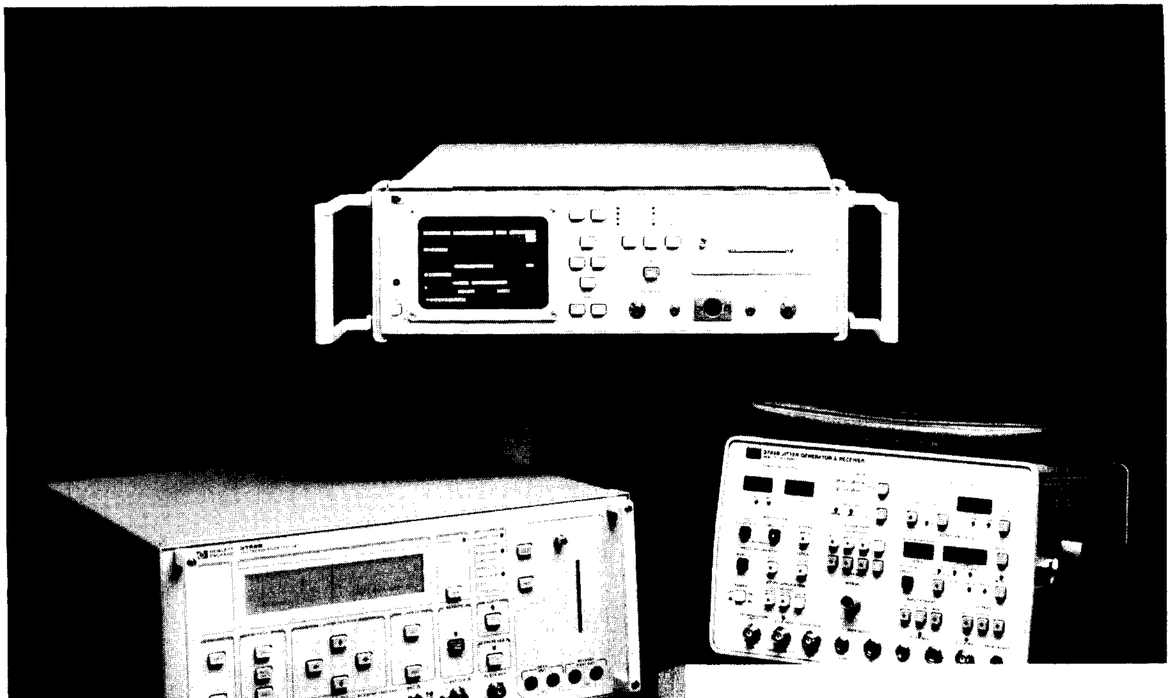
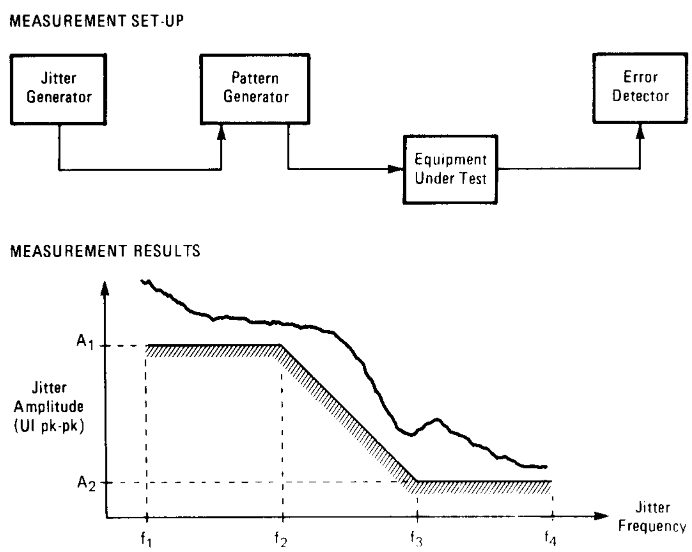
Application Note 359

HEWLETT PACKARD

Jitter
Selecting a Jitter Test Set

Personal Property of
Mike Martin





Introduction

Hewlett-Packard offers several dedicated test sets which can measure timing jitter at the DS1, DS1C, DS2 and DS3 levels of the North American telecommunications transmission time division multiplex hierarchy. This Application Note compares their jitter measurement capability and makes it easier to select the right test set for your application.

Which bit rate ?

Dedicated jitter measurement sets designed to measure jitter in digital transmission systems have clock recovery circuits tuned to extract a timing signal at specific bit rates. Jitter measurements are always made on this recovered clock signal. Table 1 summarizes the instruments manufactured by Hewlett-Packard which can be used to make jitter measurements at each bit rate of the North American time division multiplex hierarchy.

Table 1 shows that there are several instruments available at each bit rate, each one with different measurement capability. The problem is how to decide which one provides the best solution for your application. One way of tackling it is to look at the reasons for measuring jitter in specific applications in more detail.

Which application ?

Timing jitter is an impairment which can cause bit errors in digital transmission links if the amplitude becomes excessive. Network operators attempt to control jitter by setting transmission network performance standards for planning purposes which specify the maximum amplitude of jitter which can occur at any hierarchical interface in the network under any traffic loading conditions. The network performance standards or objectives are then used to set jitter performance design objectives for manufacturers of digital transmission terminal and link equipment. These two sets of objectives have a common goal but they pose very different measurement problems to be solved by the test equipment.

In the transmission network, where traffic load and environmental conditions are changing continuously, the measurement of jitter amplitude at the output of operational equipment should be treated statistically. The test set needs to be able to sample the maximum jitter amplitude over a sufficiently long period of time to ensure that the network limit will not be exceeded. More information on this follows in the section "Analyzing Time-Varying Jitter". An important point is that a test set intended for use in troubleshooting and maintenance applications in telecommunications networks does not need to be able to generate jitter since most measurements can be made by monitoring live traffic signals.

The manufacturer of digital transmission equipment needs to be able to make jitter performance measurements using test signals which simulate live traffic in the network but which give fast, repeatable results. The jitter performance of operational equipment is specified by three measurements which are intended to ensure firstly that the equipment can tolerate the maximum amplitude of jitter likely to be present in the network with a good design margin,

Table 1 Instruments with jitter measurement capability at North American bit rates

Application	Interface Bit Rate (kbit/s)				
	1544 DS1	3152 DS1C	6312 DS2	44736 DS3	139264 (Optical Fiber)
Generate only	HP 3781B*	HP 3781B*	HP 3781B*	HP 3781B*	
Generate and measure	HP 3785B	HP 3785B	HP 3785B	HP 3785B	HP 3764A
Measure only	HP 3787B			HP 3789B	
Measure DS1 jitter by decoding DS1 justification bits at DS3 access point	HP 3789B				

*The HP 3781B Pattern Generator has a built-in jitter modulator but requires an external signal generator to supply the modulating signal.

and secondly that the equipment will not introduce unacceptable jitter onto the network or cause jitter to accumulate uncontrollably. These measurements are the Maximum Tolerance to Input Jitter (MTIJ), the Maximum Intrinsic Output Jitter (MIOJ) and the Jitter Transfer Function (JTF). A summary of these measurements is given in the Appendix. The manufacturer needs jitter test equipment which can add controlled amounts of jitter to a test signal and also measure low jitter amplitudes accurately.

The main applications of jitter test sets are summarized in Table 2 which also shows the different measurement needs of manufacturers and network operators. The remainder of this Application Note looks at these needs in more detail and matches them with the measurement capability of Hewlett-Packard's dedicated jitter test sets.

Selecting a jitter test set for manufacturing applications

Table 2 identifies Maximum Tolerable Input Jitter, Jitter Transfer Function and Maximum Intrinsic Output Jitter as the main jitter measurements made by manufacturers and indicates that the ability to generate jitter modulated test signals, measure low jitter amplitudes accurately and perform some jitter spectrum analysis are important features of jitter test sets for these applications. This section describes these features in more detail and compares the capabilities of Hewlett-Packard's test sets for manufacturing applications.

Generating jittered test signals

Jittered test signals are used in jitter tolerance and transfer function measurements. Table 1 shows that the HP 3781B Pattern Generator and HP 3785B Jitter Generator and Receiver have generation capability but the HP 3781B requires an external signal generator to supply the jitter modulating signal. If jitter tolerance is the only jitter test to be made the HP 3781B is a good choice but if jitter amplitude measurements are also needed, the HP 3785B offers a number of advantages.

Table 2 Jitter measurement capability needed in test equipment for main applications

User :	**Manufacturer**			**Network Operator**
Application :	Maximum Tolerable Input Jitter	Jitter Transfer Function	Maximum Intrinsic Output Jitter	Maximum Output Jitter
Reason for Measurement :	Check that equipment will operate reliably in the presence of network jitter	Check that equipment will not cause jitter to accumulate uncontrollably	Check that equipment will not introduce excessive jitter and identify sources	Relate jitter performance to traffic loading and error performance
Measurement Capability :				
Generate jitter	•	•		
Swept measurement	•	•		
High resolution low amplitude measurement		•	•	
Lower resolution high amplitude measurement				•
Statistical analysis				•
Spectral analysis			•	•

When a measurement requires that jitter is added to a test signal which has an unusual framing structure or ternary line code, the HP 3785B allows this to be done by modulating the signal as it passes through the instrument. The internal configuration of the HP 3785B in THROUGH DATA mode is shown on Figure 1.

Jitter tolerance and transfer function need to be measured through a range of jitter frequencies which is time consuming. The HP 3785B has an automatic mask sweep feature which can be used with an error detector to check that the jitter tolerance of a piece of equipment is at least better than the minimum limit. An alternative approach is to use HP-IB control to automate the test equipment and make swept measurements quickly without an operator in attendance.

The HP 3787B Digital Data Test Set (T1 and DDS applications) and the HP 3789B DS3 Transmission Test Set do not have any jitter generation capability and thus are not ideal for jitter tolerance or transfer function measurements. Jittered test signals can be generated by these instruments by supplying a jittered clock signal to the external clock input. This could be done by using the HP 3785B Jitter Generator as a clock source or alternatively a frequency synthesizer with frequency modulation capability can be used. More information on the latter approach can be obtained from a companion Application Note, AN 360, "Jitter Tolerance Testing using External Jitter Modulation Sources and Bit Error Rate Test Sets".

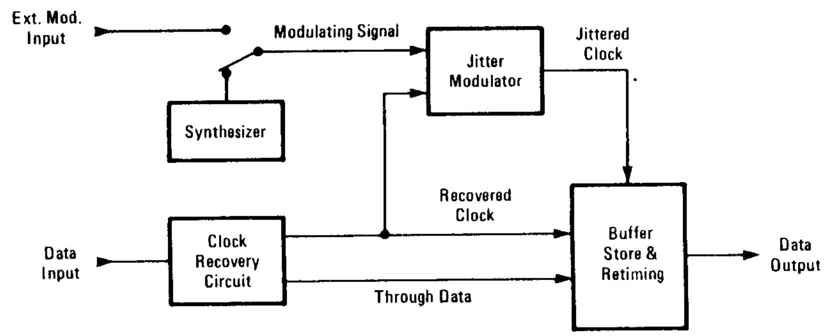


Figure 1 HP 3785B internal configuration in THROUGH DATA mode

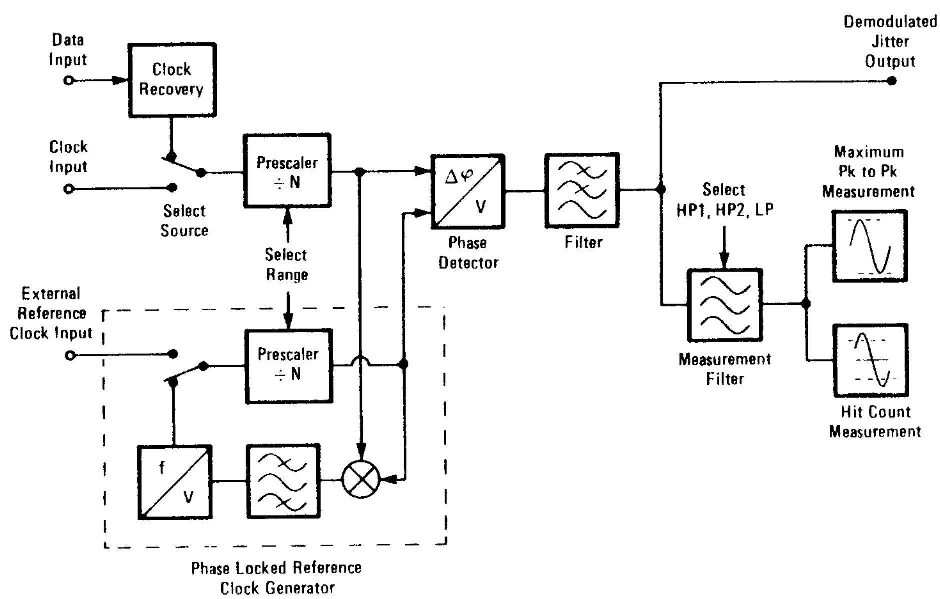


Figure 2 Generalized block diagram of a jitter amplitude measuring circuit

Jitter amplitude measurement

Jitter can be measured by a number of general purpose instruments including the digital sampling oscilloscope, spectrum analyzer and precision counter. Measurement techniques using these instruments can be particularly useful during the research and development of digital circuits but there are some advantages in using a dedicated jitter test set when making measurements on telecommunications equipment. The measurements can be made directly on the signals appearing at the output of equipment under test and the results are presented in the form in which they appear in national and international network performance standards.

Dedicated jitter test sets treat jitter as a continuous-time function equivalent to phase modulation of the recovered clock and the amplitude measurement technique is essentially phase difference demodulation. A generalized block diagram of the jitter measurement circuit of a jitter test set is shown in Figure 2. A phase locked loop extracts a stable reference clock for the phase measurement detector.

The amplitude range of the phase detector is extended by prescaling down the bit rate, an approach which means there is a trade-off between amplitude range and the upper limit of jitter frequency which can be measured.

It is common practice on jitter measuring instruments to provide at least two amplitude measurement ranges by using different values of N in the prescaler. Thus there can be a low amplitude, high resolution, wide bandwidth range which is particularly useful for intrinsic output jitter measurements during development and manufacturing test and a high amplitude, low resolution, narrower bandwidth range which can be used to measure jitter accumulation at the interfaces of an operational network.

The performance of jitter measuring sets can be compared by looking at four key specifications.

- The amplitude ranges, where phase difference measurement is usually expressed in Unit Intervals (UI) peak-to-peak. (1 UI is equivalent to a phase displacement of 360 degrees or 1 bit.)
- The measurement resolution in each amplitude range.
- The bandwidth or jitter frequency range over which the phase detector output is linear. (Usually measured between 3 dB points.)
- The accuracy of measurement in each amplitude range. This usually includes terms for intrinsic jitter introduced inside the measuring instrument by the clock recovery circuit and the phase locked reference clock generator. The accuracy of measurement can be improved by measuring jitter on a clock signal applied to the clock input and by replacing the internally generated reference clock with a stable external clock applied to the external reference clock input.

We can use these key specifications to compare the jitter measurement capability of the HP 3785B Jitter Generator and Receiver with the HP 3787B Digital Data Test Set at the DS1 bit rate (1544 Mbit/s) and the HP 3789B DS3 Transmission Test Set at the DS3 bit rate (44736 Mbit/s).

Table 3 Key jitter measurement specifications at DS1 of the HP 3785B and 3787B test sets

	Low Amplitude Range	High Amplitude Range
HP 3785B		
Name :	RANGE 1	RANGE 10
Amplitude Range :	0.000 to 1.010 UI pk-pk	00.00 to 10.10 UI pk-pk
Resolution :	0.001 UI pk-pk	0.01 UI pk-pk
Bandwidth :	20 Hz to 424 kHz	5 Hz to 63 kHz
Accuracy :	± 4% + 0.035 UI	± 4% + 0.23 UI
HP 3787B		
Name :	(Single range only)	
Amplitude Range :		0.00 to 13.00 UI pk-pk
Resolution :		0.01 UI pk-pk
Bandwidth :		2 Hz to 40 kHz
Accuracy :		± 3% ± 0.08 UI

Note : The specifications given in Tables 3 and 4 of this Application Note are nominal values included here for illustrative purposes and should not be considered to be warranted performance specifications for the instruments described.

DS1 (1544 Mbit/s) Jitter Amplitude Measurement

(on an internally recovered clock from a random data pattern)

First of all compare Range 1 and Range 10 specifications for the HP 3785B on Table 3. The trade-off between amplitude range and bandwidth can be clearly seen and in fact the upper frequency in Range 10 is approximately one tenth of that in Range 1. Now compare the HP 3785B with the HP 3787B. The HP 3787B does not have a low amplitude, high resolution range but can measure jitter amplitude up to 13 UI pk-pk compared with the 10.1 UI pk-pk limit on the HP 3785B. This means the HP 3785B offers greater resolution and jitter bandwidth for intrinsic output jitter measurements while the HP 3787B offers greater amplitude range for network jitter measurements.

DS3 (44736 Mbit/s) Jitter Amplitude Measurement

(on a recovered clock from a random data pattern)

The HP 3789B and 3785B specifications are a little more difficult to compare because although the HP 3789B has only one phase detector range, it has two separate amplitude measurement circuits, each one associated with a set of measurement filters. This approach has advantages in making network jitter measurements which will be described later in the section "Jitter Spectrum Analysis in Digital

Networks". The HP 3789B also presents results in the form of peak measurements so the equivalent peak-to-peak values of amplitude range measurement have been included in brackets in Table 4.

The HP2 range of the HP 3789B is equivalent to Range 1 of the HP 3785B and the HP1 range is equivalent to Range 20. When these ranges are compared it is clear that the HP 3785B has a wider amplitude measurement and jitter frequency range and greater accuracy making it more useful in development and manufacturing test applications.

Jitter spectrum analysis in the development and manufacture of digital communications equipment

Dedicated jitter test sets make a wideband jitter amplitude measurement which gives no information about the spectral content of the jitter function. Jitter tolerance decreases with the jitter frequency so it is useful to be able to measure the jitter amplitude in different parts of the jitter spectrum. Jitter test sets usually have internal fixed measurement filters which can be switched in to split up the jitter spectrum for separate measurement as shown on Figure 2 and for most manufacturing test and network measurement applications this approach is adequate. The values of cutoff frequencies are specified in national and international standards for jitter tolerance of operational equipment and jitter amplitude at network interfaces. Values of the internal measurement filters in the HP 3785B, 3787B and 3789B are listed in Table 5. Note that at DS3, values of cutoff frequencies are still under review as national standards are developed by ANSI and international standards are developed by CCITT. This accounts for the different filters in the HP 3785B and 3789B. The HP 3785B has provision for inserting external measurement filters between the phase detector and the peak detector/measurement circuits.

When characterizing the intrinsic output jitter of telecommunications equipment under development and locating the sources of jitter problems it is often useful to be able to look at the jitter spectrum and measure amplitudes at individual jitter frequency components more accurately. The HP 3785B, 3787B and 3789B all have a demodulated jitter output which can be connected directly to a spectrum analyzer or selective level meter. The internal measurement filters do not act on the demodulated output but in the case of the HP 3785B the jitter amplitude range and frequency bandwidth depends on the measurement range selected as shown in Tables 3 and 4.

Table 4 Key jitter amplitude measurement specifications at DS3 of the HP 3785B and 3787B test sets

	Low Amplitude Range	High Amplitude Range
HP 3785B		
Name :	RANGE 1	RANGE 20
Amplitude Range :	0.000 to 1.010 UI pk-pk	00.00 to 20.20 UI pk-pk
Resolution :	0.001 UI pk-pk	0.01 UI pk-pk
Bandwidth :	20 Hz to 4.5 MHz	5 Hz to 545 kHz
Accuracy :	± 4% + 0.045 UI	± 4% + 0.40 UI
HP 3789B		
Name :	HP2	HP1
Amplitude Range :	0.050 to 0.200 UI peak (0.100 to 0.400 UI pk-pk)	0.05 to 5.00 UI peak (0.10 to 10.00 UI pk-pk)
Resolution :	0.01 UI peak	0.01 peak
Bandwidth :	60 kHz to 300 kHz	10 Hz to 300 kHz
Accuracy :	± 5% ± 0.03 + 0.12 UI	± 5% +0.1 -0.05 + 0.12 UI
HP 3789B Demodulated jitter output:	**Amplitude Range :** 0.05 to 5.00 UI peak **Bandwidth :** 10 Hz to 900 kHz	

Table 5 Cutoff frequencies of the internal filters for the measurement of output jitter on the HP 3785B, 3787B and 3789B test sets

Measurement Filters at DS1 (1544 Mbit/s)				
Instrument	**HP1**	**HP2**	**LP**	**Based on Standard**
HP 3787B	10 Hz	8 kHz	40 kHz	CCITT Rec G.824
HP 3785B	10 Hz	8 kHz	40 kHz	CCITT Rec O.171
Measurement Filters at DS3 (44736 Mbit/s)				
Instrument	**HP1**	**HP2**	**LP**	**Based on Standard**
HP 3789B	10 Hz	60 kHz	900 kHz	Bell TR 43802
HP 3785B	10 Hz	900 kHz	1.1 MHz	CCITT Rec O.171

Summary

Manufacturing jitter test applications require test equipment which can generate test signals with a controlled amount of jitter, measure low amplitude signals accurately and is capable of being remote controlled to perform swept measurements automatically.

The HP 3785B has the jitter generation capability, jitter amplitude measurement ranges and jitter bandwidth required for most manufacturing applications. This instrument does need to be used with an external pattern generator and error detector. The HP 3787B and 3789B need an external jittered clock source to be able to perform jitter tolerance and transfer function tests.

Selecting a jitter test set for digital communications network commissioning and maintenance applications

Table 2 identified the measurement of Maximum Output Jitter as the main jitter measurement made by telecommunications network operators and indicated that useful test set features are the ability to measure high jitter amplitudes, collect data to allow statistical analysis of time-varying jitter and perform some analysis of the spectral content of the jitter function.

Jitter amplitude measurement

The recommended amplitudes of maximum output jitter within digital networks based on the 1544 kbit/s hierarchy are given in Table 6 below. The values are from Bell Technical Reference 43802 and show the amplitude measurement resolution, range and jitter bandwidth required in the jitter test set.

The test equipment must have an amplitude measurement resolution better than 0.1 UI pk-pk and a measurement range better than 5.0 UI pk-pk. When these requirements are compared with the key jitter measurement specifications for the HP 3785B at DS1 and DS3, HP 3787B at DS1 and HP 3789B at DS3 it can be seen that all of the instruments have ranges which meet the output jitter measurement requirements. The HP 3787B and 3789B have the advantages that they can also relate excessive jitter to error performance because they have simultaneous error measurement capability and neither instrument has jitter generation capability which is rarely required for network jitter measurements.

Since the output jitter at network interfaces is a time-varying function, it is useful to be able to record the maximum value of jitter amplitude which has occurred in any measurement interval in addition to measuring the instantaneous jitter amplitude. The HP 3785B can do this at all rates and the HP 3789B detects the peak jitter amplitude on a DS3 signal.

The HP 3789B can be used to produce a graphic plot of the variation of the jitter amplitude on a DS3 signal against time on its internal printer by setting a short repeating gating interval and logging the maximum peak amplitude.

Table 6 Maximum output jitter permitted in digital networks

Digital Rate	Jitter Frequency Range	Maximum Permitted Amplitude
1544 kbit/s (DS1)	10 Hz to 40 kHz 8 kHz to 40 kHz	5.0 UI pk pk 0.1 UI pk pk
44736 kbit/s (DS3)	10 Hz to 300 kHz 60 kHz to 300 kHz	5.0 UI pk-pk 0.1 UI pk pk

Analyzing time-varying jitter

Since the jitter in operational telecommunications networks varies with traffic loading and environmental conditions, the measurement of maximum output jitter should be treated as a statistical measurement. The reasons for making this type of measurement are first of all to check with a high degree of confidence that the maximum output jitter limit will not be exceeded and secondly to identify errors caused by jitter and locate the source of excessive jitter.

Statistical measurements need to be made over long time periods so it is desirable that the measurement can be left to run unattended while collecting data. The test set needs to have an internal real-time clock to control the measurement and time-stamp events and the ability to log results on a printer or other data storage device.

The HP 3789B and 3787B both have a built-in 20-column impact printer for logging results but the HP 3785B requires an external printer which is connected to the HP-IB port.

When estimating the number of bit errors caused by jitter, it may be helpful to record when the jitter amplitude exceeds some preset threshold value, for example the input jitter tolerance of a piece of operational equipment in the network. The test set needs offer the opportunity of setting a jitter threshold and detect when the threshold is exceeded, sometimes called a jitter hit.

All of Hewlett-Packard's jitter test sets can perform the jitter analysis described so far but the HP 3787B and 3789B go a stage further. These instruments help the user to estimate the number of errors caused by jitter by counting the number of bits which are being transmitted during the time that the jitter amplitude exceeds the preset threshold. These bits are called "hit bits" and the relationship between hit bits and jitter amplitude is illustrated on Figure 3. The HP 3787B and 3789B can also simultaneously measure error performance, making it much easier to correlate errors and jitter.

Instruments like the HP 3785B and 3789B which have a maximum peak amplitude detector and a repeated gating interval timer can be used to collect data for the construction of a jitter amplitude probability distribution curve. This can be done by setting a short repeating interval and logging the maximum amplitude in each interval until enough data to construct the curve is obtained. The time required to analyze the results of this type of measurement can be considerably reduced if it is made under HP-IB control, using a microcomputer to reduce the data and present results.

The time-varying jitter analysis features of Hewlett-Packard's jitter test sets are summarized in Table 7.

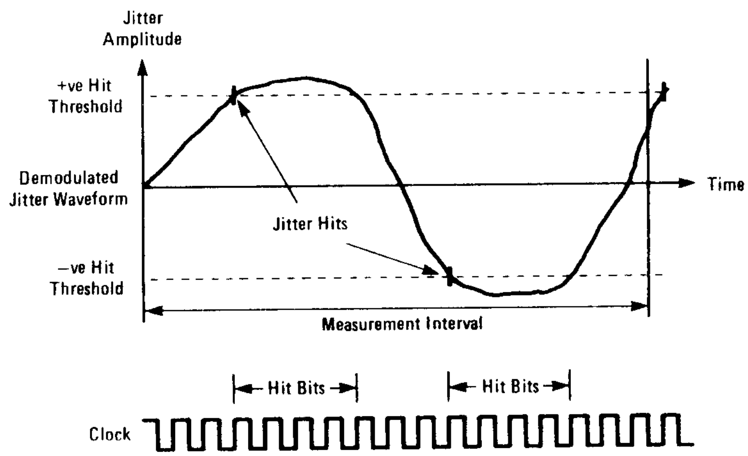


Figure 3 Analyzing time-varying jitter with "Hit Thresholds"

Table 7 Time-varying jitter analysis features on the HP 3785B, 3764A, 3787B and 3789B test sets

Feature	HP 3785B	HP 3764A	HP 3787B	HP 3789B
Internal printer		•	•	•
Real time clock	•	•	•	•
Gating timer	•	•	•	•
Maximum peak	•			•
Hit threshold	•	•	•	•
Hit count	•	•	•	•
Hit seconds/hit free seconds	•	•	•	•
Hit bit count			•	•
Hit bit ratio			•	•
Simultaneous jitter measurement and error detection			•	•

Jitter spectrum analysis in digital networks

The section on jitter spectrum analysis for manufacturing applications earlier in this Application Note described the fixed measurement filters which are used to measure jitter amplitude in each part of the jitter spectrum separately. Table 6 showed the maximum amplitude permissible over different bandwidth ranges in digital networks and this supports the view that the use of fixed filters is adequate jitter spectrum analysis for network measurements.

The HP 3789B DS3 Transmission Test Set offers the opportunity to reduce the measurement time when analyzing the spectral content of network jitter. Normally only one set of measurement filters can be used at one time during a jitter spectrum measurement but the HP 3789B has a separate peak amplitude measurement circuit and threshold detector for the HP1 and HP2 filters allowing both sets of filters to be used simultaneously. The measurement arrangement is shown on Figure 4.

Jitter hit thresholds can be set as a percentage of the maximum jitter tolerance mask and jitter hits from each hit detector are summed. This allows a more realistic estimate of the errors caused by jitter to be made. If, for example, a jitter amplitude of 3 UI pk pk occurs at a jitter frequency of 100 Hz or 60% of mask, it is extremely unlikely to cause bit errors. If the same amplitude occurs at a jitter frequency of 100 kHz or 3000% of mask, bit errors are almost certain to occur.

The maximum peak amplitude which occurs is expressed as a percentage of the network limit. The example on Figure 4 would give a result of 90% of mask.

Summary

Test sets to be used in the installation, maintenance and troubleshooting of digital transmission networks should be able to measure jitter amplitudes at network interfaces and characterize time-varying jitter statistically. The HP 3785B can perform some statistical analysis but for DS1 and DS3 measurements the HP 3787B and 3789B jitter options offer some significant advantages in this type of application. Both instruments can measure jitter and errors simultaneously, log results on a built-in printer and offer a choice of methods for estimating the errors caused by jitter. In addition the HP 3789B can decode DS2 justification bits embedded in the DS3 bit stream to indicate the jitter on any of the DS1 tributaries. (See Appendix for more details of this measurement.)

Conclusion

Selecting a jitter test set is not an easy task. The instruments have a wide range of features and measurement specifications can be explained in a number of different ways, making comparison difficult. This Application Note has attempted to make the job easier by describing some major applications of jitter test sets and identifying the key features needed for each application. These features have then been used to compare the jitter measurement capability of some of Hewlett-Packard's test sets operating at North American bit rates, showing which one is best suited to each application.

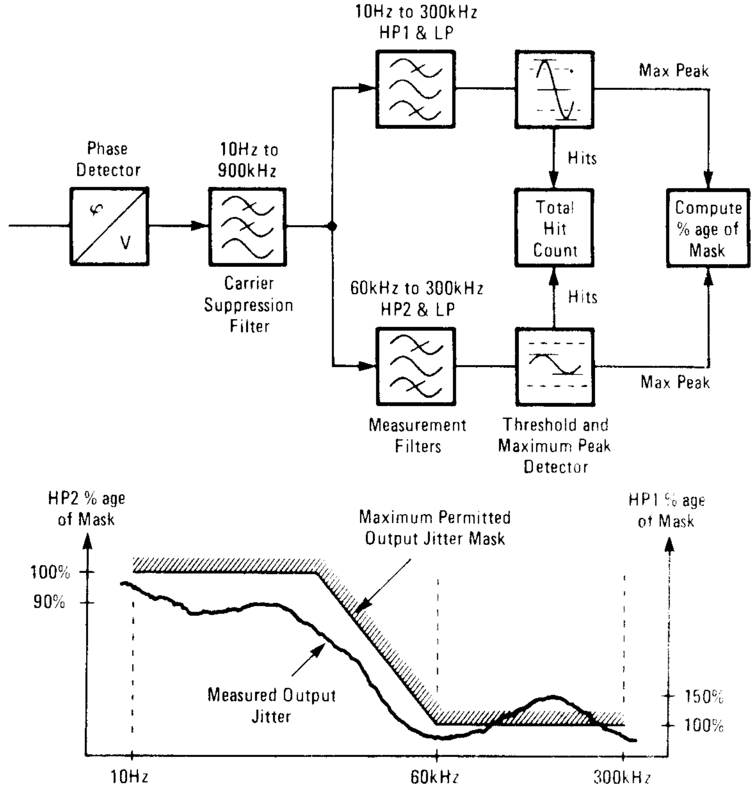


Figure 4 Jitter spectrum analysis with the HP 3789B DS3 Transmission Test Set

Instrument descriptions

HP 3785B Jitter Generator and Receiver
North American digital transmission hierarchies.

HP 3787B Digital Data Test Set
Option 001 gives DS1 jitter measurement capability.

HP 3789B DS3 Transmission Test Set
Option 003 gives jitter measurement at DS3 and DS1 jitter by decoding DS2 justification bits.

HP 3764A Digital Transmission Analyzer
Option 002 gives jitter generation and measurement at 140 Mbit/s.

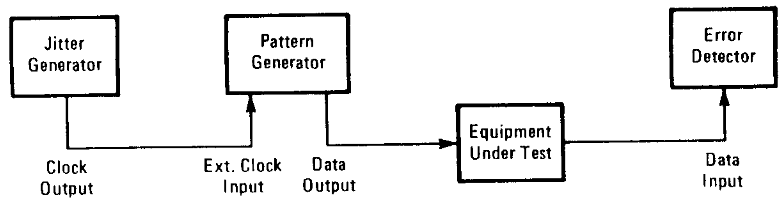
Appendix

MTIJ, MIOJ and JTF measurements

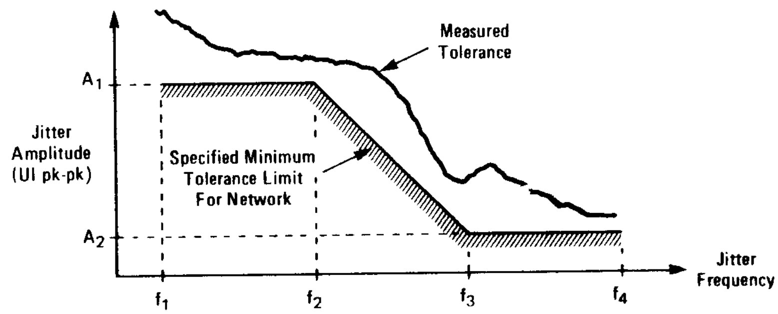
Maximum tolerable input jitter

Apply sinusoidal jitter modulation at a single jitter frequency to the test pattern. Increase the jitter amplitude until bit errors are detected by the error detector. Repeat for a number of jitter frequencies to create a Maximum Tolerance Mask. Check that this exceeds the minimum jitter tolerance requirements of the network at every point on the jitter frequency spectrum.

MEASUREMENT SET-UP



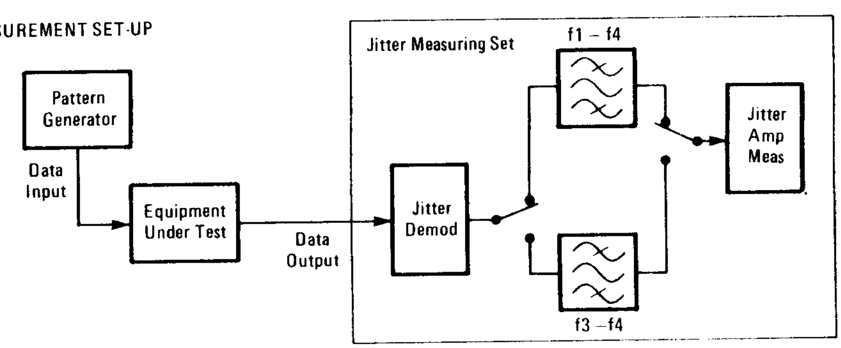
MEASUREMENT RESULTS



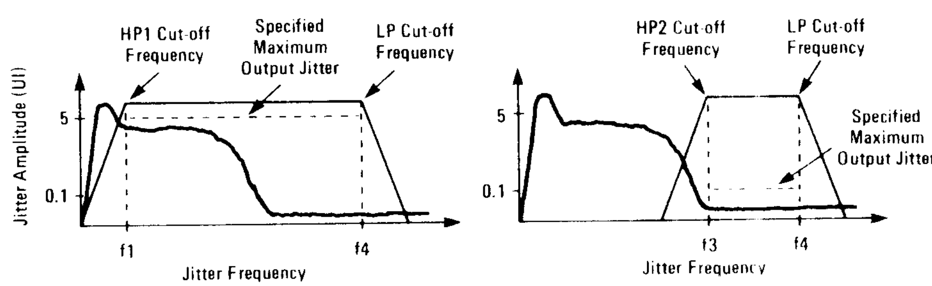
Maximum intrinsic output jitter

Apply a jitter free test pattern to the equipment under test. Select HP1 and LP filters on the jitter measuring instrument and measure the maximum amplitude of output jitter. Check that this does not exceed the specified maximum output jitter limit. Repeat the measurement using HP2 and LP.

MEASUREMENT SET-UP



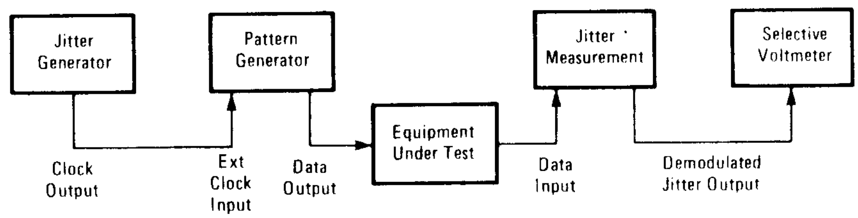
MEASUREMENT RESULTS



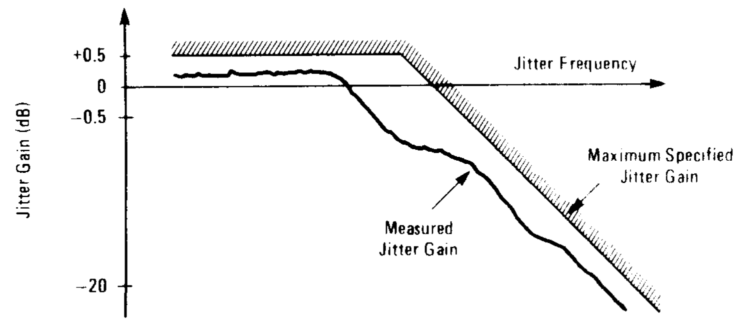
Jitter transfer function

Apply sinusoidal jitter modulation at a single jitter frequency to the test pattern. The amplitude of the applied jitter should not exceed the jitter tolerance of the equipment under test at the highest jitter frequency to be measured. Measure the amplitude of the output jitter (it may be necessary to use a narrow band filter or a selective voltmeter to improve the accuracy of the measurement at high frequencies). Calculate the jitter gain in dB. Repeat for a number of jitter frequencies to create a transfer function mask and compare with the maximum specified jitter gain.

MEASUREMENT SET-UP



MEASUREMENT RESULTS



$$\text{Jitter Gain} = 20 \log_{10} \frac{\text{Output Jitter Amplitude}}{\text{Input Jitter Amplitude}} \text{ (dB)}$$

DS1 jitter measurements with the HP 3789B

The HP 3789B DS3 Transmission Test Set measures jitter on DS1 digroups multiplexed together to make up the DS3 signal by decoding the justification or stuffing bits at the DS2 frame level. The jitter function constructed in this way consists of three components :

- Jitter and timing wander on the DS1 tributaries of the last multiplexer, sampled once every DS2 frame.
- Justification jitter, a high frequency, 1 unit interval amplitude component caused by the multiplexer adding bits to the DS1 data to compensate for differences in phase and frequency between the DS1 tributaries.
- Waiting time jitter, a low frequency component of low amplitude, caused by the fact that justification bits are not added exactly when the phase difference exceeds 1 bit but at the next justification opportunity.

This jitter measurement is intended for troubleshooting DS1 signals from a DS3 access point. The following points need to be kept in mind when interpreting the results of DS1 jitter measured in this way.

The instrument compensates for justification jitter from the multiplexer by subtracting 1 UI pk-pk from the measured peak-to-peak amplitude before displaying the result. Positive peak and negative peak measurements are also adjusted to eliminate justification jitter. It is possible to separate jitter and wander components by selecting a High Pass filter at a jitter frequency of 10 Hz.

The upper jitter frequency limit is set by the DS2 frame rate, equivalent to a DS1 jitter sampling rate of approximately 5 kHz. Because of this the demodulated jitter waveform available from the HP 3789B's demodulated jitter output has been filtered to attenuate jitter frequencies above 2 kHz to suppress the sampling frequency.

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For more information, call your local HP sales office listed in your telephone directory or an HP regional office listed below for the location of your nearest sales office.

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Printed in U.K.
November 1987
5954-9563