Errata

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HP References in this Application Note

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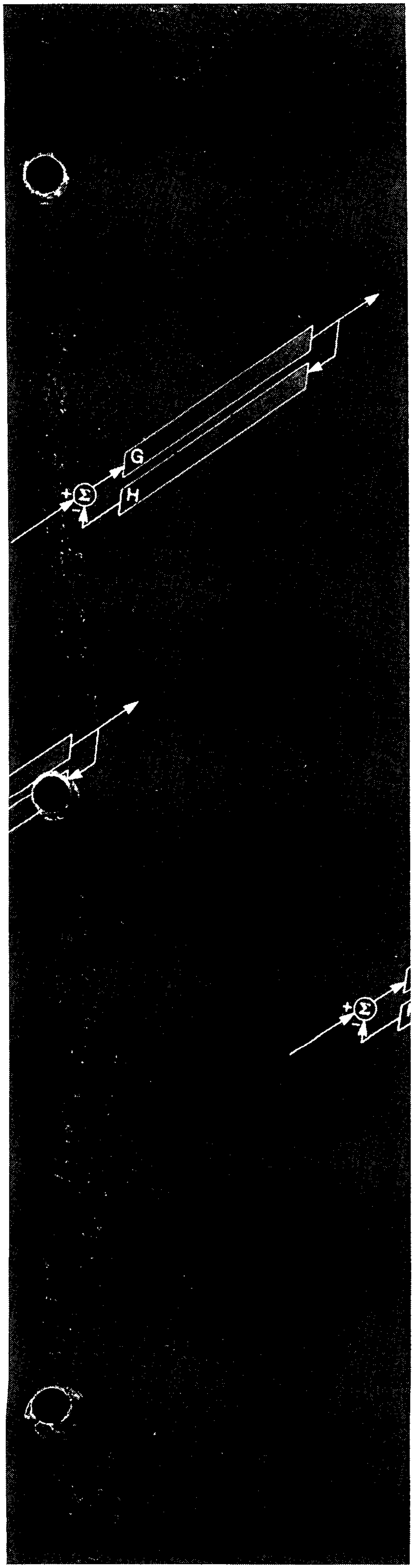


APPLICATION NOTE 243-2
SUPPLEMENT

HEWLETT PACKARD

Measuring Switching Power Supply Stability with the HP 3562A

OVERVIEW

There are two measurement techniques that will give you an accurate measurement on the stability of a switch power supply while the power supply is operating. The first technique consists of injecting a sine wave signal into the power supply control loop and measuring two signals at different points in the control loop. This measurement will directly give the open loop frequency response. The second technique consists of applying a sine wave signal on top of a DC offset at the reference voltage point on the comparator circuit and measuring the DC output. This measurement will give the closed loop response, T, which will yield the open loop frequency response after a, T / (1-T), math calculation.

The injection point must meet the following criteria in the first technique:
1) The signal is confined to one path and 2) the impedance looking into the input of the feedback circuits be high relative to the impedance looking into the output of the feedback loop.

The comparator circuit must meet the following criteria in the second technique:
1) The comparator is an ideal summing junction over the frequency range that determines the phase and gain margin and 2) the measurement takes into account all the control loops in the circuit.

MEASURING STABILITY USING THE INJECTION TECHNIQUE

Figure 1 outlines the major blocks in a voltage mode switching power supply. The injection point selected in figure 1 meets the injection criteria since 1) the signal is limited to one path; and 2) the impedance looking into the pulse width modulator (PWM) is large compared with the impedance looking into the output of the loop shaping circuits.

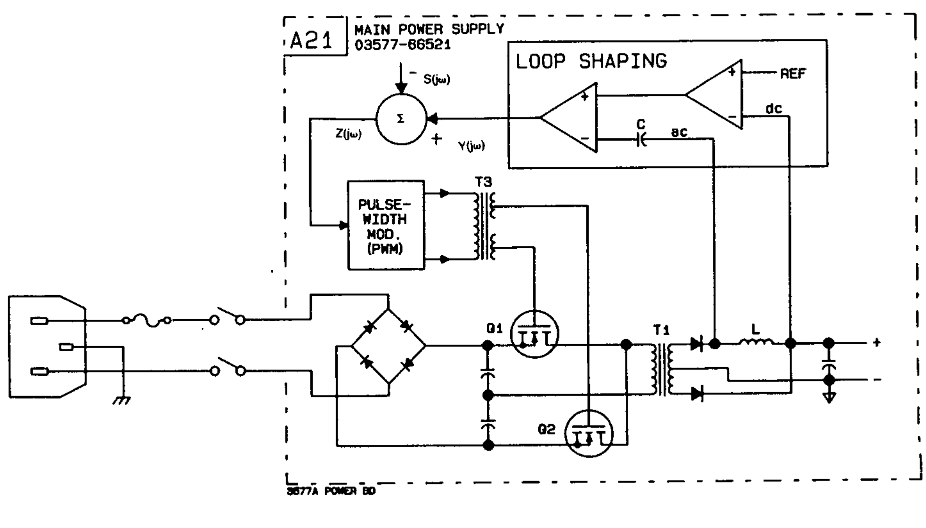


Figure 1: *Block diagram of the switching power supply used in the HP 3577A 200 MHz Network Analyzer.*

Two types of signal injection devices can apply the sine wave perturbation into the control loop. Figure 2 shows a OP-AMP injection device and figure 3 shows a transformer injection device. The OP-AMP technique has a flat frequency response function over a 0-2 MHz frequency range while the transformer technique has a flat frequency response over a 20 Hz to 200 MHz frequency range. Moreover the OP-AMP technique will yield a better S/N value when the sine wave perturbation amplitude needs to be under 50 mv peak. Figure 4 shows that the OP-AMP and transformer injection technique give the same open loop frequency response using the injection point shown in figure 1.

After a suitable injection point and injection device has been chosen it is time to make the open loop frequency response measurement. Connecting the HP 3562A analyzer as shown in figure 5 will yield the open loop response with a phase shift of 180 degrees. This phase shift is inherent in the injection technique and can be taken out of the measuremnt by using the 3562A Math Negate function. To make the measurement use the key sequence outlined in table 1.

Table 1: *Injection HP 3562A setup*

```
 1   MEAS MODE, SWEPT SINE
 2   AVG, INTGRT TIME 2 Sec
 3   AVG, AUTO INTGRT 50 PERCNT
 4   FREQ (SPAN), FREQ SPAN 20.50000 kHz
 5   FREQ (SPAN), RESLTN 59.2 Points /Dec
 6   FREQ (SPAN), RESLTN AU FIX (1/0) 1
 7   SOURCE, SOURCE LEVEL 50 mV
 8   RANGE, AUTO 1 UP&DWN
 9   RANGE, AUTO 2 UP&DWN
10   INPUT COUPLE, CHAN1 AC  DC (1/0) 1
11   INPUT COUPLE, CHAN2 AC  DC (1/0) 1
12   INPUT COUPLE, GROUND CHAN1
13   INPUT COUPLE, GROUND CHAN2
14   CAL, SINGLE CAL
15   CAL, AUTO ON OFF (1/0) 0
16   A
17   MEAS DISP, FREQ RESP
18   B
19   MEAS DISP, FREQ RESP
20   START
```

The hardkeys and softkeys located directly underneath the 3562A CRT are used to display the data in a variety of different formats on the CRT. For example a Nyquist diagram or Nichols chart can be displayed on the CRT with COORD. The 180 degree phase shift that is inherent in the injection technique can be removed by using the key sequence outlined in table 2.

Table 2: *Remove 180° phase shift from Injection measurement*

```
1   A
2   MEAS DISP, FREQ RESP
3   COORD, MAG <dB>
4   B
5   MEAS DISP, FREQ RESP
6   COORD, PHASE <CENTER> 0 Degree
7   A B
8   MATH, NEGATE
```

Figure 2: *OP-AMP Injection Device*

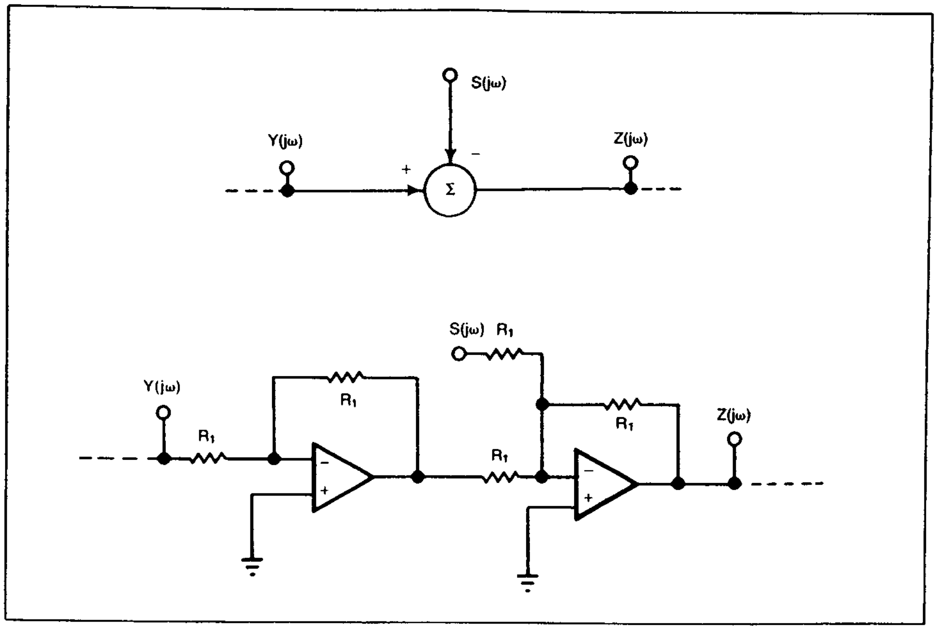


Figure 3: *Transformer Injection Device*

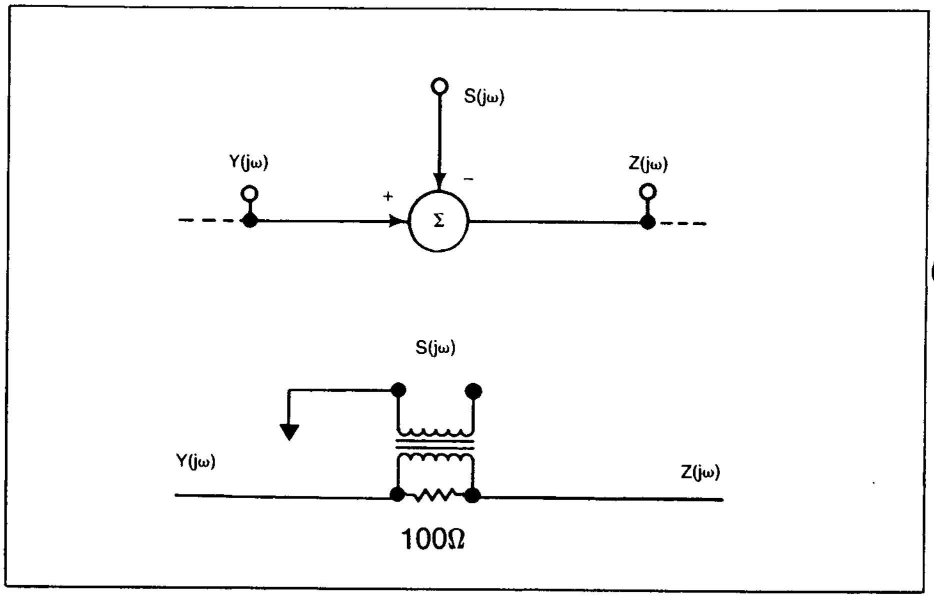
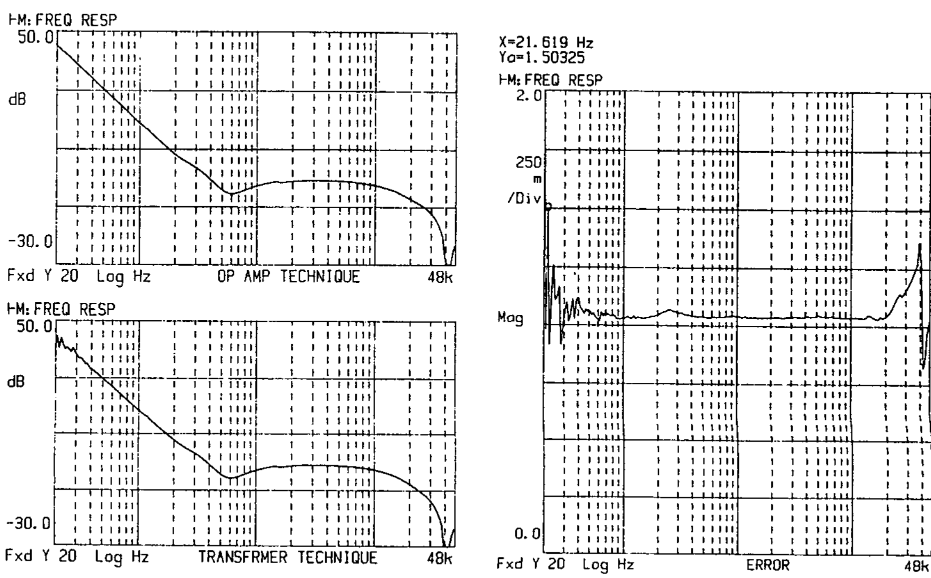


Figure 4: *Comparison between a OP-AMP and transformer injection device.*



Now the gain and phase margins can be measured using the MARKER values displayed in figure 6. To verify that your measurement results are correct look at the closed loop frequency response to make sure that the gain approaches 1 and the phase approaches 0 degrees as the frequency approaches DC. Again the 3562A math capability can derive the closed loop response (figure 7) by simulating Closed Loop Response = Open Loop Response / (1+Open Loop Response) with the Add, Recip, and MPY math keys.

Table 3: *Reference HP 3562A setup*

```
1  MEAS MODE: SWEPT SINE
2  AVG: INTGRT TIME 2 Sec
3  AVG: AUTO INTGRT 50 PERCNT
4  FREQ (SPAN): FREQ SPAN 20.50000 Hz
5  FREQ (SPAN): RESLTN 59.2 Points /Dec
6  FREQ (SPAN): RESLTN AU FIX (1/0) 1
7  SOURCE: DC OFFSET 5 V
8  SOURCE: SOURCE LEVEL 50 mV
9  RANGE: AUTO 1 UP&DWN
10 RANGE: AUTO 2 UP&DWN
11 INPUT COUPLE: CHAN1 AC  DC (1/0) 1
12 INPUT COUPLE: CHAN2 AC  DC (1/0) 1
13 INPUT COUPLE: GROUND CHAN1
14 INPUT COUPLE: GROUND CHAN2
15 CAL: SINGLE CAL
16 CAL: AUTO ON OFF (1/0) 0
17 START
```

Figure 5: *HP 3562A Connections for injection measurement.*

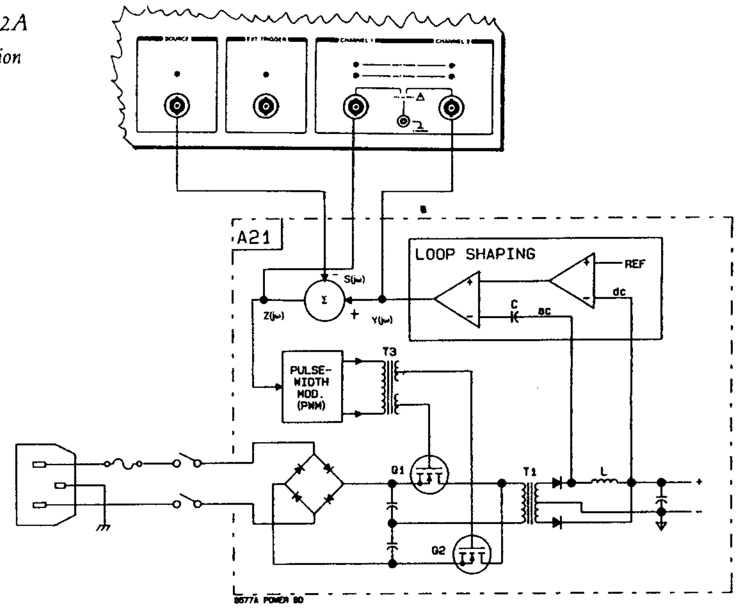


Figure 6: *Gain and Phase margins using the OP-AMP technique.*

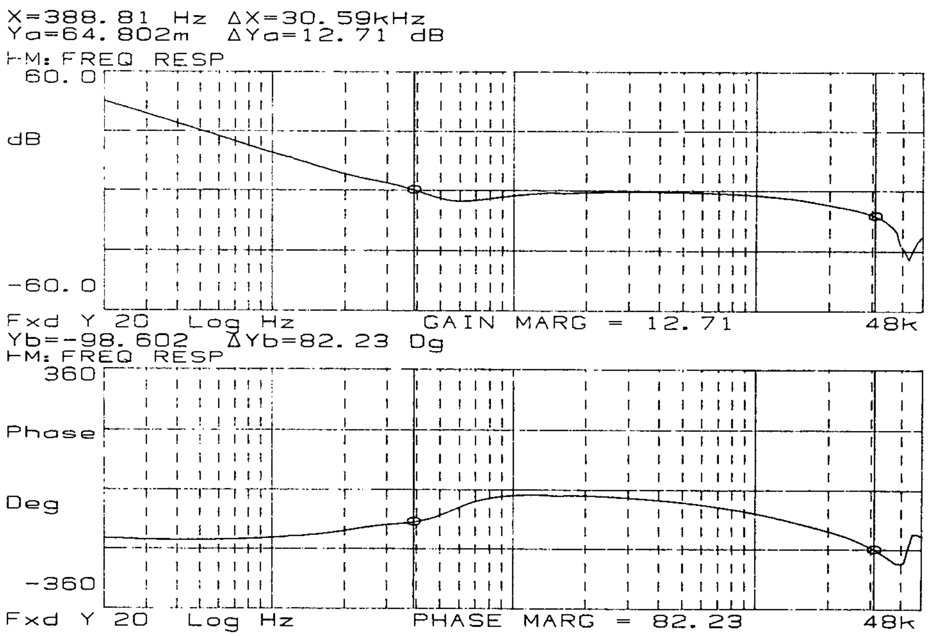
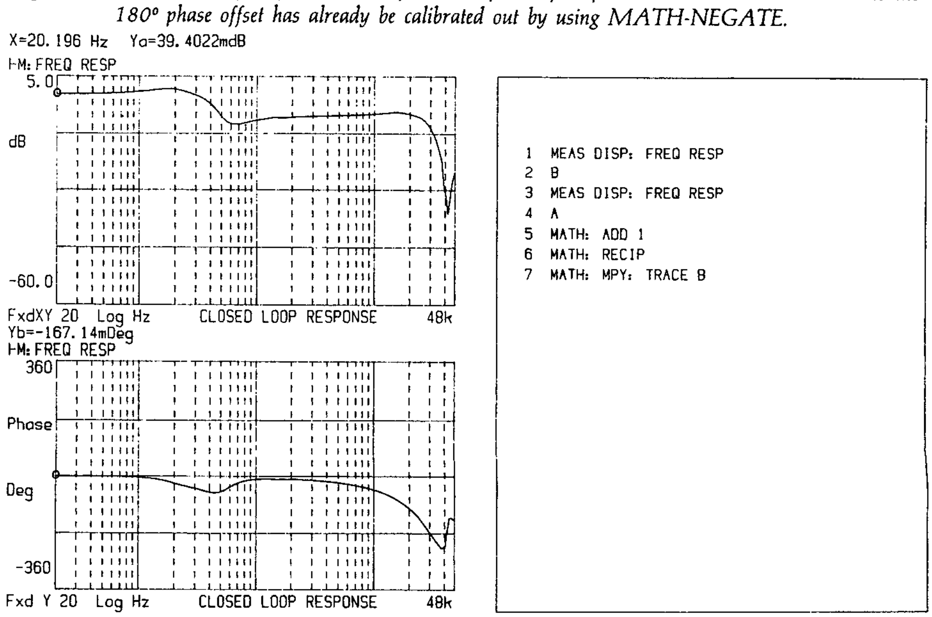


Figure 7: *The closed loop response derived from the open loop response. The Math routine assumes the 180° phase offset has already be calibrated out by using MATH-NEGATE.*



MEASURING STABILITY USING THE REFERENCE TECHNIQUE

Figure 8 shows a single control loop switching power supply. The reference technique meets the comparator criteria since 1) this is a single control loop power supply; and 2) the comparator is an ideal summing junction over the frequency range that determines the phase and gain margins. The 3562A will provide both the DC reference signal and the sine wave perturbation signal. Connecting the 3562A as shown in figure 8 will yield the closed loop frequency response. The open loop frequency response is derived from the closed loop frequency response by using the 3562A Math T / (1-T) functions where T is the closed loop frequency response measurement. To make the measurement use the key sequence outlined in table 3.

After the measurement is complete use the hardkeys and softkeys located underneath the CRT to display the frequency response function. This measurement is the closed loop response and as the frequency approaches DC the gain should approach 1 and the phase should approach 0 degrees. Use T / (1-T) to derive the open loop frequency response where T is the closed loop frequency response. Figure 10 shows the phase and gain margin. Figure 11 shows the effect of the comparator not being an ideal summing junction at frequencies below 140 Hz by comparing the measurement to the results obtained by using the OP-AMP injection technique.

SUMMARY

The reference measurement technique is the easiest measurement to make since the measurement points are at easily accessible points in the circuit. However one must make certain that the comparator is an ideal summing junction over the gain and phase margin frequency range and all the control loops of interest are included in the measurement. This technique could not be used with the power supply shown in figure 1 because there are two control loops in the feedback path.

The injection technique will always work provided that the injection point meets the single path and impedance criteria. However this technique requires extra measurement hardware and the desired injection point is difficult to access.

Finally, the 3562A provides some powerful post measurement analysis functions. The CURVE FITTER, SYNTH, and MATH keys will allow you to ask "What if" questions with the measured data.

Figure 8: *Single control loop switching power supply*

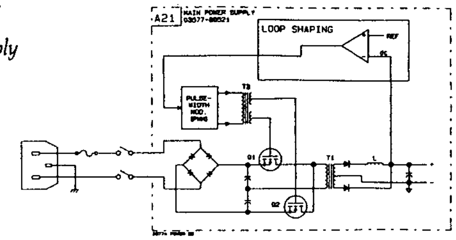


Figure 9: *HP 3562A connections for reference measurement*

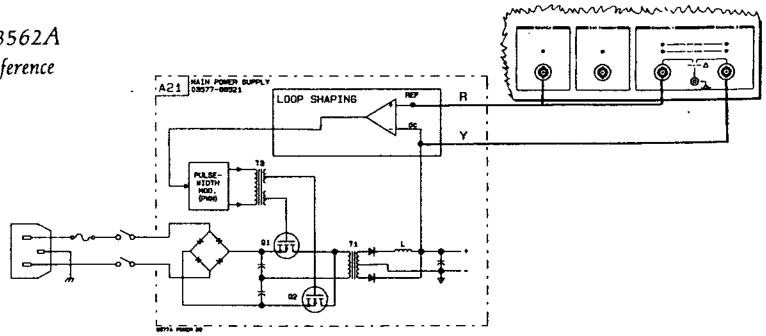


Figure 10: *Gain and phase margin after deriving the open loop response from the closed loop response*

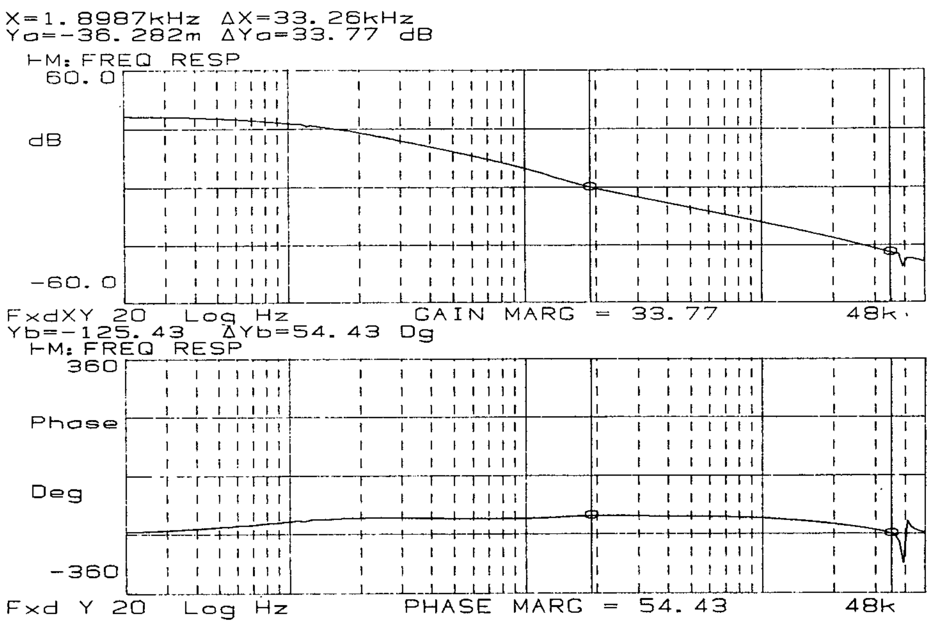


Figure 11: *Comparison between injection and reference measurement technique.*