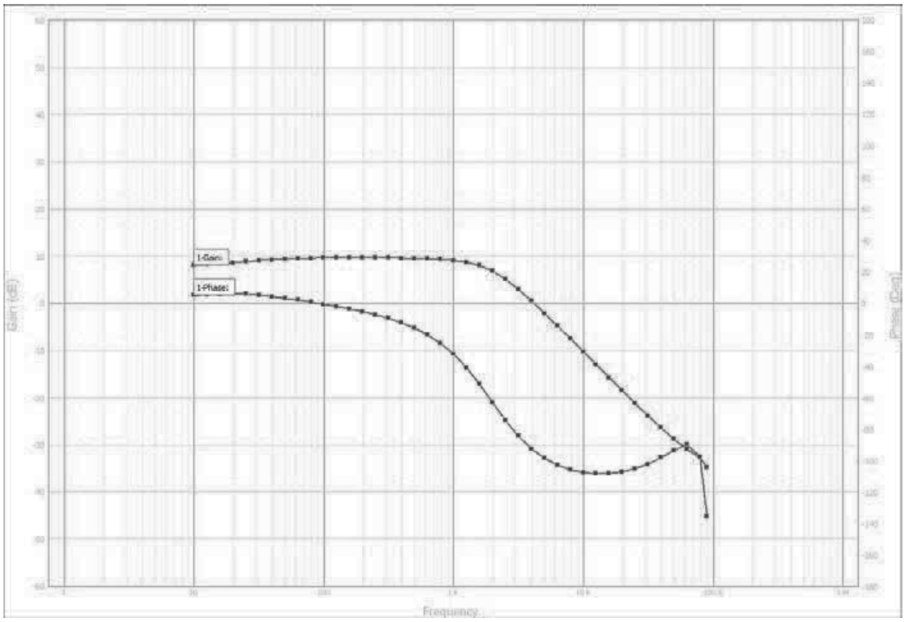
Adjusting operating point with pot across 5V reference of PWM chip.

The DC voltage can then be read with a voltmeter and the FRA output DC voltage pre-set to the approximate operating point. To set the DC output voltage of the FRA, open the Analyzer Control menu and set the "DC Volts Out" to the desired value. Then click the "Turn DC Volts ON" button to set the FRA output to that DC value. Once the approximate operating point is set, it is easy to increment the DC voltage from the FRA to "tweak" the system output to the desired value. The buttons next to the DC voltage setting box increment the DC voltage in 10 mV increments. The DC output voltage is not affected by the sweep.

3. If you haven't already done so, connect Channel 1 of the FRA to the input of the modulator (the error amplifier output) and Channel 2 of the FRA to the output of the modulator (the system output). Use the furnished BNC-Mini-grabber cables unless the system under test is affected by the capacitance of the cables. If it is, use a 10:1 scope probe on both Channel 1 and Channel 2. (See the section on calibrating probes in the advanced applications portion of this manual.)

4. In the Analyzer Control window, set the AC volts to a small number, typically 10 millivolts or less depending on how much you want to modulate the operating point. If you are not sure, start low and raise the voltage slowly while monitoring the amount of modulation you are injecting. When you click the "Take Data at Start Freq" button, the FRA will output that small signal superimposed on the DC voltage. The modulator output will be the modulator input multiplied by the modulator gain, therefore the ratio of output voltage to input voltage is the modulator gain.

5. To get the modulator transfer function, click the "Run Sweep" button in the Analyzer Control window. The measurement system will then automatically sweep the frequency of the AC portion of the FRA output signal from the start frequency to the stop frequency at the specified number of steps per decade and display the gain vs. frequency and phase vs. frequency data on the graph.

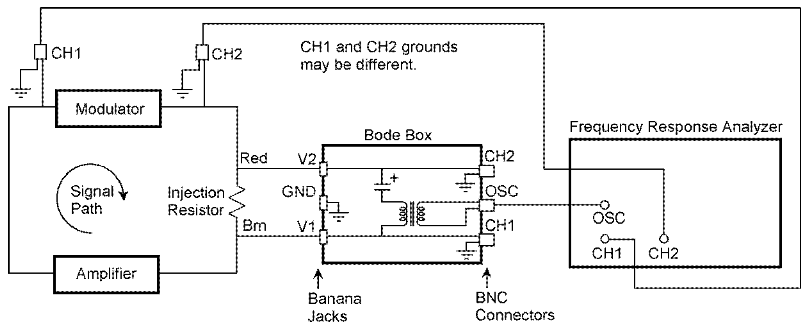


Modulator Transfer Function

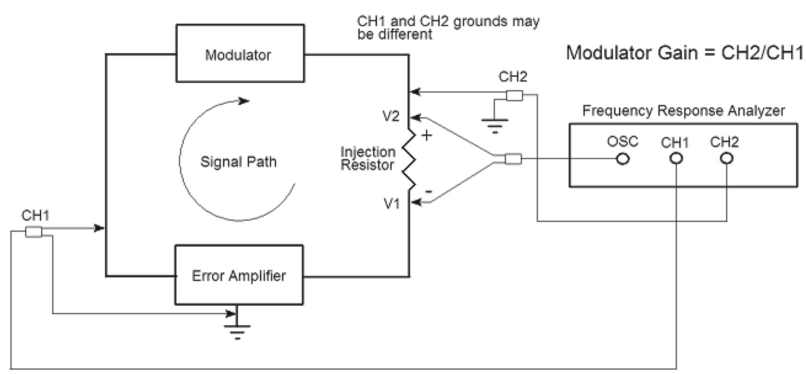
Measuring a Modulator Transfer Function – Closed Loop Method

The open loop method described in the previous section is the best method for going directly to the desired system performance without any trial-and-error. Quite often, however, the loop is already closed and the objective is to "fix" the loop rather than design it. In this case, the modulation signal is injected as an error voltage in series with the feedback loop exactly as it is when measuring loop gain (see section on measuring loop gain).

The principal difference between measuring the modulator and measuring the loop is that the simple connection where the injection signal is connected automatically to the FRA inputs through internal connections in the Bode Box injection transformer is not used. The Bode Box injection transformer is still needed to inject the signal to vary the operating point, unless the analyzer has a floating oscillator. Separate BNC-Minigrabber or scope probe connections are used to measure the modulator input and output voltage, just as in the open loop case.



The advantage of measuring the modulator transfer function while the system under test is operating closed loop is that the bias adjustment procedure described in the previous section is not needed. The disadvantage is that the signals are generally noisier and the accuracy is not as good, especially at high frequency.



Measurement with a Floating Oscillator and No Transformer

Servo Control Recommended

The Servo Control dynamically changes the AC Volts Out to keep an input channel at a fixed voltage while the analyzer takes data. The Servo Control compares the input voltage on the monitored channel to the AC Volts In and changes the AC Volts Out until they are equal. It changes the AC Volts Out by a maximum of AC Out Step Size. This feature is helpful in preventing the analyzer oscillator from overdriving the circuit past Max AC Volts Out during a sweep. The recommendation is to set Servo on the output channel (typically channel 2) at 20 mV to 30 mV and Max AC Volts Out to your circuit limits below the maximum output of 10 Vpk.