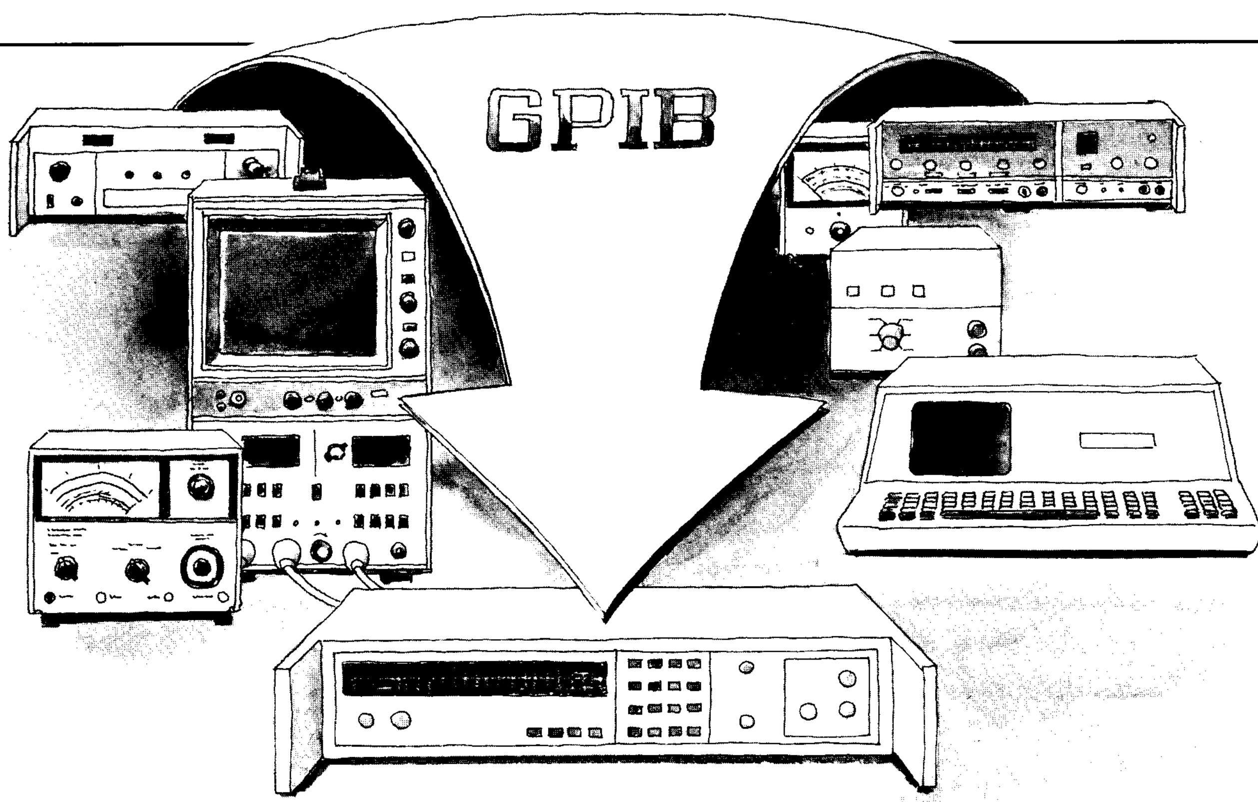
APPLICATION NOTE #203

GPIB CONTROL OF NON-GPIB SIGNAL SOURCES

Fully automatic test and measurement systems, usually called Automatic Test Equipment (ATE), are becoming increasingly important in improving efficiency. A single controller can supervise the operation of a full complement of instruments which are all connected to a General-Purpose Interface Bus (GPIB). Such a system can make a great many measurements quickly and accurately—without the constant attention of highly skilled and highly paid technical personnel.



The ATE Designer's Problem

The IEEE standard covering the GPIB was introduced in 1975. Although its value was quickly apparent, it took time for manufacturers to design and build equipment to accommodate GPIB control. The first available equipment, of course, was the simplest to adapt to digital control—such instruments as digital voltmeters and frequency counters. Complex analog devices, such as microwave sweep generators, were among the last to be offered with GPIB control capability.

Such signal sources have always been expensive, and the new GPIB-controlled versions cost even more. Since many companies have large investments in sweepers which cannot be retrofitted for GPIB control, some ATE designers have resorted to "stop-gap" measures to make use of existing equipment.

For example, Figure 1 shows a GPIB-controlled frequency counter combined with a D/A converter to form a frequency-control loop. The software must be set up so the controller can issue instructions, read the result, then repeat the process until the desired frequency is achieved. The arrangement works, but it is quite slow, and it provides limited frequency accuracy. It is used simply because the cost of available alternatives is too high.

Another problem facing the ATE designer who is involved with microwave frequencies is the rapid move to higher frequencies. While 18 GHz was recently considered a high frequency, signals of 100 GHz and above are not uncommon now. Sources operating at these frequencies seldom include GPIB control. Moreover, the solid-state sources that operate in the millimeter-wave region are typically quite unstable. They can vary by tens of megahertz in a few seconds. As a result, this new frequency area, with the limited availability of signal sources, presents a special challenge to the ATE designer.

Cost-Effective Solution

EIP Microwave has developed a simple, easily implemented way to put the frequency of virtually any electrically controllable microwave source under GPIB control. The only additional equipment required is an EIP Model 575 or 578 source-locking frequency counter. (The primary difference between the two models is the frequency range: 10 Hz to 18 GHz for the 575, and 10 Hz to 110 GHz for the 578.) Since the cost of one of these counters is a fraction of what a new sweeper would cost, the savings can be substantial.

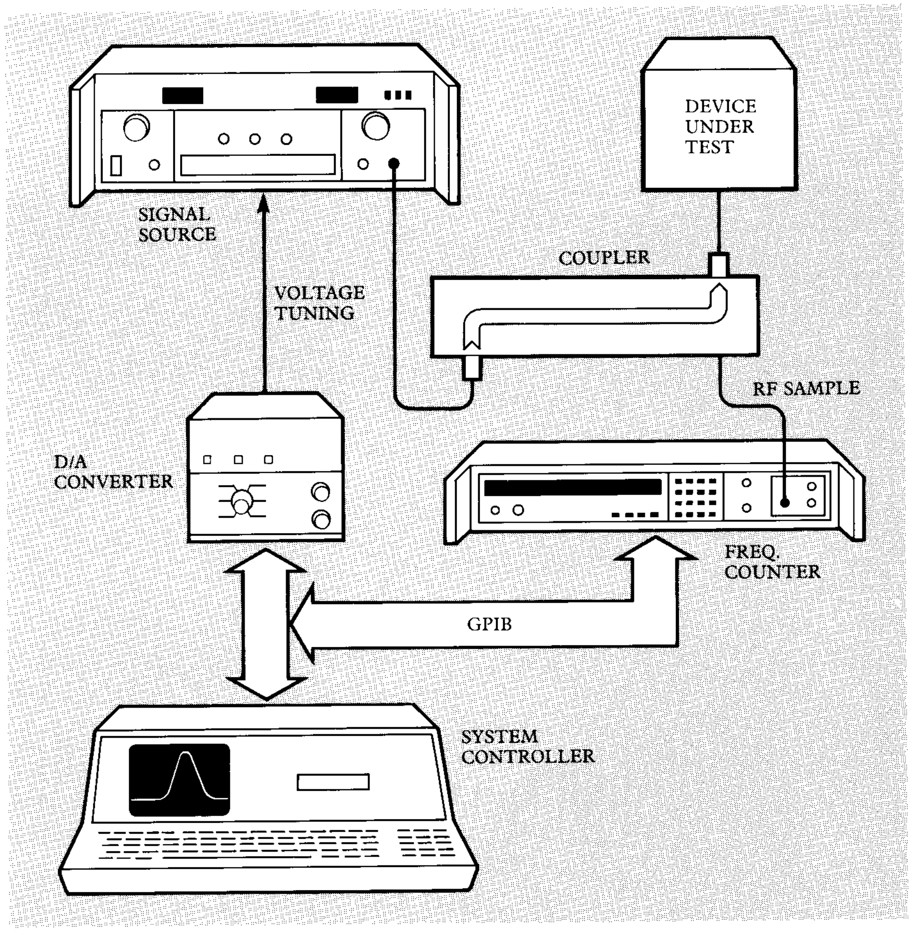


Figure 1. *Software frequency-lock loop suffers from slow operation and limited frequency accuracy.*

As Figure 2 indicates, only three cables between the counter and the signal source are required to permit the counter to exercise full frequency control over the source. One cable provides a sample of the RF output to the counter, while the other two carry the coarse-tune and phase-lock commands to the sweeper. The system controller supervises the counter through its built-in interface.

The only necessary GPIB commands are instructions to the counter. And the only monitoring required of the controller is to check the lock status bit from the counter. The results that can be obtained with existing signal sources are dramatic, in terms of both speed and accuracy.

In contrast, the frequency-loop arrangement of Figure 1 requires the controller to communicate directly with the signal source and the counter.

Flexibility in equipment arrangements is another advantage of using the source-locking counter. Since the only software instructions issued by the controller are those to the counter, signal sources can be easily changed to meet new requirements. A new source can be put into the ATE system simply by connecting the three cables to the counter.

Of course, this interchangeability also offers software standardization among all ATE systems that use source-locking counters. The HP-85 subroutines shown in Figure 3 apply, regardless of the signal source used in a particular system.

Program	Remarks
100 OUPUT 719 ;"PF"&VAL$(F)&"G"	Instruct the counter to Lock
110 WAIT 1000	
120 ENTER 719 ; R	Read the frequency
130 DISP R	
200 END	

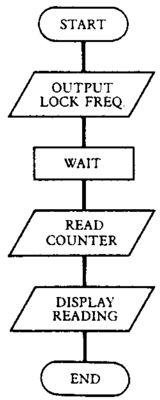


Figure 3a. *Represents the simplest of programs to tell the counter to lock frequency F (Line 100). Wait 1 second (Line 110) and read and display the frequency (Lines 120 and 130).*

Program	Remarks
100 OUTPUT 719;"B3R3PF"&VAL$(P)&"G"	Set counter to Band III on Lock instruction
110 S=SPOLL(719)	Monitor Status byte for Ø Lock indication
120 IF BIT(S,3)=1 THEN 140	
130 GOTO 110	
140 ENTER 719 ; R	
150 DISP R	
200 END	

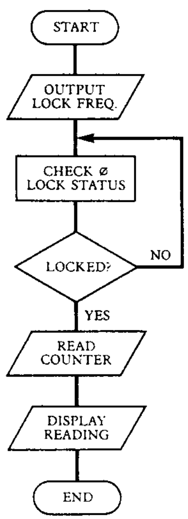


Figure 3b. *Represents a program with minimum time of execution for a lock at a specific frequency F thru the use of serial Poll to check for Ø Lock (Line 110 and 120).*

Program	Remarks
1060 SET TIMEOUT 7;10000	Breaks Program if handshake fails
1070 ON TIMEOUT 7 GOTO 8000	
1080 OUTPUT 719 ;"SR08B41R3"	Set counter for SRQ on Ø Lock, Band 41, 1KHz Resolution
• • • • • • •	
6825 ON INTR 7 GOTO 9000	Configure IO for Service Request Interrupt
6830 ON TIMER# 1,5000 GOTO 9500	Breaks program if counter fails to Lock
6835 OUTPUT 719 ;"PF"&VAL$(F(S))&"G"	Instruct Counter to Lock
6840 ENABLE INTR 7;8	
6850 WAIT 10 @ GOTO 6850	
• • • • • • •	
8000 OFF TIMEOUT 7	Inhibit Timeout interrupt
8010 PRINT "HP-IB Timeout"	Reset all instruments on the bus
8020 RESET 7	Return to the beginning of the program
8030 GOTO 100	
• • • • • • •	
9000 OFF TIMER# 1	Inhibit Timer #1 interrupt
9005 STATUS 7,1 ; A	Read status bit to clear SRQ
9010 ENTER 719 ; S1	Read count
9020 PRINT S1	Display count
9025 F(S)=F(S+1)	Increment Lock frequency
9030 IF F(S)>=40 THEN 9999	
9035 GOTO 6825	
• • • • • • •	
9500 IF N=1 THEN 9990	Limit attempt to Ø Lock to two
9505 N=N+1	
9510 GOTO 6825	
• • • • • • •	
9990 PRINT "NO PHASE LOCK ACHIEVED AT";F(S);"GHz"	
9995 N=0	
9999 END	

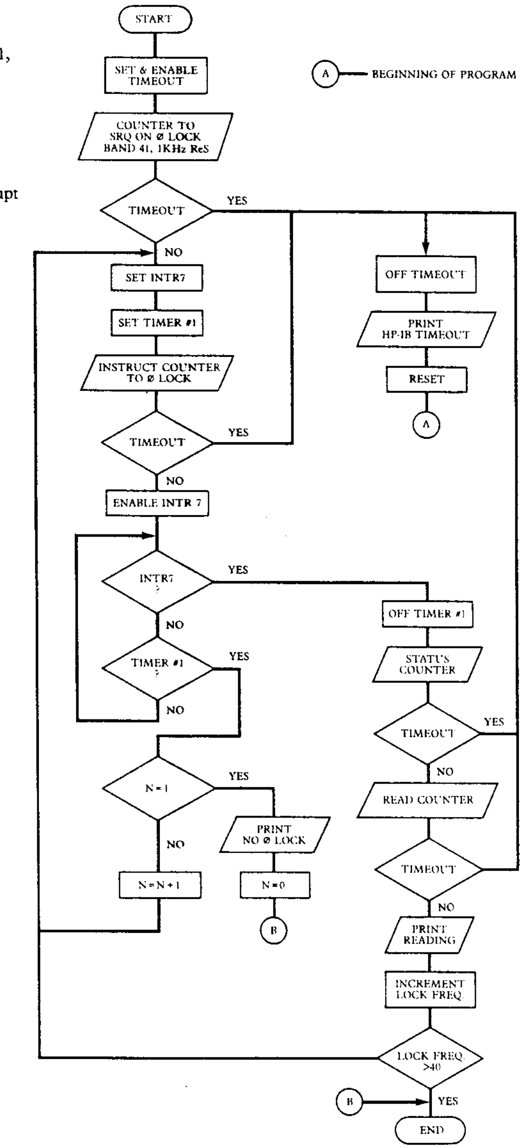


Figure 3c. *Represents a portion of a complex system program with precautions taken to deal with problems in the handshake routine and failure to achieve a Phase Lock. This program also implements the Service Request function to indicate when Phase Lock has been achieved.*

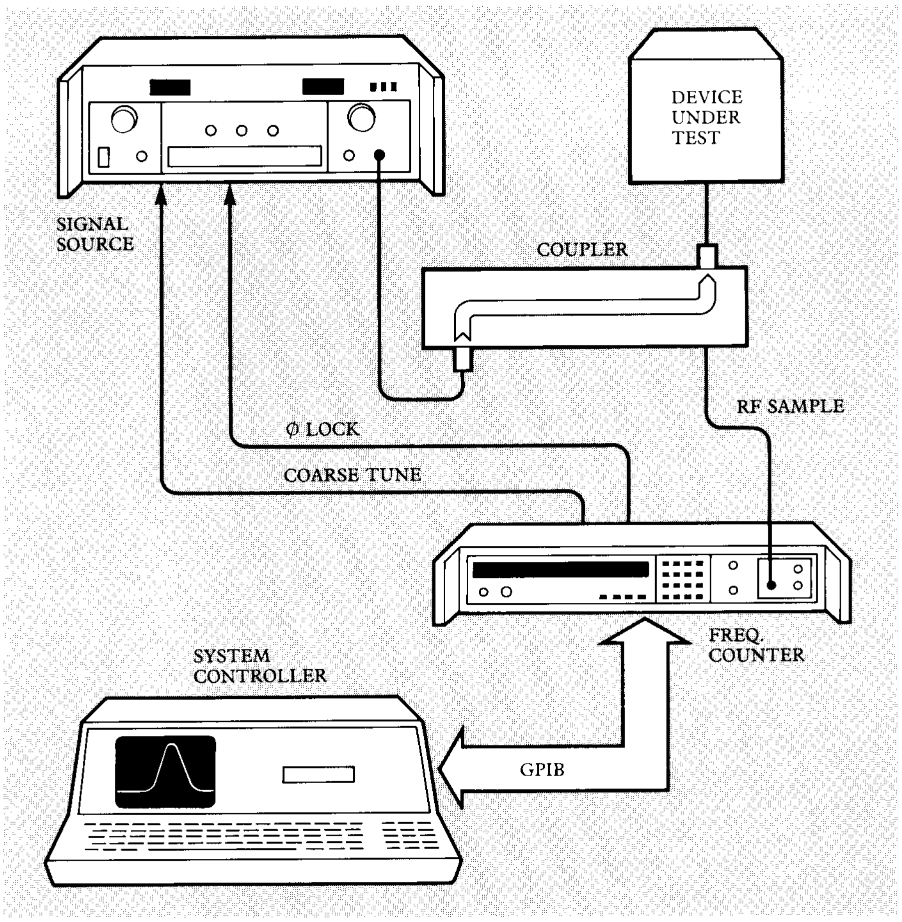


Figure 2. *Source-locking loop uses EIP 575 or 578 counter to provide rapid response and frequency accuracy equivalent to counter's time base.*

Added Value

Source locking is only one function of the 575/578 counters. They not only offer the flexibility of general-purpose counters, but they include other capability (also under GPIB control) that might otherwise require additional instruments:

1. Optional power measurement provides the simultaneous measurement of signal frequency and power.
2. A frequency-limiting feature permits spectral analysis. Both the frequency and power of individual signals can be measured in a multi-signal environment—even when unwanted signals are stronger.

Such capability, combined with a frequency range of up to 110 GHz, offers the ATE designer almost unlimited possibilities.

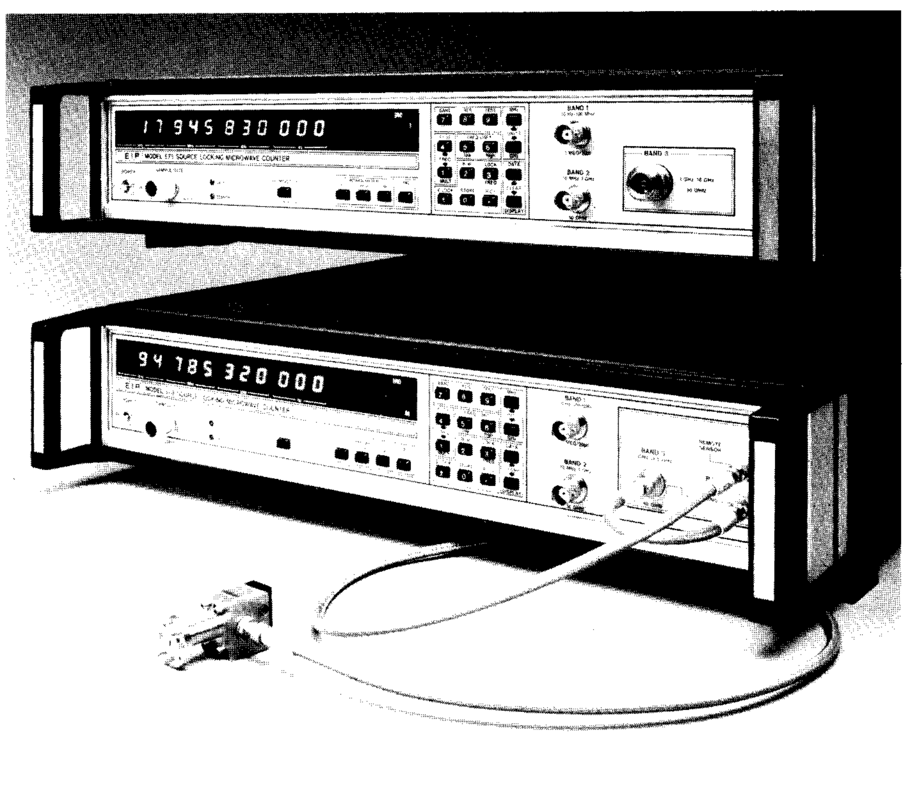
More Information

EIP Microwave publishes application notes on a variety of subjects involving high-performance counters. And an applications-engineering staff is available to provide advice and answer specific questions. For more information, contact EIP or any EIP representative.

Performance

The accompanying specifications show the basic source-locking performance of the 575 and 578 counters. Most microwave sources (even the older ones) meet the counter's requirements. This provides an opportunity to extend the useful life of equipment that might otherwise be considered obsolete.

Since most microwave sweepers provide poor frequency accuracy, some applications require a very expensive synthesizer. Now the same accuracy can be achieved by *putting* an ordinary sweeper under the control of a source-locking counter. Then the frequency accuracy becomes as good as the counter's time base. With the standard 575/578 time base, this means short-term accuracy of one part in 10^9. The optional oven-controlled time base offers accuracies of up to one part in 10^{11}. While the source-locking arrangement does not transform an ordinary sweeper into a synthesizer, it approximates much of the synthesizer's costly performance.



EIP's 575/578 series counters combine frequency measurement and source locking capability to 110 GHz.

SOURCE LOCKING SPECIFICATIONS

Frequency Range	10 MHz-Max. capability of counter.
Resolution	10 kHz for phase lock freq. ≥ 50 MHz 2.5 kHz for < 50 MHz
Accuracy	Equal to counter's Time Base
Long Term Stability	Equal to counter's Time Base
Minimum Phase Lock Signal Level	Equal to counter sensitivity
Polarity	Automatically selected
Bandwidth	User select, 10 kHz, 2 kHz or 500 Hz, or automatically selects widest bandwidth capable of locking.

LOCK TIME (Typical)

Coarse Tune	50 m sec + 1 counter aquisition time for source bandwidth greater than 100 Hz; limited by source tuning speed below 100 Hz.
Phase Lock	200 m sec
Recall Stored Data	1 counter aquisition + 100 m sec limited by source tuning speed.

OUTPUT DRIVE (Maximum)

Coarse Tune Output	+ 10 V into 5 K ohm min.
Phase Lock Output	±10 V into 5 K ohm min for source gain constant <64 MHz/V. ±75 MA into 10 ohm max for source gain constant <3.2 MHz/MA. ±.6 V into 5 K ohm min for source gain constant ≥64 MHz/V. ±4.5 MA into 10 ohm max for source gain constant ≥3.2 MHz/MA.

CAPTURE RANGE

Coarse Tune	Entire range of selected counter band limited by maximum output drive.
Phase Lock	Source gain constant X maximum output drive.

OUTPUT CONNECTOR

Coarse Tune	Rear panel BNC, female
Phase Lock	Rear Panel BNC, female

PHASE LOCKED SPECTRUM (See figure below)

Noise Floor vs Input Frequency:
The noise floor extends from the carrier to approximately the loop bandwidth. Beyond this the noise floor decreases 12 dB/bandwidth octave. The noise floor is the greater of:

1. NOISE FLOOR = .70 dBC/Hz
2. NOISE FLOOR = (20 log F -65) dBC/Hz
   where F = Input frequency in GHz

REQUIRED SOURCE CHARACTERISTICS

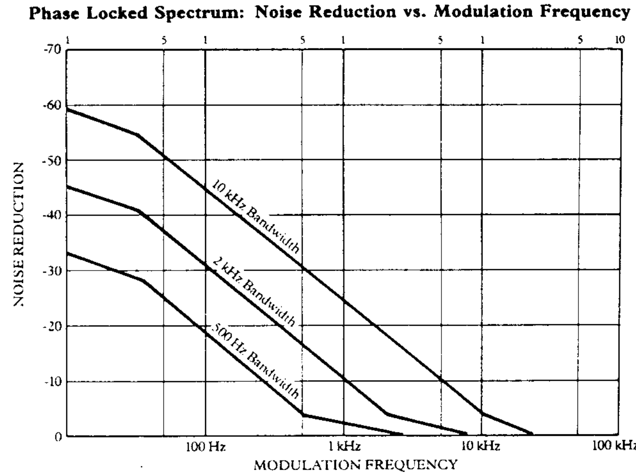
External Sweep (Coarse Tune) Input:

Bandwidth	5 Hz minimum
Tuning Sensitivity	10 MHz/V minimum; 10 GHz /V maximum

FM (Phase Lock) Input:

Bandwidth	2 kHz minimum
Tuning Sensitivity	
Voltage Driven Input	±2 MHz/V minimum ±1000 MHz/V maximum
Current Driven Input	±0.1 MHz/mA minimum ±50 MHz/mA maximum

Phase Locked Spectrum: Noise Reduction vs. Modulation Frequency



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