Errata

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1000 Computer Programming Guide (AN 401-16)

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HP References in this Application Note

This application note may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this application note copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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HP 436A Microwave Power Meter ⟷ HP-IB ⟷ HP 1000 Computer

Programming Guide

HEWLETT PACKARD

Application Note 401-16

Device Introduction

The HP 436A power meter is a general purpose digital power meter intended for RF and microwave power measurements. Power meters are usually indispensible for microwave measurement. At microwave frequencies, power is the best measure of signal amplitude because, unlike voltage and current, power remains constant along a lossless transmission line.

The 436A power meter is designed to be connected to a compatible power sensor to form a complete power measurement system. The frequency and power range of the system are determined by the particular power sensor selected for use. With the power sensors available from Hewlett-Packard, the overall frequency range of the system is from 100 kHz to 18 GHz, and the overall power range is −70 to +45 dBm.

The power meter has five ranges, and can automatically switch these ranges (autoranging), or be set and locked to a particular range. The power meter automatically decodes the sensitivity of the power sensor to which it is connected. This information is then used to control the decimal point location and set the appropriate power unit multiplier.

The 436A power meter can read in either absolute power or relative power. Absolute power can be read out in either watts or dBm. Relative power is read out in dB. Although relative power measurments are useful in manual testing, the relative mode is seldom required when the power meter is connected to an HP 1000 computer system. The HP 1000 can compute the relationship between two values much faster than the power meter. Therefore, power measurements tend to be absolute when taken in an HP-IB system.

Addressing

In the 436A, the HP-IB TALK and LISTEN address can be set by either jumpers or switches located on the A6 printed circuit board assembly. The factory usually presets the power meter address to 15 octal. *If more than one power meter is used in a system, make sure that each power meter has a seperate HP-IB address.*

To set the HP-IB address, perform the following steps:

a. Disconnect the power line.

b. Disconnect any HP-IB cables from the HP-IB connector on the power meter.

c. Remove the top cover of the power meter.

d. Locate the A6 printed circuit board assembly (refer to figure 16-1). It is parallel to the front panel, and furthest back (closest to the power supply).

e. If the A6 board has switches, set the switches. Refer to figure 16-2 for switch positions. Replace the top cover, power cord, and HP-IB cables.

f. If the A6 card has jumpers, the A7 board should be removed. The A7 board is perpendicular to the A6 board and has the HP-IB connector attached to it. Remove the two screws holding the A7 board assembly to the rear panel.

g. Unplug the flat cable connected to the A7 board. Pay attention to the direction which this plug goes. If replaced upside down, the data returning from the power meter will be garbled.

h. Set the jumpers on the A6 board, as shown in figure 16-2.

i. Reinstall the A6 and A7 boards, and reconnect the flat cable. Replace the screws holding A7 board.

j. Replace the top cover power cord and HP-IB cables.

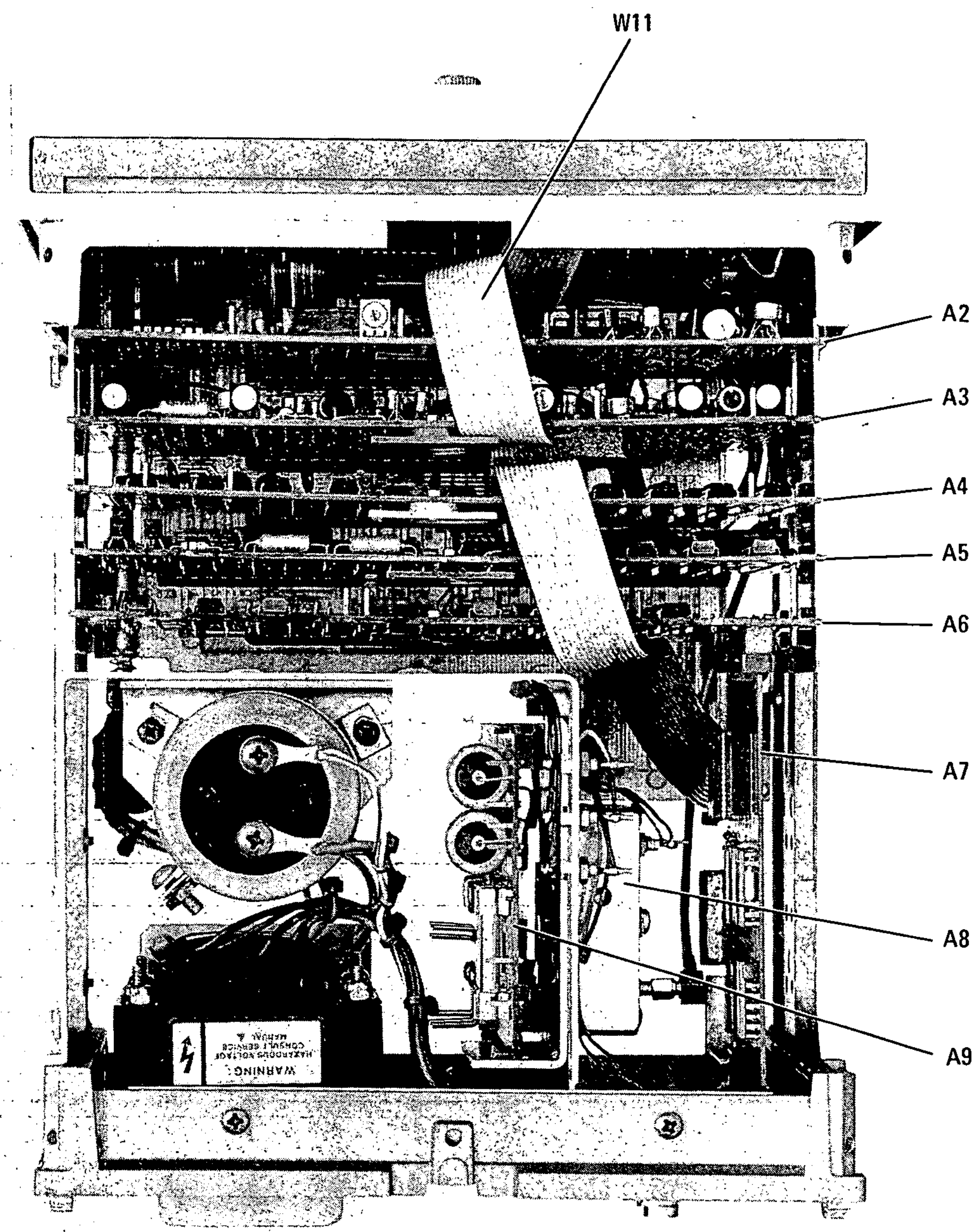

Figure 16-1. A6 Printed Circuit Board Location

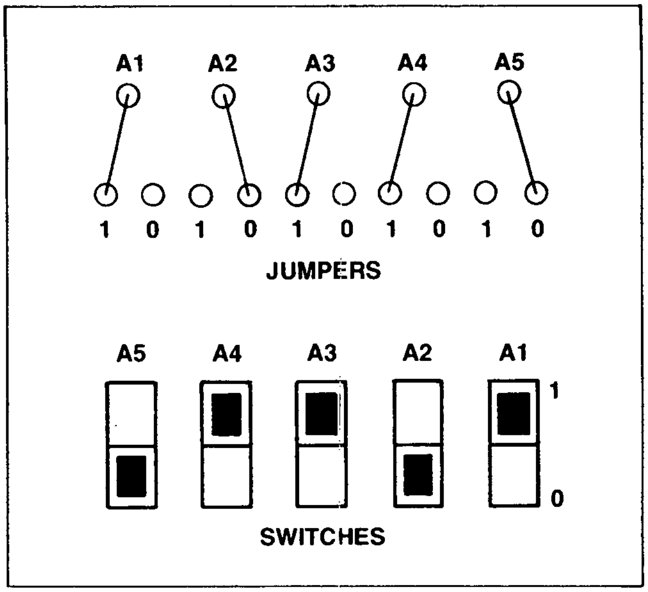

Figure 16-2. HP-IB Switch or Jumper Positions

System Preparations[1]

LU Assignment

One logical unit number (LU) should be assigned to the 436A power meter. After setting the power meter address as discussed above, assign a logical unit number. To do so from the File Manager:

```
:SYLU,15,10,15B
```

will assign LU 15 to equipment table 10. The device address associated with LU 15 will be 15 octal in this example.

Buffering

The buffering option for the 436A EQT is not needed. It should be turned off.

```
:SYEQ,10,UN
```

would set the equipment table in the above example to the unbuffered mode. Remember, the bus must be unbuffered if the user program performs its own error checking.

Time-out

In certain cases, the 436A power meter can delay response for up to 3 seconds. When selecting a time-out value for an HP-IB system, remember that the time-out value will affect all the devices on the same EQT, and should encompass the needs of all these devices.

From File Manager, a system request may be used to set the time-out value.

```
:SYTO,10,500
```

will set the time-out value on EQT 10 to 5 seconds.

Configuration

A time-out condition will be handled through RTE by default. However, the user program may handle the situation by setting the device configuration word accordingly. When bit 6 (the E bit) of the configuration word is 0, the operating system will set the logical unit of the 436A down after a time-out, and cause the user program to wait until the "UP" operator request is entered from a user terminal. This is called the "general wait state" in RTE.

When the E bit is configured to 1, the time-out will not stop execution of the user program. Instead, the current bus status should be checked by calling the subroutine "IBERR" each time an I/O request is made to determine whether the time-out has occurred.

Two examples of the device configuration word are shown in figure 16-3, one for operating system processing of the time-out condition, and the other for user program processing of the error.

A File Manager request may be used to adjust the error bit in the device configuration word. If the LU to be configured is 15, the File Manager command,

```
:CN,15,25B,17400B
```

declares that time-out processing will be performed by the user program. The File Manager command,

```
:CN,15,25B,17000B
```

declares that the system will handle time-outs.

DMA is not usually allocated for the 436A power meter. Typically, the two DMA channels in RTE are used for the faster devices in the system like magnetic tape drives, and discs. Leave bit 13 (the D bit) set to 0 in the device configuration word.

---

[1] *See the 436A Operating and Service Manual (part number 00436-90058) and Application Note 401-1 (5953-2800).*

Other bits also have specific meanings in the device configuration word as shown in figure 16-3. The I,J,O, and P Bits all default to the correct value of 1.[2]

Remote

The 436A does not need to be set into remote operation before programming operations can begin, and there is no remote indicator on the instrument. However, the HP-IB Bus can be placed in remote. To do so from File Manager,

```
:CN,15,16B
```

will place the power meter and bus into remote. Also, the statement

```
CALL RMOTE (15)
```

will remote-enable the bus from a FORTRAN program.

Programming

HP-IB programming of the 436A power meter is classical. First, the power meter is made a LISTENER. An ASCII string is sent telling the power meter the range, mode, calibration factor, and triggering technique to use. Then, the power meter is made a TALKER, and it sends back a reading. Table 16-1 shows the program codes for the power meter. For example:

```
    WRITE(15,101)
101 FORMAT("9D+T")
```

tells the power meter on LU 15 to autorange, take an absolute reading in dBm, disable the calibration factor switch, and trigger with internal settling time.

```
          15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
           S* R  D  I* J  O  P* E  X  X* X  X  X* X  X  X
          --*--------*--------*--------*--------*--------
           1  0  0  1  1  1  1  0  0  0  0  0  0  0  0  0
          --*--------*--------*--------*--------*--------
           1        1        7        0        0        0
          --*--------*--------*--------*--------*--------

   S=1  I/O REQUEST ABORTS ON AN SRQ.
   R=0  NO I/O RESTART ATTEMPT AFTER SRQ.
   D=0  DMA IS NOT ALLOCATED FOR THIS DEVICE.
   I=1  REQUIRE AN EOI FROM DEVICE WITH THE LAST BYTE.
   J=1
   O=1  ISSUE AN EOI WITH THE LAST BYTE.
   P=1
   E=0  HP-IB ERRORS WILL ABORT THE PROGRAM.
```

Figure 16-3. Configuration Evaluation

---

[2]Application Note 401-1, Chapter 3, describes a utility program called the BSCU that is used to observe the status of the HP-IB, including the configuration word.

Table 16-1. Program Codes for Input Messages

Function	ASCII Character
Range	
Least sensitive	5
	4
	3
	2
Most sensitive	1
Auto	9
MODE	
Watt	A
dB (Rel)	B
dB [Ref]	C
dBm	D
Sensor auto-zero	Z
CAL FACTOR	
Disable (100%)	+
Enable (front-panel switch setting)	–
Measurement Rate	
Hold	H
Trigger with settling time	T
Trigger, immediate	I
Free Run at maximum rate	R
Free Run with settling time	V

A feature available via remote programming is selection of standby, triggered, or free running operation of the 436A power meter. Normally, only the triggered mode is used. There are two commands for triggered operation:

a. *Trigger Immediate (I).* — This programming command directs the the power meter to make one measurement and output the data in the minimum time. The power meter then goes into hold mode until the next trigger command is received.

b. *Trigger With Delay (T).* — This programming command is identical to the "I" command except that it causes the power meter to delay taking the measurement by an internally generated time. The delay time is sufficient to insure that the power meter has settled to within 1% of its final reading on all but the most sensitive range.

On the most sensitive range the 0-99% response time is about 10 seconds, but the internal delay time is only about 1 second. A simple but time-consuming method of assuring that each reading is within 1% of its final value is to first sense whether the power meter is on the most sensitive range. If it is, wait 10 seconds before making a reading.

A second method is to make several power meter readings and not consider them settled until they are the same. Waiting for two low level readings to be the same has its own problems. One problem is that because of noise, the probability of two successive readings being identical on the most sensitive range is small. This can require many readings and an excessive amount of time. The time and number of readings can be reduced considerably by continuing to take readings until the successive readings are within .05 dB (±1.2%).

An additional problem is that in the dBm mode, the under range limit of −70 dBm could be sent out for several successive readings, even though the final reading will be considerably up scale. The testing of two successive power meter readings should accommodate this possibility.

When addressed to TALK, the power meter sends back 12 bytes plus the carriage return and line feed. The first three bytes are ASCII characters, defining status, range, and mode. The remaining 9 characters are the value in exponential (E field) format. The recommended FORTRAN format for the message is:

```
     READ(15,102)A,B,C,D
 102 FORMAT(3A1,E9.0)
```

Refer to figure 16-4 and table 16-2 for a description of the output data message.

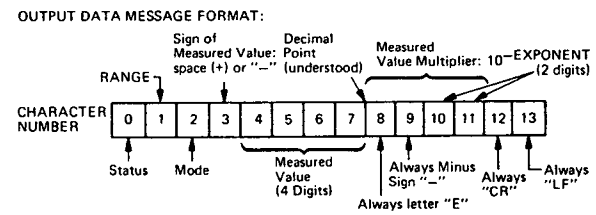

Figure 16-4. Output Data Message Format

Table 16-2. Program Codes for Output Messages

	Definition	ASCII Character
STATUS	Measured value valid	P
	Watts Mode under Range	Q
	Over Range	R
	Under Range dBm or dB [REL] Mode	S
	Power Sensor Auto Zero Loop Enabled; Range 1 Under Range (normal for auto zeroing on Range 1)	T
	Power Sensor Auto Zero Loop Enabled; Not Range 1, Under Range (normal for auto zeroing on Range 2-5)	U
	Power Sensor Auto Zero Loop Enabled Over Range (error condition—RF power applied to Power Sensor; should not be)	V
RANGE	Most Sensitive 1	I
	2	J
	3	K
	4	L
	Least Sensitive 5	M
MODE	Watt	A
	dB REL	B
	dB REF (switch pressed)	C
	dBm	D
SIGN	space (+)	SP
	— (minus)	—
DIGIT	0	0
	1	1
	2	2
	3	3
	4	4
	5	5
	6	6
	7	7
	8	8
	9	9

The dBm mode of operation is preferred in programs. One advantage is that, for a broad range of input powers, it is easy to format "print" statements with two decimal places and to plot graphs without the complexity of exponential prefixes, such as milliwatts, microwatts, and nanowatts. Furthermore, the ± half-count uncertainty from digitizing is ± .005 dB ± 0.12% of the power while reading in the dBm mode. In absolute watts, the % error from the ± half-count uncertainty depends on the reading.

If it is desired, dBm can easily be converted back to milliwatts. There is a logarithmic relationship between dBm and watts, with zero dBm = 1 milliwatt. To convert dBm to milliwatts, divide the dBm value by 10 and take the base 10 antilog. This can be performed by the FORTRAN equation:

```
B=10.0**(A/10.0)
```

where B is milliwatts, and A is dBm.

For example, 3 dBm will equal 2 mw.

In order to obtain a correct reading, the power meter must be adjusted to zero. This process is called zero setting. The importance of being accurately zero set is much more critical when measuring powers on the lower ranges of the power meter. A zero that reads 5% up scale on the most sensitive range, for example, causes a 50% error for a reading that is 10% of full scale. This same offset error will cause a 5% error for a full scale reading, and a 0.5% error for a reading that is 10 dB above full scale of the most sensitive range. If operation is only on the upper ranges of a power meter, frequent resetting of the power meter is seldom necessary.

The primary cause of zero set drift is that the power sensing element experiences a temperature change or temperature gradient since the last zero setting. Likely sources of temperature change include atmospheric changes, thermal conduction down the RF transmission line, and sources of heat near the power sensing element.

Some recommendations about zero setting are:

1. After moving the power sensor to a new RF port, significant thermal gradients near the sensor are likely to exist. It is usually necessary to wait at least 2 minutes before zero setting and measuring.

2. In a steady environment and after one hour of operation, zero setting every ten minutes is usually adequate and necessary. During the first hour of operation, zero setting may be necessary every minute or two.

3. If accurate readings are desired on the most sensitive range of the power meter, zero setting should be done every few minutes.

The proper procedure to zero set the power meter is:

1. Turn off the RF power, or switch it away from the sensor.
2. Auto zero the power meter (on the most sensitive range if possible) until the meter reading is effectivly zero.
3. Remove the auto zero function by programming the power meter to the watts or dBm mode.
4. Before applying RF power, be sure the power meter is no longer in the auto zero mode.

NOTE

> This last step is extremely important! The 436A auto zero circuits continue to operate for about 4 seconds after another mode is programmed. If any power enters the sensor during this time, including transients, the remaining power meter readings will be in error.

The calibration factor dial on the 436A power meter is used to normalize the power readings over the frequency range as shown on the power sensor. Under HP-IB program control, the calibration factor dial of the 436A should be disabled. The reason is that more precise correction for the calibration factor can be made in software when necessary, and without human intervention required with the power meter front panel.

The flow chart and source code for two widely used device subroutines are shown in figures 16-5 and 16-6. The first device subroutine performs the zero setting operation. The second device subroutine obtains and returns a power meter reading.

Several parts of the routine require special comment. The zero setting subroutine assumes that the RF power has already been turned off before the subroutine is called. It further assumes that the power will be turned back on only after the zero setting subroutine has completed. Besides zero setting, this subroutine also places the 436A power meter in the dBm mode of operation and disables the calibration factor switch for remote operation.

There is no advantage in using the internal delay when triggering the 436A during the zeroing operation because each measurement is tested anyway. With the immediate trigger there is the possibility of saving one second of elapsed time. When in automatic operation with HP-IB, the only way to remove the power meter from the auto zero mode is to program it to another mode. Even then, the power meter will continue to zero for about another 4 seconds. To protect the power meter from premature application of power, the device subroutine does not return to the main calling program until the power meter indicates that it is out of the auto zero mode.

The subroutine to trigger and read the power meter is straightforward except when the power meter is reading on the most sensitive range. On that range, the subroutine keeps making readings until either two successive readings are within .05 dB of each other, or until 10 readings are taken. That way if the signal itself is unstable, the power meter is not kept reading indefinitly. It takes about 10 seconds to make these 10 readings. The subroutine allows for the fact that the 436A can remain in the underrange condition for several seconds when on the most sensitive range, while the final result will be within range. Such a condition is likely to occur when the power meter has just down ranged from a higher range.[3]

[3] *For a further discussion of power meters, and the device subroutines used in this section, refer to Application Notes 64-1 and 64-2.*

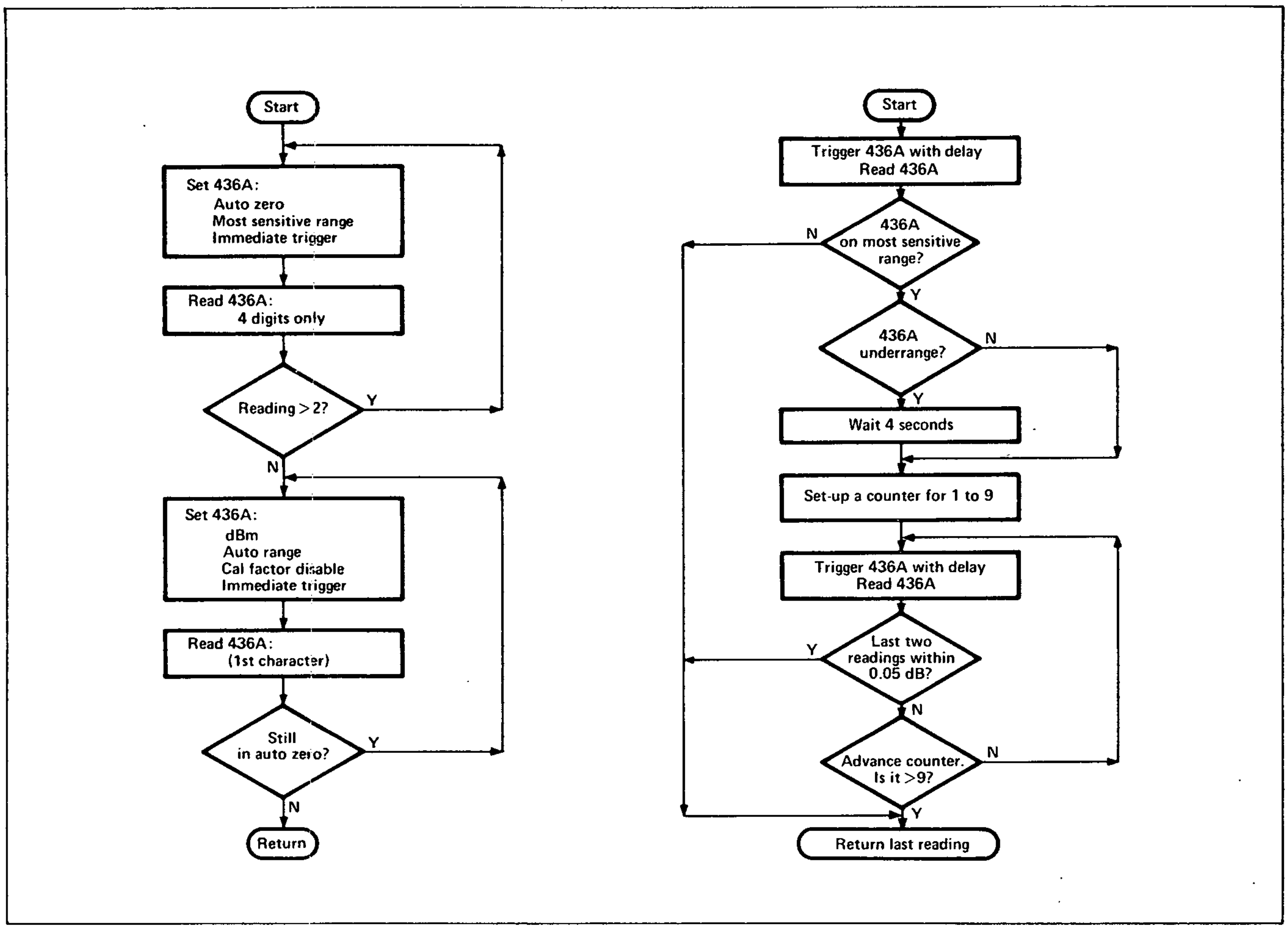

Figure 16-5. Flowchart for 436A Device Subroutines

```
FTN4,L
        SUBROUTINE PZSET(MLU), POWER METER ZERO
C       THIS IS A SUBROUTINE TO ZERO AND SET UP AN HP436A POWER METER.
C       THE ROUTINE SETS THE POWER METER TO AUTOZERO WITH IMMEDIATE
C       TRIGGER.  THEN, IT READS AND LOOPS UNTIL THE METER IS ZEROED.
C       ONCE ZEROED, THIS ROUTINE TAKES THE POWER METER OUT OF THE AUTO-
C       ZERO MODE BY PROGRAMMING THE DBM MODE AND TESTING THE 436A OUTPUT
C       UNTIL THE AUTO-ZERO MODE HAS TERMINATED.
        INTEGER MLU,A
C       SET METER TO ZERO
401     WRITE(MLU,101)
101     FORMAT("Z1I")
        READ(MLU,102) A
102     FORMAT(4X,I4)
C       CHECK TO SEE IF READING IS CLOSE TO ZERO. IF NOT, TRY AGAIN.
        IF (A.GT.2) GO TO 401
C       SET UP METER TO MAKE READINGS
402     WRITE(MLU,103)
103     FORMAT("D9+I ")
C       NOW, CHECK TO SEE THAT METER IS READY
        READ(MLU,104) A
104     FORMAT(1A2)
C       IF NOT, TRY AGAIN
        IF (A.GT.2HSM) GO TO 402
        RETURN
        END
C
C
        SUBROUTINE PMR(MLU,P), POWER METER READ
C
C       THIS IS A DEVICE SUBROUTINE TO TAKE A READING FROM THE HP436A POWER
C       METER.  IF NECESSARY, THE SUBROUTINE CONTINUES TO TAKE READINGS
C       UNTIL THE READING IS STABLE OR UNTIL 10 READINGS HAVE BEEN TAKEN.
C       THE LAST READING TAKEN IS THE VALUE RETURNED.
        INTEGER MLU,A,B,C
C       TRIGGER THE 436 TO TAKE A READING
        WRITE(MLU,101)
101     FORMAT("T")
C       TAKE A READING
        READ(MLU,102) A,B,C,P
102     FORMAT(3A1,E9.0)
C       IF THE SECOND CHARACTER IS NOT AN "I" THE READING IS GOOD--RETURN
        IF(B.NE.1HI) GO TO 999
C       IF THE FIRST CHARACTER IS "S" THEN THE 436 IS IN AN UNDER-RANGE
C       CONDITION-- LET 4 SECONDS ELAPSE AND TRY AGAIN
        IF(A.NE.1HS) GO TO 401
        CALL EXEC(12,0,1,0,-400)
401     DO 888 I=1,9
        WRITE(MLU,101)
        E=P
        READ(MLU,102) A,B,C,P
        IF(ABS(P-E).LT..05) GO TO 999
888     CONTINUE
999     RETURN
        END
END$
```

Figure 16-6. Source Listing of 436A Device Subroutines

Performance

With most analog instruments, the settling and gating time is much longer than the digital computation and communication time. The 436A power meter is no exception. The communication rate for the data message is approximately 10 kilobytes/sec for the 12 bytes sent, but the analog delays and settling times can require several seconds. Figure 16-7 shows a flow chart of the measurement sequence for the 436A power meter. The performance of the power meter can be seen as consisting of four parts: configuration, delay, analog to digital conversion, and data output.

Configuration: The power meter stays in the hold loop until the trigger is received. The power meter then adjusts itself as necessary to assure that it is configured according to the last received instructions. It then proceedes to the delay portion of the measurement sequence. Once in the delay section, the power meter will process a measurement according to its current configuration. If new configuration instructions are received after passing into the delay sequence, they will not be honored until the next measurement. The current measurement will be according to the old configuration. This possibility can be avoided by using the "T" or "I" trigger just before each measurement. The time in the configuration stage is minimal.

Delay: During the delay part of the sequence, the power meter initalizes circuits to make a new analog-to-digital conversion. This preparation takes 17 milliseconds in the watts mode, or 33 milliseconds in the dBm mode, even if no delay is requested. If delay is programmed (the "T" trigger command), the preparations for A-to-D conversion are made while the delay clock is running. Figure 16-8 shows the settling for the power meter response on different ranges. It can be seen that for all but the most sensitive range, the delay is sufficient.

A-to-D Conversion: The A-to-D conversion takes 35 to 53 milliseconds depending on what portion of the measurement range the meter reading falls. If the dB relative mode is used, an additional 70 milliseconds is needed for each measurement.

Output: When the power meter is assigned to talk, it will output its data to the assigned listeners. When ready to talk, the 436A can transmit data bytes at the rate of 10 kilo-bytes per second. Twelve bytes are sent back plus carriage return and line feed.

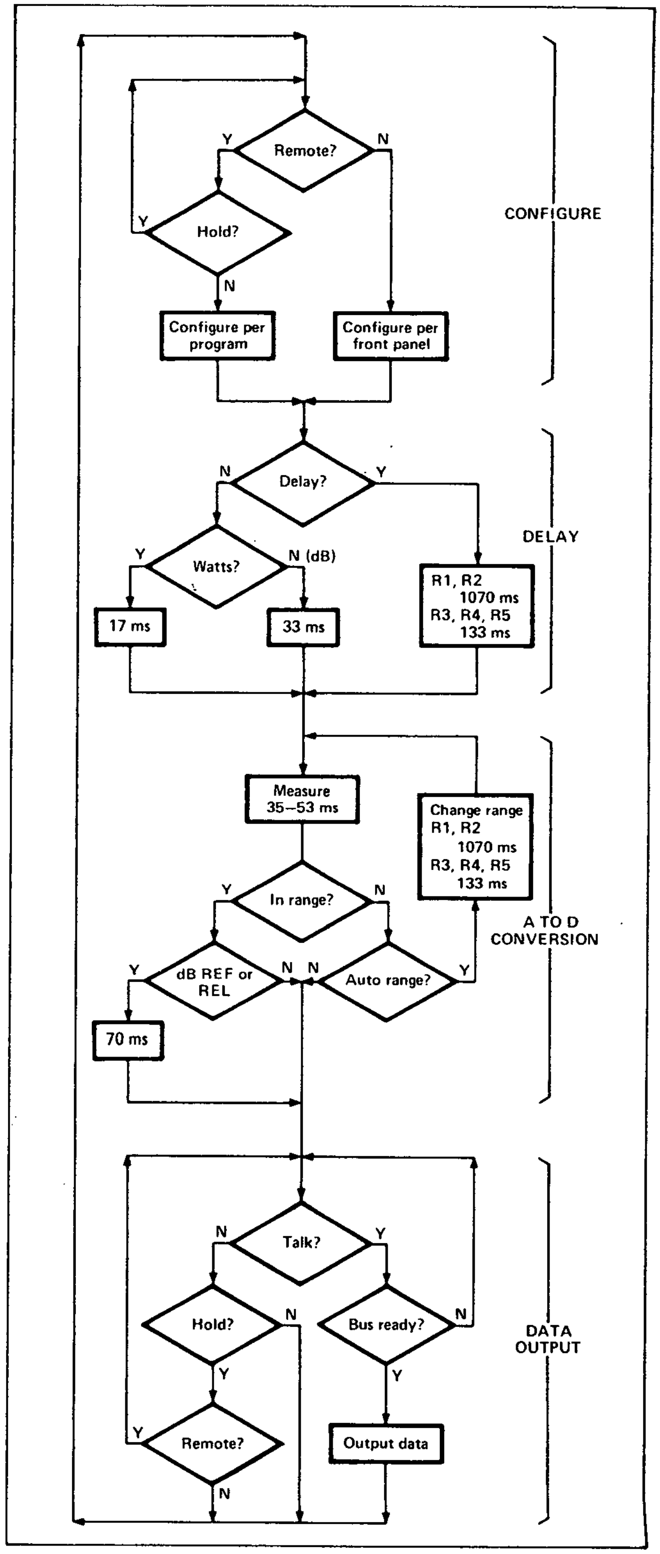

Figure 16-7. Flowchart for 436A Internal Timing

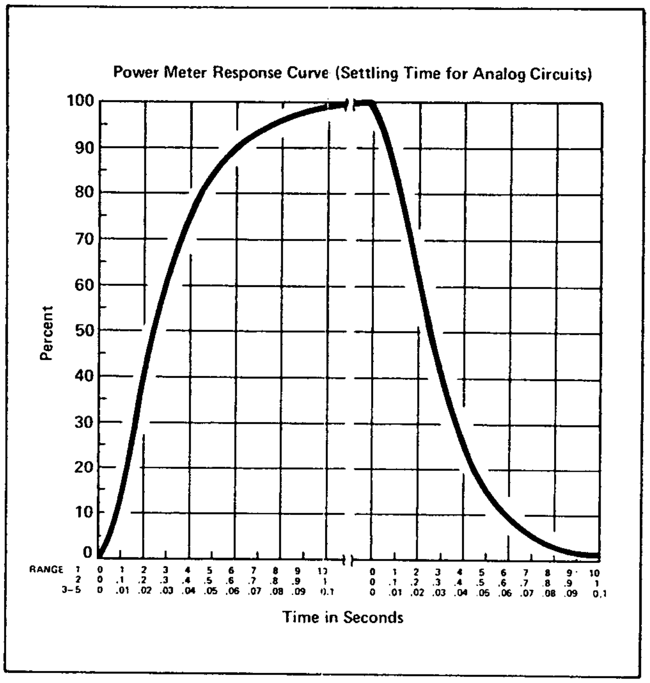

Figure 16-8. Settling Time for Power Meter Ranges

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