HEWLETT PACKARD

3764A

Digital Transmission Analyzer

DESIGNED FOR HP-IB SYSTEMS

TECHNICAL DATA OCTOBER 1983

The portable solution for error and jitter analysis at 139 Mbit/s

Save time, money and effort with..

Flexible Configuration

- **139.264 Mbit/s error measurement to CCITT Recommendation 0.151** – essential for checking the performance of CCITT interfaces built to Recommendation G.703 and includes binary operation to 170 Mbit/s.
- **Multi-rate operation** – covers the four main CEPT hierarchy rates of 2, 8, 34 and 139 Mbit/s in one compact, cost-effective instrument.
- **Jitter generation and measurement to CCITT Recommendation 0.171 at 139 Mbit/s** – evaluates the response of a digital transmission system to the effects of timing jitter.
- **Delayed data outputs** – useful in the testing of digital radio systems and stimulating 4 x 139 Mbit/s multiplexers, giving an increased system testing capability.

Easy-to-Use

- **Non-volatile memory** – provides quick set-up times and guarantees the integrity of measurement results during a power failure. This also provides an auto-restart facility.
- **Simple measurement control** – pre-stored measurement parameters are easily recalled making the instrument very easy-to-use.
- **Light-weight, compact and rugged single cabinet construction** – both portable and easy-to-use making it especially useful for commissioning and maintenance. To guard against accidental damage a protective front-panel cover is provided.

Comprehensive Data Logging

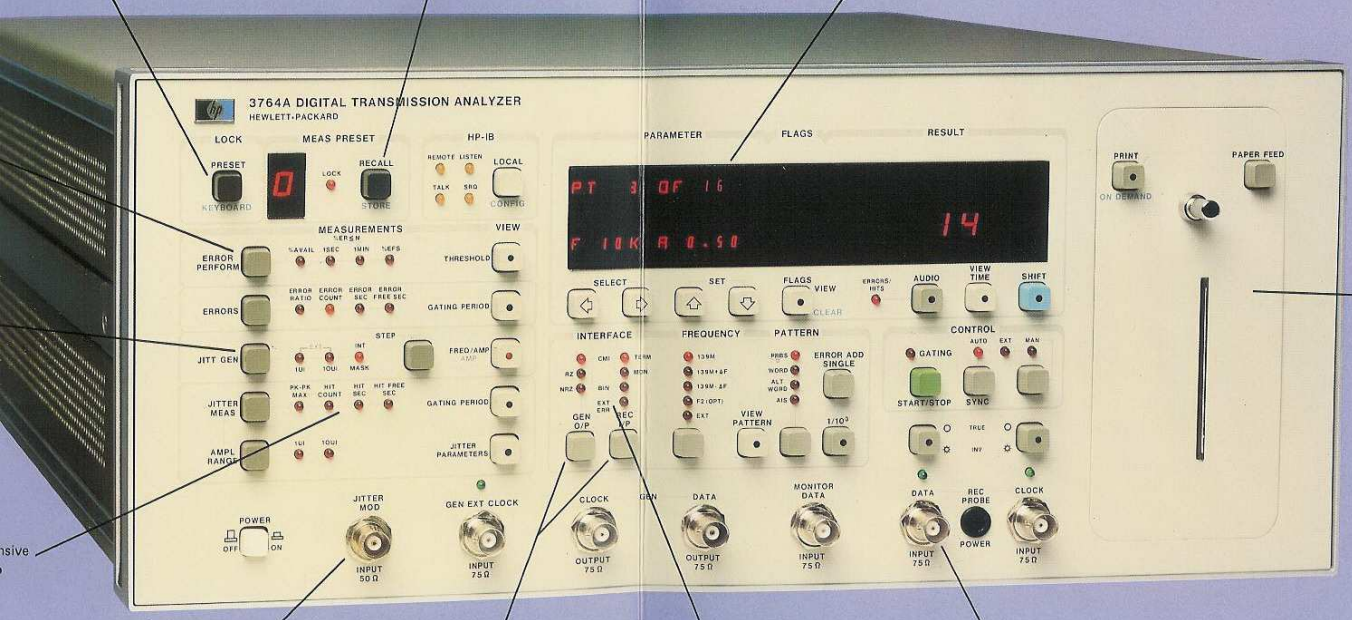
- **HP-IB** – permits full remote operation in automatic test systems, using an external controller, or the output of data to an external printer using the Talk Only mode.
- **Choice of built-in Printer or Tape Cartridge Unit (TCU)** – by selecting option 010 a tape storage facility is fitted instead of the standard 20-column printer. This ensures that a data logging facility is always available and simplifies record keeping.
- **Auxiliary inputs, one analog and seven digital** – useful for recording external data, e.g. alarm conditions, agc voltage of digital radios etc.
- **Built-in real-time perpetual clock** – gives time-of-day and date information which can be used in data logging to give chronological references to results or external data.

A Digital Transmission Analyzer:
apability (option 002).....

ck facilities — to protect the -set memory locations and to ck-out' the front-panel keys.

Recall — up to nine complete sets of front-panel parameters can be stored for future use.

Alpha-numeric display — a comprehensive display for showing the selected measurement results, measurement parameters, 'flag' conditions or real-time clock information.



Built-in data logger — a 20-column Printer is fitted as standard to all 3764A's, unless the Tape Cartridge Unit (TCU) is ordered, option 010.

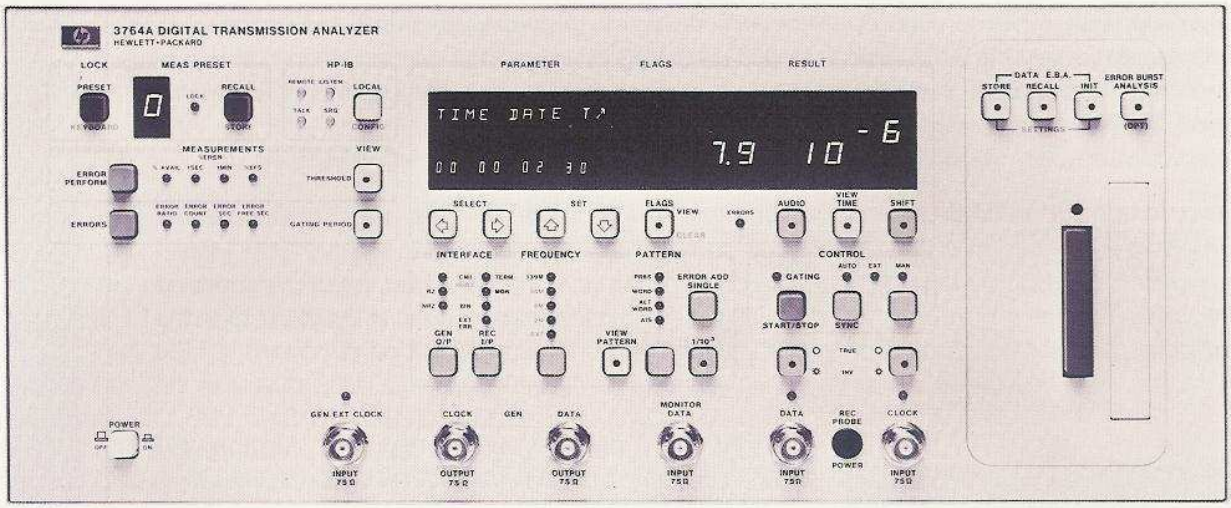
ternal jitter input — accepts jitter dulation from an external source, he range 2 Hz to 5 MHz.

External Error Analysis — errors detected by external equipment can be analyzed using the 3764A.

Individual generator and receiver interface

Data interface — with a frequency range of 1 kbit/s to 170 Mbit/s.

Versatile capabilities



Hewlett-Packard's 3764A Digital Transmission Analyzer is a versatile new instrument for analyzing the performance of high-speed digital transmission systems. In order to satisfy the many requirements encountered in different sectors of the digital transmission industry, three main versions of the 3764A are available. Each of these instruments is capable of full remote operation over the HP-IB and is provided with a built-in data logging facility. This approach allows the 3764A to provide substantial benefits over a wide range of applications, from design and development to commissioning and maintenance.

- **Dedicated 139 Mbit/s Error Analyzer** – The standard 3764A is a low-cost, dedicated 139 Mbit/s digital transmission analyzer with pattern generation, error detection and error analysis capabilities. Its error analysis provision includes error performance measurements for testing the proposed Integrated Services Digital Networks (ISDN). Two useful enhancements may be added to this instrument. The first, option 003, is the addition of three data outputs which are delayed in phase from the main output. The second enhancement, option F2, is a special option crystal frequency in the range 1 MHz to 170 MHz. In some applications these options avoid the need to buy extra test sets.

- **Multi-rate (2, 8, 34 and 139 Mbit/s) Error Analyzer** – Option 001 of the 3764A is a flexible error analyzer providing the same measurement capability as the standard product, but at the four main CEPT bit rates of 2, 8, 34 and 139 Mbit/s. This reduces the number of test sets required in multiple frequency environments.

- **Comprehensive Analysis of Jitter Performance at 139 Mbit/s** – Option 002 instruments provide the standard 3764A's error measurement capability, plus jitter generation and timing jitter measurement at 139.264 Mbit/s. This offers a cost-effective solution for complete 139 Mbit/s testing requirements.

For on-site measurements

Multi-rate measurements — Built with operators of multi-rate networks in mind and designed to CCITT Recommendations, the 3764A option 001 provides the essential measurements required to verify the correct installation, commissioning and maintenance of systems at the CEPT bit-rates of 2, 8, 34 and 139 Mbit/s.

Ruggedly constructed for reliability — A punishing series of tests has been used to ensure the 3764A's ability to operate reliably when subjected to the every-day treatment of a portable instrument and in adverse conditions. These tests included operation in extremes of temperature, pressure and humidity, with further vibration and physical shock tests. Furthermore, to help protect the 3764A's front-panel, a cover is supplied for in-transit use.

Additional delayed data outputs — Option 003 instruments provide four data outputs which increase the 3764A's system testing capabilities. These outputs can be useful for stimulating multiplex equipment and loading adjacent digital radio channels.

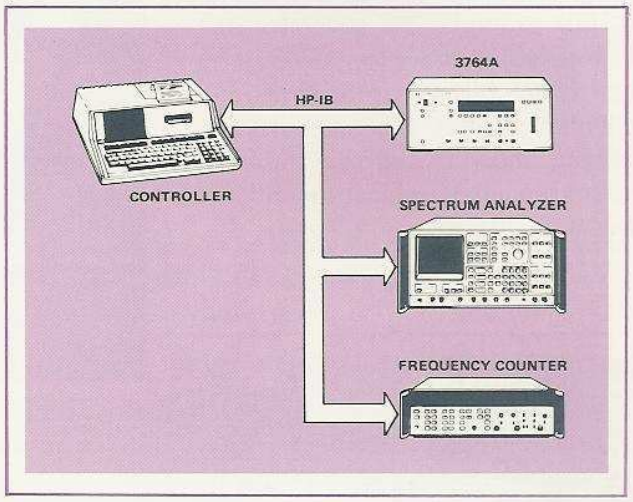
Easy-to-use for fewer operator errors — The easy-to-use 3764A helps operators complete their tasks quickly with fewer errors. Its ability to store parameters for up to nine tests in non-volatile memory allows measurements to be recalled quickly, eliminating set-up errors and improving the consistency of results. Use of a non-volatile memory also ensures that measurement information is retained when the line supply is switched off, or fails, and allows the 3764A to 'power-up' in its 'last used' state. If the line supply does fail, this is taken into account when the 3764A computes its results. These features ensure that less operator training is needed.

Built-in data logging gives permanent results storage — The built-in Printer, or optional Tape Cartridge Unit (TCU), can provide a permanent record of relevant data. For example, the time at which measurements are made can be important, so the 3764A has a built-in perpetual clock to provide time and date information which will be recorded along with the results. Further extensions to the data logging function are provided by eight auxiliary inputs (one analog and seven digital), which are useful for recording alarm conditions etc.

Analyze external error inputs — Errors detected in external equipment can be input to the 3764A and its full error analysis capability may be used to examine them.

For production measurements

Fast, repeatable but simply controlled measurements — When the 3764A is under local control, measurement times can be greatly reduced and front-panel set-up errors eliminated by using the STORE/RECALL facility. This enables up to nine sets of test parameters to be stored in non-volatile memory, so that complex and repetitive tests can be done quickly without any supervision. Further speed improvements can be achieved by using the built-in data logger to automatically record the results.



Complete programmability — The 3764A is fully HP-IB programmable, allowing complete control of all its functions and the interrogation of all measurement results, 'flags', front-panel LEDs and the TCU's tape (if fitted). This enables the 3764A to be used in automatic systems where tests are scheduled to take place at any time of day (e.g. out of office hours) or at remote locations.

Automatic testing — Using its HP-IB capabilities the 3764A can be combined with other compatible devices to form an automated test system. This will improve productivity and quality, because automatic testing ensures that all production throughput is checked with the same degree of thoroughness. Fault-finding times are also improved because any failures which do occur can be readily identified and their exact test conditions quickly duplicated.

Further reliability improvements can be achieved by processing the results of long-term tests, stored using the TCU, for failure analysis. In this role the 3764A records the details of all failures which occur over the test period and these are subsequently correlated with other relevant data in a computer. This can identify failure-patterns and equipment weaknesses before they cause warranty problems.

Access all results — Although its display shows only one measurement result, the results of all the other possible measurements (and where applicable, at all the possible threshold levels) are computed simultaneously. These results are stored in non-volatile memory and can be accessed via the HP-IB at any time for subsequent analysis.

For use in research and development

Accurate and dependable results — The 3764A's high level of accuracy and stability are allied to measurement capabilities which conform to CCITT Recommendations. This gives the 3764A the performance characteristics demanded in most applications. For example, the generator's data and clock outputs exhibit low levels of intrinsic jitter which, when coupled with the instrument's inherent high stability, ensure consistent, accurate and repeatable results. Furthermore, all of the instrument's options reflect these basic design criteria.

Simplify complex jitter verification — In option 002 instruments the ability to construct a 'jitter mask' of up to 16 discrete jitter frequency/amplitude points is particularly useful. This greatly simplifies the task of establishing the actual performance of a digital system against a given performance specification, e.g. when checking the lower limit of maximum tolerable input jitter at 139.264 Mbit/s against the limits set out in CCITT Recommendation G.703. Additionally, up to nine such 'masks', along with all other relevant parameters, may be stored in the instrument's non-volatile memory for future use. This ensures that test set-ups are consistent, saves time programming the front panel and, consequently, allows product development times to be reduced.

Binary Data to 170 Mbit/s — Two features which increase the 3764A's usefulness are: the choice of an additional optional crystal frequency in the range 1 MHz to 170 MHz and the four output version (option 003). These help in development work at higher bit-rates.

The error analysis users require..

All versions of the 3764A provide the following measurements:

- Bit Error Ratio
- Bit Error Count
- Error Seconds
- Error Free Seconds
- % Availability
- % Error Free Seconds (% EFS)
- % Error Ratio < N (% ER < N)

Although the 3764A is primarily designed to perform its measurements at the CCITT hierarchy bit rate of 139 Mbit/s, option 001 instruments also allow testing at bit rates of 2, 8 and 34 Mbit/s. To help ensure that operator errors are kept to a minimum, the 3764A's software initiates automatic selection of the appropriate CCITT recommended code (CMI or HDB3) and PRBS ($2^{23}-1$ or $2^{15}-1$) for the chosen bit-rate.

All measurements are made simultaneously and any result may be accessed for viewing at any time without interrupting the instrument's gating. If repetitive gating periods are used, these have no 'dead-time' between them and, therefore, no system errors go undetected.

Bit Error Ratio and Bit Error Count – Conventional measurements of Bit Error Ratio and Bit Error Count are made using either a single period or a repetitive gating period. When using a preset gating period, integer time intervals from one second to approximately 100 days can be selected. Alternatively, manual control of the gating period is possible using the START/STOP key.

Error Seconds and Error Free Seconds – Two methods of defining and measuring Error Seconds are in use. The first is a synchronous method, where the start of a gating period is coincident with an error, and the second is an asynchronous method, where gating intervals are independent of the receipt of errors. The 3764A uses the second method because this gives a more realistic indication of a system's quality when bursts of errors are present.

% Availability – a system is considered to be 'unavailable' when the Bit Error Ratio is worse than 1×10^{-3}* for ten* consecutive seconds; Consequently, the % Availability measurement gives an indication of a system's 'outage' time.

**Note:* *These limits are specified in CCITT Recommendation G.821 and are subject to change. The 3764A provides a wide range of threshold limits.*

% EFS – This is the number of error free seconds counted by the 3764A, expressed as a percentage of the total number of available seconds in the gating period.

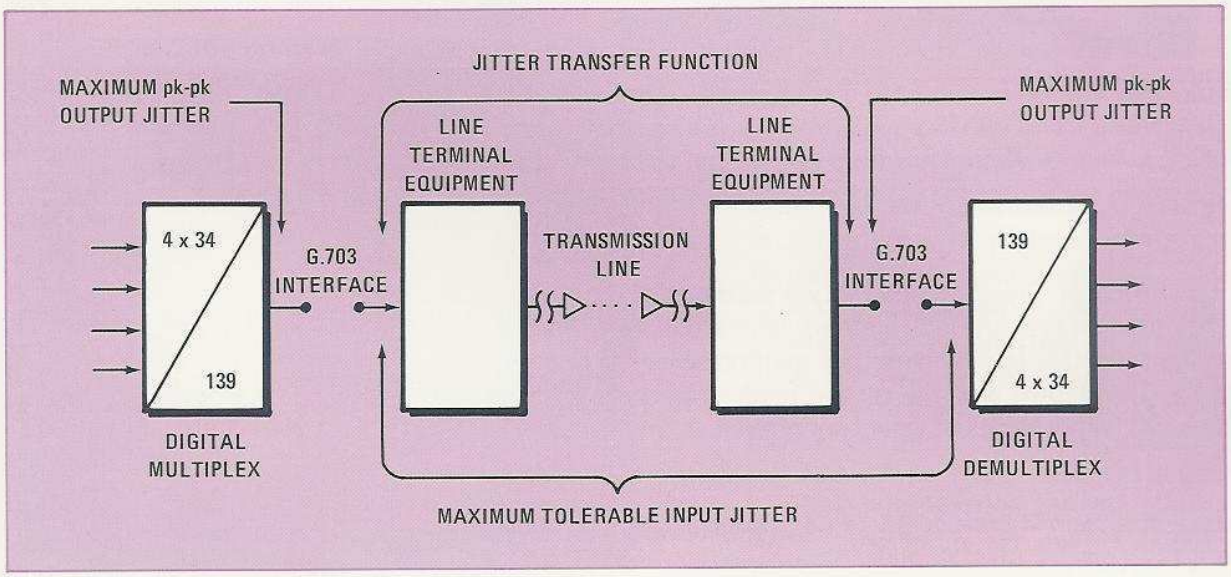
% ER < N – This is the length of time, expressed as a percentage of the gating period, that the error ratio is less than the threshold level N. Here, the gating period is initiated using the START/STOP key and measurements are made over one second or one minute repetitive time intervals. The value of N is variable and can be selected by the operator.

..with jitter analysis as an option

For those who need to analyze jitter performance at 139.264 Mbit/s the 3764A option 002 offers a most attractive and cost-effective solution. Designed to CCITT Recommendation 0.171, this single instrument combines high performance with simplicity and allows inventory savings by performing all of the standard 3764A's measurements plus the following jitter measurements:

- Maximum pk-pk Output Jitter
- Tolerance to Input Jitter
- Jitter Transfer Function
- Totalized Jitter Hit Count
- Totalized Jitter Hit Seconds Count
- Totalized Jitter Hit Free Seconds Count

All jitter measurements are made simultaneously and the desired result is selected for display.

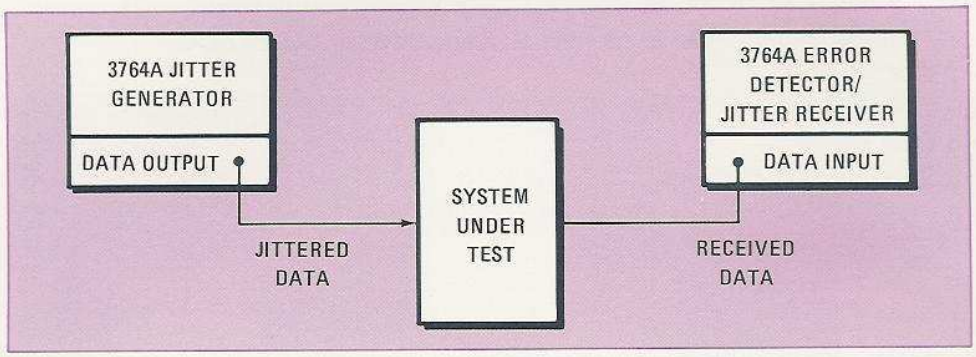


Maximum pk-pk Output Jitter – This is a measure of a system under test's inherent timing jitter. No input jitter is applied to the system while this measurement is made.

Tolerance to Input Jitter – The Maximum Tolerable Input Jitter is the level of timing jitter at which a system under test begins to introduce errors.

A Lower Limit of Maximum Tolerable Input Jitter is specified in CCITT Recommendation G.703. This aims to give some degree of freedom to equipment designers and network planners, yet ensures error free connection between the equipment of different suppliers and countries. It is a measure of the minimum jitter tolerance that all equipment must exhibit without introducing errors.

The Measured Value of Maximum Tolerable Input Jitter is the level of input jitter at which a system under test begins to introduce errors, i.e. it is a qualitative measurement of the level of input jitter a system can withstand before errors are introduced.



Jitter Transfer Function – The Jitter Transfer Function (i.e. Jitter Gain) is an indication of the accumulated jitter introduced when systems are cascaded. This must be controlled if data errors due to timing jitter are to be avoided. A system's Jitter Transfer Function can be expressed as:

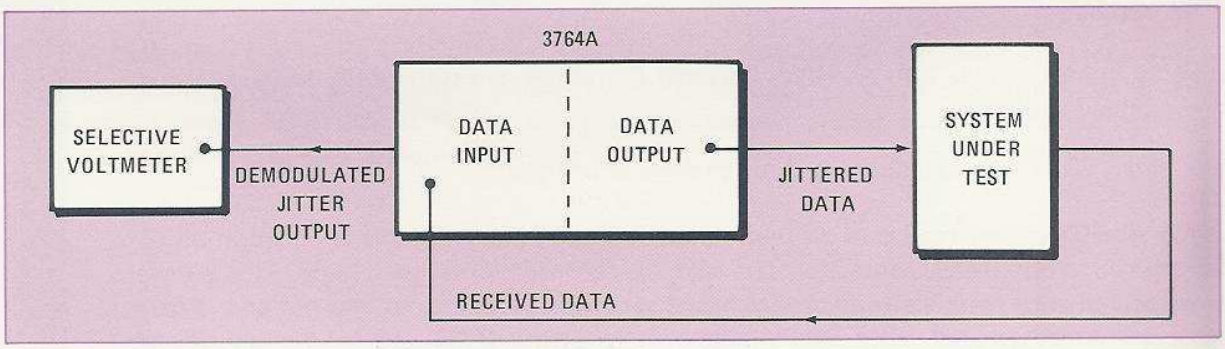
$$\text{Jitter Gain} = 20 \log_{10} \frac{\text{Jitter Measured at a System's Output}}{\text{Jitter Measured at a System's Input}}$$

where, the Jitter Measured at a System's Output can be either:

- **Wideband**, as indicated on the 3764A's Jitter Measurement results display.

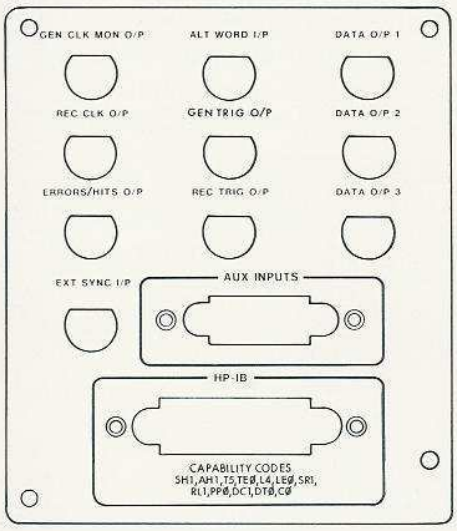
  or

- **Selective**, by measuring the 3764A's rear panel Demodulated Jitter output using a selective voltmeter. (A spectrum analyzer may also be used to quantify the Demodulated Jitter output.)



Totalized Jitter Hit Measurements – A Jitter Hit occurs when the peak-peak amplitude of received jitter exceeds a set threshold level. The number of jitter hits occurring during a gating period is counted. In addition, the number of seconds during a gating period in which a Jitter Hit occurred can be counted (Jitter Hit Seconds), as can the number of seconds in which no Jitter Hits occurred (Jitter Hit Free Seconds).

Extra output capabilities for greater flexibility..



. . . with a Delayed Data Outputs version

3764A option 003 provides three additional data outputs on the rear panel. These outputs are delayed in phase from the main front panel data output, but have the same format, CMI coded or binary ECL.

Delayed Data outputs are useful in a variety of applications, including digital radio testing and digital multiplex stimulation; for improving efficiency by reducing inventory requirements and saving on both time and labour costs.

. . . and a choice of built-in data logger

Many users require hard-copy measurement results which are recorded along with time-of-day and date information. To meet this requirement Hewlett-Packard supply each 3764A with a built-in data logger, a 20-column Printer is fitted to every instrument unless the optional Tape Cartridge Unit (TCU) is specified. This simplifies test configurations and reduces test equipment costs.

Customers who already possess HP-IB compatible printers can, of course, still use them along with the 3764A, since full HP-IB operation is a standard feature of all versions of the instrument.

The TCU (option 010) may be specified to replace the built-in Printer and provide an alternative storage medium for measurement results which can be put to many uses. Information recorded from the 3764A can be:

- Read directly from the tape into an HP85 Personal Computer and statistically analyzed using customer supplied software.
- Read indirectly, via HP-IB, to a peripheral for analysis or printing.

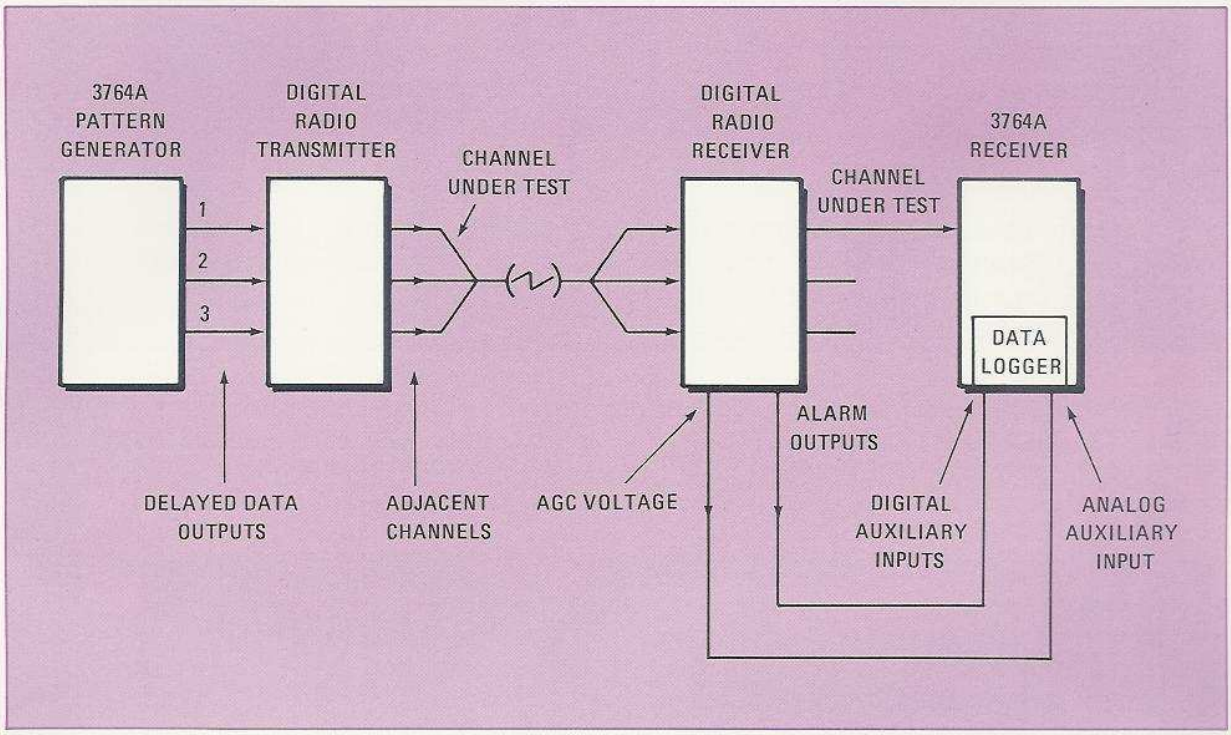
A further use of the TCU and tape is as a pre-programmed test library. In this application up to nine pre-programmed front panel parameter sets can be recorded onto each tape. This allows operators to quickly change their instruments from one set of test routines to another and is particularly useful in non-automated roles where unproductive set-up time can be avoided. When this facility is in use, the Front Panel Lock and Non-volatile Memory Lock functions can be used to prevent corruption of the tape-entered data and ensure the consistency of measurements.

Internal buffering and a dedicated microprocessor ensure that the 3764A is capable of logging high rates of error information, e.g. during error bursts or radio fades. In addition, even closely spaced events will not go unrecorded since there is no 'dead-time' between consecutive gating periods.

The ability to cater for specialized applications

Digital Radio 1: using option 003 and the auxiliary inputs

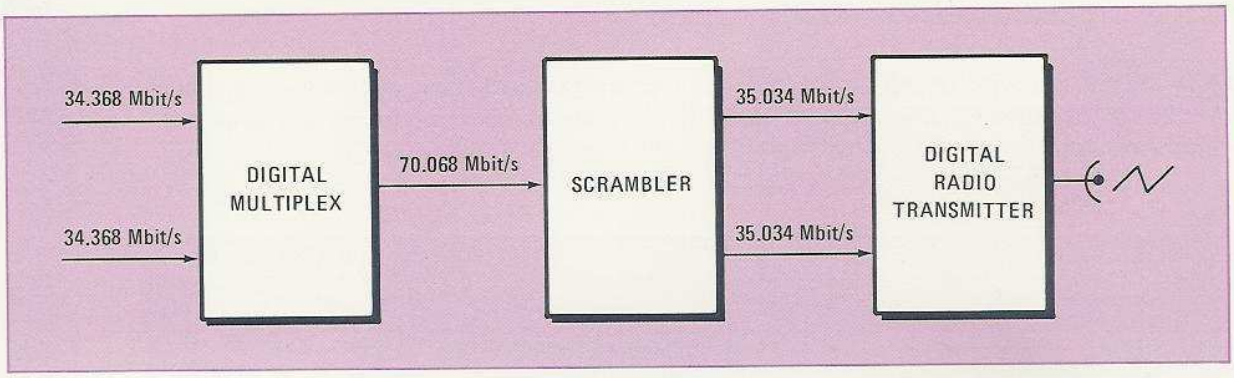
When using a 3764A fitted with delayed data outputs (option 003) adjacent channels on a digital radio system can be loaded with uncorrelated data, while error measurements are performed on the channel under test.



In this application the built-in data logger is very useful. The 3764A has eight auxiliary inputs (one analog and seven digital) which permit event recording, e.g. alarm conditions, along with measurement results. This data is logged along with information from the instrument's real-time clock. Consequently, a very effective low-cost solution to long term testing requirements is provided.

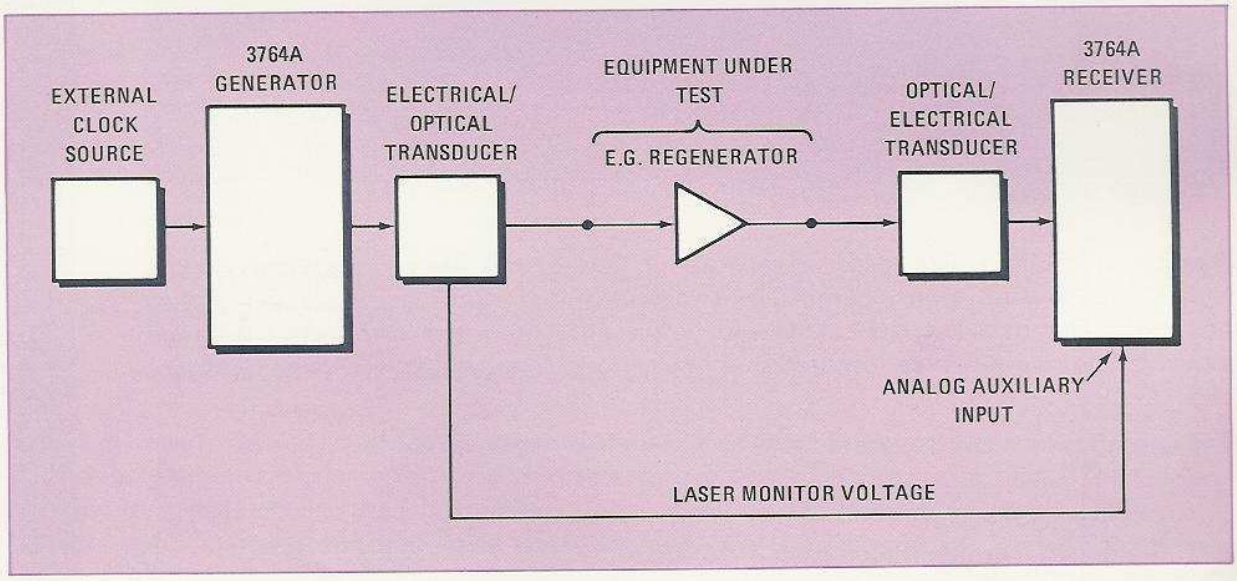
Digital Radio 2: using special option frequency F2

In some 4 GHz digital radios two plesiochronous data streams at 34.368 Mbit/s are made synchronous and combined in a digital multiplex. The resultant output is a binary data stream at 70.068 Mbit/s. After scrambling, this stream is split into two synchronous binary data streams at 35.034 Mbit/s and these are fed to a QPSK radio modem for subsequent transmission. Non-standard bit-rates such as these can be provided by the 3764A, with crystal oscillator accuracy.



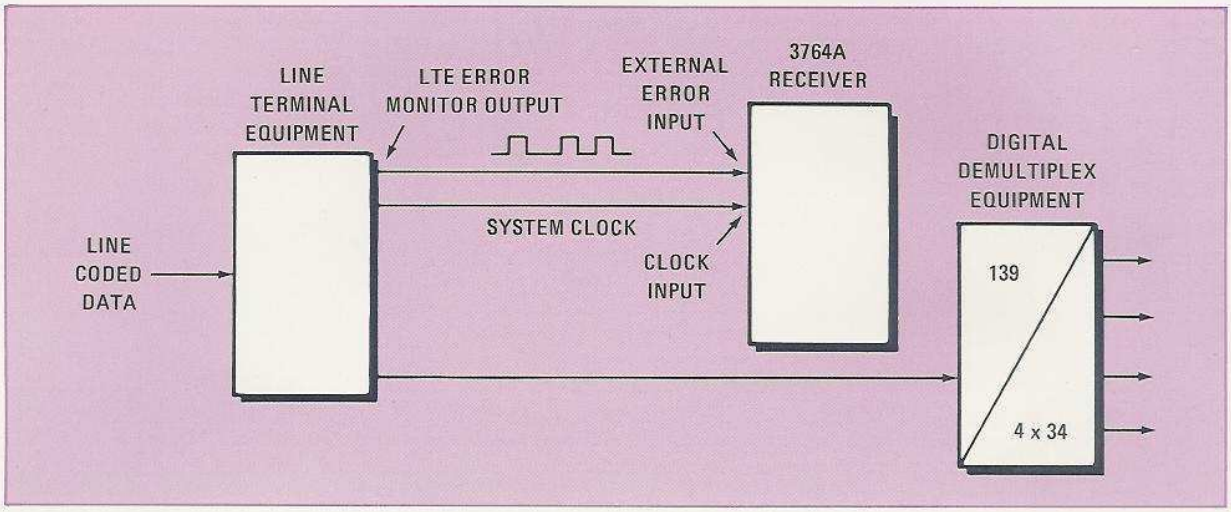
Any non-standard bit-rate between 1 Mbit/s and 170 Mbit/s can be provided at the binary interface by employing the 3764A's special option frequency, F2. Another typical example would be 140.434 Mbit/s which is used in a number of 11 GHz digital radios. This feature is useful in the manufacture and production test of digital radio systems.

Fibre Optic Application: using the binary interface to 170 Mbit/s and the auxiliary inputs



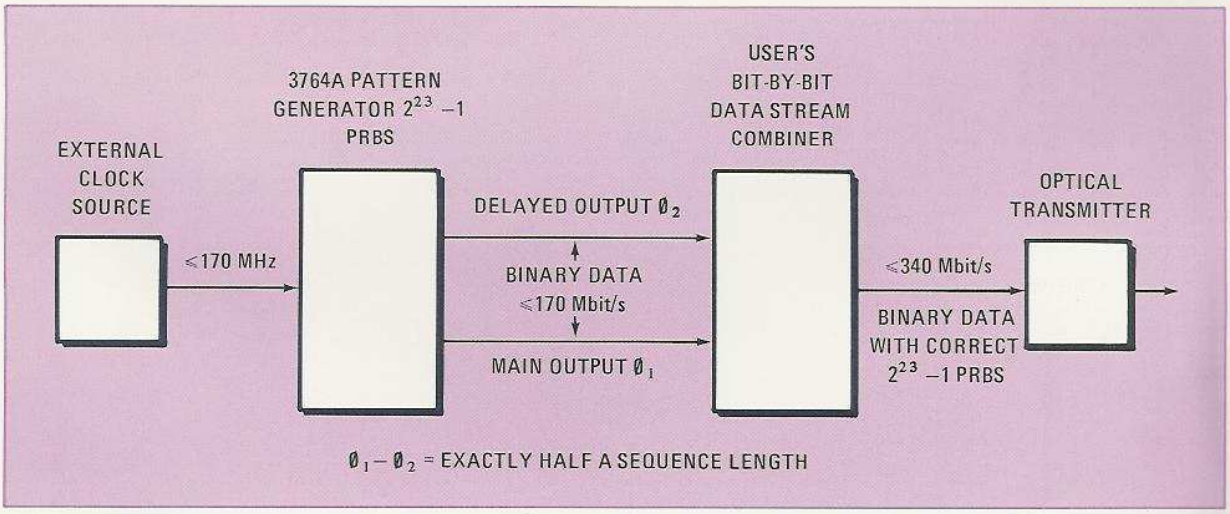
The 3764A's binary interface can operate over the range 1 kbit/s to 170 Mbit/s. This allows error measurements to be performed at the line rates of many digital transmission systems (e.g. 139 Mbit/s coded in 5B6B format gives a line rate of 167 Mbit/s). The value of the laser voltage can also be correlated with the measurement results and information from the built-in clock.

Analysis of Externally Detected Errors



The 3764A's external error input allows errors detected by other equipment to be fully analyzed. This includes outputs from code and parity error detectors, where the error monitor equipment outputs its error information using the format one pulse per error.

Pattern Generation to 340 Mbit/s: using the binary interface and delayed data outputs



Recent advances in fibre optic technology have enabled submarine cable designers to consider using optical fibre as their transmission medium. Several systems have been proposed which involve multiplexing two 139 Mbit/s data streams. In the example shown, the 3764A's binary data streams are combined enabling an optical fibre system to be stimulated up to a line-rate of 340 Mbit/s. This removes the need for a separate high-cost high-speed signal generator.

Specifications

Except where otherwise indicated the following parameters are warranted performance specifications. Parameters described as 'typical' or 'nominal' are supplemental characteristics which provide a useful indication of typical, but non-warranted, performance characteristics.

GENERATOR SECTION

Data Outputs

CODED
Format: Coded Mark Inversion (CMI).
Rate: 139.264 Mbit/s.
Impedance: nominal 75Ω unbalanced to GND.
Levels: + and − 0.5V ± 10%.
Transition Times: < 2 ns into 75Ω.
Transition Tolerance (139.264 MHz internal clock):

negative transitions	± 100 ps;
coincident positive transitions	± 500 ps;
mid-period positive transitions	± 350 ps.

Overshoot/Preshoot: < 5% of pulse amplitude.
Protection: open/short circuit protected, maximum voltage ± 6V short term.

BINARY
Format: binary RZ or NRZ.
Rate: 1 kbit/s to 170 Mbit/s.
Impedance: nominal 75Ω unbalanced to −2V.
Amplitude: nominal ECL levels.
RZ duty cycle: nominally 50% on internal clock.
NRZ Width: 100% ± 5%.
Transition times: < 1.8 ns.
Transition timing tolerance: 0.5% of period + 350 ps.
Overshoot/Preshoot: < 10% pulse amplitude.

Clock Source

INTERNAL
Frequency: 139.264 MHz.
Accuracy: setting tolerance at ambient temperature is better than ± 3 ppm.
Temperature Stability: typically < ± 12 ppm (0°C to +55°C).
Ageing: typically < ± 5 ppm per year.

OFFSET
Frequency: 139.264 MHz + 15 ppm and 139.264 MHz −15 ppm.
Other parameters: as for Internal Clock Source.

EXTERNAL
Frequency: 1 kHz to 170 MHz.
Impedance: nominal 75Ω to GND (selectable by internal link to −2V).
Triggering: nominal GND, nominal ECL or TTL thresholds selectable by internal link.
Amplitude: maximum 3V pk-pk.
Sensitivity: better than 300 mV at 170 MHz.

Clock Output

Format: squarewave, 50% ± 10% duty cycle on internal clock.
Impedance: low, unbalanced.
Amplitude: nominal ECL levels.
Jitter (Jitter Generator off): < 0.5% period +50 ps pk-pk (e.g. < 0.005 UI pk-pk at 1 kHz; < 0.0135 UI pk-pk at 170 MHz).
External Load: 75Ω to −2V, dc coupled; 75Ω to GND, ac coupled.

Generator Clock Monitor Output (Rear Panel)

Source: internal or external clock.
Format: when the jitter generator is used this clock output will not be jittered by it.
Impedance: low, unbalanced to GND.
Amplitude: nominal ECL levels.
External Load: 50Ω to −2V, dc coupled; 50Ω to GND, ac coupled.

Patterns

PRBS: $2^{23}-1$. Polynomial is D(23) + D(18) + 1 = 0. Inverted sequence 23 zeros.
Word: variable length from 1 to 16 bits.
Alternating Word: external signal controls output of two half length words, changeover is synchronous with the end of a word. The half length word can be varied in length from 1 bit to 8 bits.
AIS: continuous "all ones" pattern.

Error Add (Binary Errors)

Fixed: average error ratio of 1 error in 1000 clock periods (1.10^{-3}).
Flexible: one error introduced for each press of the SINGLE ERROR ADD key.

Pattern Trigger Output (Rear Panel)

Format: one pulse per PRBS or Word pattern.
Position: fixed.
Width: two clock periods.
Impedance: nominal 50Ω unbalanced.
Amplitude: 1V pk minimum.
Protection: open/short circuit protected, maximum voltage ± 5V short term.

Alternating Word Control Input (Rear Panel)

Function: the frequency of the applied signal controls the changeover rate of the half length words in alternating word mode.
Impedance: nominal 1KΩ unbalanced.
Maximum Input: 5V rms.
Sensitivity: 250 mV pk-pk squarewave dc to 100 kHz; 500 mV pk-pk sine or triangular wave 200 Hz to 100 kHz.

RECEIVER SECTION

Data Inputs

CODED (TERMINATED MODE)
Format: Coded Mark Inversion (CMI).
Impedance: nominal 75Ω unbalanced to GND.
Rate: 139.264 Mbit/s ± 3 Mbit/s.
Amplitude: nominal maximum pk-pk voltage into 75Ω is 1V.
Jitter Tolerance: better than 10 UI pk-pk up to 100 kHz; better than 0.5 UI pk-pk at 2 MHz.
Equalization: automatic equalization for cable loss of up to 12 dB at half bit-rate.
Polarity: Data or $\overline{\text{Data}}$ switched at the binary level.

CODED (MONITOR MODE)
Additional Gain: an additional gain of 26 dB is available to allow for flat loss at equipment monitor points.
Other Parameters: as for Terminated Mode.

BINARY
Rate: 1 kbit/s to 170 Mbit/s.
Format: binary RZ or NRZ.
Impedance: nominal 75Ω unbalanced to –2V.
Amplitude: nominal ECL levels.
Data Polarity: Data or $\overline{\text{Data}}$ switched at the binary level.

EXTERNAL ERROR
Parameters: as for Binary Data Input.
Clock Format: an external clock must be supplied, parameters as for Binary Clock Input.
Format: minimum pulse width 3 ns.

Clock Source

RECOVERED
Rate: 139.264 Mbit/s ± 3 Mbit/s.

BINARY
Rate: 1 kHz to 170 MHz.
Impedance: nominal 75Ω unbalanced to –2V.
Amplitude: nominal ECL levels.
Polarity: Clock or $\overline{\text{Clock}}$.

Receiver Clock Output (Rear Panel)

Impedance: low, unbalanced.
Amplitude: nominal ECL levels.
External load: 50Ω to –2V dc coupled, or 50Ω to GND ac coupled.

Synchronisation

Modes: automatic, manual or external.

AUTOMATIC (for bit-rates > 500 kbit/s)
Sync. Loss: greater than 10,000 errors in 90,000 clock periods.
Sync. Gain: less than 10 errors in 90 clock periods.

MANUAL
Operation: pressing the MANUAL SYNC. key will initiate a resync.

EXTERNAL SYNC. INPUT (REAR PANEL)
Operation: a "high" level on the input signal initiates a resync.
Format: nominal ECL levels.
Impedance: nominal 50Ω unbalanced to –2V.
Pulse Width: minimum 20 ns.

Receiver Pattern Trigger Output (Rear Panel)

Format: one pulse per PRBS or Word pattern.
Position: Fixed.
Width: two clock periods.
Impedance: nominal 50Ω unbalanced to GND.
Amplitude: 1V pk minimum.
Protection: open/short circuit protected, maximum voltage ± 5V short term.

Error Output (Rear Panel)

Format: one edge per error. When a data loss is detected the error output port will give a continuous stream of errors. When a sync.loss is detected the output port will give an output equivalent to every other bit in error.
Impedance: nominal 50Ω to GND, unbalanced.
Amplitude: minimum 1V pk-pk about GND.
Protection: open/short circuit protected, maximum voltage ± 5V short term.

Auxiliary Inputs

ANALOG (1 OFF)
Format: voltage range 0 to +14.0V.
Resolution: 100 mV.
Impedance: nominal 1 MΩ.

DIGITAL (7 OFF)
Format: 3 are nominal ECL levels. Impedance 50Ω to –2V. 4 are nominal TTL levels.

ERROR ANALYZER SECTION

Measurement Mode: the instrument will measure errors from two sources. These will be either binary errors, resulting from a bit-by-bit comparison of the received data with the internal reference pattern, or errors detected by external equipment. and input to the 3764A in the form of one pulse per error.

GATING PERIOD

Timed: a repetitive timed interval can be set in steps of 1s. (Minimum interval 1s, maximum interval approximately 100 days.) The intervals are contiguous with no 'dead-time' between them.
Manual: START/STOP key is used to control the length of the gating period.
Single: the range of the single shot gating period is in 1s increments from 1s to approximately 100 days.

Measurements

ERROR RATIO

Method: calculates the ratio of counted errors to the number of clocks in the selected gating period.
Display: of the form $X.Y \times 10^{-N}$ where N is in the range 1 to 15. If the result is based on < 100 errors the display is truncated to $X \times 10^{-N}$.

ERROR COUNT

Method: totalizes errors over the selected gating period.
Display: individual counts displayed to 99,999 then display changes to $X.Y \times 10^{N}$. N is $\geqslant 1$ (Integers).

ERROR SECONDS

Method: counts the number of seconds in the gating period which contain at least one error.
Display: as for Error Count.

ERROR FREE SECONDS

Method: counts the number of seconds in the gating period which contain no errors.
Display: as for Error Count.

% AVAILABILITY

Method: repetitively calculates the system error ratio over 1s timed intervals during the overall gating period. The system is deemed to be 'unavailable' when the error ratio is greater than a preset threshold (Th) for at least 10 consecutive 1s timed intervals. The system becomes 'available' when the error ratio is less than this threshold for at least 10 consecutive 1s timed intervals.
Threshold (Th): selected over the range 10^{-1} to 10^{-6}.

%ER < N

Method: measures the error ratio over repetitive timed intervals (t), then calculates the % of the total gating period time (T) when the error ratio was less than the threshold value (N). Results are only accumulated when the system under test is deemed 'available'. During periods of system 'unavailability' the measurement counters freeze.

Measurement Period: the repetitive timed interval (t) may be selected for 1s or 60s.
Error Ratio Threshold (N): variable over the range 10^{-3} to 10^{-9}. The value of the threshold may be changed during or after a gating period without affecting the basic measurement. This allows a first approximation of the distribution of the error ratio results.

%EFS

Method: calculates the ratio of error free seconds to the total number of 'available' seconds in the gating period. During periods of system 'unavailability' the measurement counters freeze.

REAL TIME, PERPETUAL CLOCK

Function: gives the ability to display and record the following modes.

(a) Local time : shows hours, minutes and seconds;
(b) Date : shows day, month, year;
(c) Elapsed time : shows time since the start of a gating period in days, hours, minutes and seconds.

Source: internal crystal oscillator with battery back-up.
Note: the clock allows for leap years and all monthly day variances.

FLAGS

Mode: certain flags in addition to being displayed when they occur, are latched in the 3764A and may be viewed subsequently on the display. These are Pattern Sync Loss (SL); AIS (AI); Data Loss (DL); Clock Loss (CL); Out of Lock – option 002 only (OL); Unavailability (UA); Power Loss. The flags are displayed in order of occurrence.

HP-IB

Modes: addressable or talk only.
Flags: Remote; Listen; Talk and SRQ are indicated by LED.
Implementation: IEEE Std 488 - 1978 implementation is as follows SH1; AH1; T5; TE0; L4; LE0; SR1; RL1; PP0; DC1; DT0; C0; E1.
The HP-IB capability also conforms to IEEE Std 728-1982 for Codes and Formats.

PRINTER

Type: 20 column impact printer.
Printing Speed: typically 0.7 lines per second.
Buffer Store: approximately 100 lines.

GENERAL

Power Supply: switched 230V + 10% –18% or 115V +10% –22% ac, 48 Hz to 66 Hz.
Probe Power: HP active probes may be powered from the 3764A's connector. Supplies available; +15V; –12.6V and GND.
Connectors: all connectors are BNC. Other types may be available to special order.
Dimensions: 178 mm high; 425 mm wide, 440 mm long (7 in x 16.75 in x 17.3 in).
Weight: net wt 15 kg (33 lb) approximately, depending on option;
shipping wt (inc front panel cover) 27 kg (59 lb).
Environment: operating temperature 0°C to 55°C;
printer 0°C to 50°C;
storage temperature range –40°C to +75°C.

OPTIONS

001 FOUR FREQUENCY OPERATION

Internal Clock Source

Frequency: four crystal-controlled frequencies of 2.048 MHz; 8.448 MHz; 34.368 MHz and 139.264 MHz.
Parameters: other parameters as for the Generator Internal Clock Source of the Standard Instrument.

OFFSET
No internal frequency offsets are available. Frequency offsets may be achieved utilizing an external clock source.

External Clock Source

Parameters: As for the External Clock Source of the Standard Instrument.

Data Outputs

CODED
Bit-rate: 2M 2.048 Mbit/s, 8M 8.448 Mbit/s, 34M 34.368 Mbit/s and 139M 139.264 Mbit/s.
Format: 2M, 8M & 34M HDB3/RZ; 139M CMI.
Nominal Maximum pk Volts: 2M & 8M 2.37V; 34M 1.0V 139M 0.5V.
PRBS: 2M & 8M $2^{15}-1$; 34M & 139M $2^{23}-1$.
Nominal Impedance to GND: 75Ω.
Transition Times (75Ω): 2M, 8M & 34M < 5 ns; 139M < 2 ns.
Patterns: as for Standard Instrument.
Protection: open/short circuit protected, maximum voltage ± 5V short term.

BINARY
Format (Nominal): 2M, 8M & 34M TTL RZ/NRZ; 139M ECL RZ/NRZ.
Rate: 2M, 8M & 34M 1 kbit/s to 50 Mbit/s; 139M 1 kbit/s to 170 Mbit/s.
Nominal Impedance: 2M, 8M & 34M 75Ω to GND; 139M 75Ω to –2V.

Clock Outputs

Format: 2M, 8M & 34M nominal TTL levels; 139M nominal ECL levels.
Rate: 2M, 8M & 34M 1 kHz to 50 MHz; 139M 1kHz to 170 MHz.
External Load: 2M, 8M & 34M 75Ω to GND: 139M 75Ω to –2V, dc; 139M 75Ω to GND, ac.

Receiver Clock Source

RECOVERED
Rate: 2.048 MHz, 8.448 MHz, 34.368 MHz and 139.264 MHz.

BINARY
Frequency: 2M, 8M & 34M 1 kHz to 50 MHz; 139M 1 kHz to 170 MHz.
Format: 2M, 8M & 34M nominal TTL levels; 139M nominal ECL levels.
Impedance: 2M, 8M & 34M nominal 75Ω to GND; 139M nominal 75Ω to –2V.

Data Inputs

CODED-TERMINATED MODE
Bit-rate: 2M 2.048 Mbit/s; 8M 8.448 Mbit/s; 34M 34.368 Mbit/s; 139M 139.264 Mbit/s.
Format: 2M, 8M & 34M HDB3/RZ; 139M CMI.
Nominal Maximum pk Volts: 2M & 8M 2.37V; 34M 1.0V; 139M 0.5V.
PRBS: 2M & 8M $2^{15}-1$; 34M & 139M $2^{23}-1$.
Nominal Impedance: 2M, 8M & 34M 75Ω to GND; 139M 75Ω to –2V.
Compensation for Maximum Loss: 2M & 8M 6 dB; 34M & 139M 12 dB.
Polarity: Data or $\overline{\text{Data}}$, switched at the binary level.
Equalization: automatic equalization for cable loss. See above for maximum loss compensation.
Other Patterns: as for Standard Instrument.

CODED-MONITOR MODE
Additional Gain: 2M & 8M 30 dB; 34M & 139M 26 dB.
Other Parameters: as for Terminated Mode.

BINARY
Bit-rate: 2M, 8M & 34M 1 kbit/s to 50 Mbit/s; 139M 1 kbit/s to 170 Mbit/s.
Nominal Amplitude: 2M, 8M & 34M TTL levels; 139M ECL levels.
Nominal Impedance: 2M, 8M & 34M 75Ω to GND; 139M 75Ω to –2V.
Patterns: as for Coded Data Inputs.

EXTERNAL ERRORS
Bit-rate: 2M, 8M & 34M 1 kbit/s to 50 Mbit/s; 139M 1 kbit/s to 170 Mbit/s.
Nominal Amplitude: 2M, 8M & 34M TTL levels; 139M ECL levels.
Nominal Impedance: 2M, 8M & 34M 75Ω unbalanced to GND; 139M 75Ω unbalanced to –2V.

002 JITTER GENERATION AND MEASUREMENT

Jitter Generator Section

INTERNAL JITTER MODULATION

Fixed Frequency Points:

100 Hz	1 kHz	10 kHz	100 kHz	1 MHz
200 Hz	2 kHz	20 kHz	200 kHz	2 MHz
500 Hz	5 kHz	50 kHz	500 kHz	3.5 MHz
				4 MHz

Amplitude/Frequency:

Amplitude (UI pk-pk)	Frequency Range
0 to 10.0	100 Hz to 5 kHz
0 to 1.00	10 kHz to 2 MHz
0 to 0.75	at 3.5 MHz
0 to 0.50	at 4 MHz

Amplitude Steps: 0.1 UI pk-pk in the range 100 Hz to 5 kHz; 0.01 UI pk-pk in the range 10 kHz to 4 MHz.
Frequency Accuracy: crystal controlled, better than 0.1%.
Absolute Accuracy: (referred to generator clock monitor output and measured on the 0 to 1 transition of the clock output.)

Frequency Range	Amplitude Accuracy
100 Hz to 5 kHz	As for Ext Jitter Mod, range 10
10 kHz to 4 MHz	As for Ext Jitter Mod, range 1

Intrinsic Jitter: ⩽ 0.02 UI pk-pk 5 kHz and below;
⩽ 0.01 UI pk-pk 10 kHz and above.

EXTERNAL JITTER MODULATION
Input Impedance: nominal 50Ω unbalanced to GND.
Range:

	Amplitude (UI pk-pk)	Frequency Range
Range 1	0 to 1.15	2 Hz to 2 MHz
	0 to 0.75	2 MHz to 3.5 MHz
	0 to 0.5	3.5 MHz to 5 MHz
Range 10	0 to 11.5	2 Hz to 100 kHz

Maximum Input Voltage: 10V pk-pk.
Nominal Sensitivity: Range 1 — 5V/UI pk-pk at 1 kHz;
Range 10 — 0.5V/UI pk-pk at 1 kHz.
Absolute Accuracy: (Referred to generator clock monitor output and measured on the 0 to 1 transition of the clock output)
Range 1 — better than ± 3% ± 0.01 UI pk-pk to 1 MHz additional degradation > 1 MHz less than ± 5%.
Range 10 — better than ± 3% ± 0.1 UI pk-pk.
Intrinsic Jitter: ⩽ 0.02 UI pk-pk on range 10;
⩽ 0.01 UI pk-pk on range 1.

Jitter Receiver Section

Mode: jitter can be measured either on a clock recovered from the CMI coded input data or on the binary input clock.
Jitter Reference: the jitter reference signal may be either derived internally from the input data/clock or provided externally.
Frequency Range: external jitter reference and jittered data/clock must be within ± 20 ppm of 139.264 MHz.

Jitter Reference Clock Input (Rear Panel)

Impedance: nominal 75Ω to GND, unbalanced.
Amplitude: nominal ECL levels.

Demodulated Jitter Output (Rear Panel)

Impedance: nominal voltage source, minimum load nominally 50Ω to GND.
Amplitude: range 1 — 5.0V/UI pk-pk;
range 10 — 0.5V/UI pk-pk.
Accuracy: as per measurement circuit (when terminated 50Ω to GND).
Bandwidth: nominally 2 Hz to 3.5 MHz.

Jitter Measurement Input (Rear Panel)

Impedance: nominal 50Ω to GND.
Sensitivity: range 1 — 0.2 UI/V pk-pk;
range 10 — 2.0 UI/V pk-pk.

Jitter Measurement Section

All jitter measurements are made over a selected gating period, as per the error measurements.

JITTER AMPLITUDE
Method: measures maximum value of pk-pk timing jitter over the selected gating period.

	Jitter Amplitude Range	
	1 UI	10 UI
Max jitter amplitude (UI pk-pk)	1.15	11.5
Lowest specified frequency		
(Internal Reference)	200 Hz	200 Hz
(External Reference)	nominally 2 Hz	nominally 2 Hz
Highest specified frequency	3.5 MHz	10 kHz

RANGE 1

Accuracy (at 1 kHz):
(Internal Reference) ± 3% ± 0.01 UI pk-pk;
(External Reference) ± 3% ± 0.02 UI pk-pk.
Intrinsic Jitter: ⩽ 0.01 UI (as measured on binary clock with filters Off and Internal Reference).

RANGE 10

Accuracy (at 1 kHz):
(Internal Reference) ± 3% ± 0.1 UI pk-pk;
(External Reference) ± 3% ± 0.2 UI pk-pk.
Intrinsic jitter: ⩽ 0.1 UI (as measured on binary clock with filters Off and Internal Reference.)

Additional Degradation Factors: applicable to ranges 1 and 10.
Frequency Response: < 200 Hz and > 1 MHz — less than ± 5%.
Pattern Dependency: ⩽ 0.08 UI pk-pk (CMI; $2^{23}-1$ PRBS; filters Off).

JITTER HIT COUNT

Method: counts the number of times the received jitter amplitude exceeds a user-set threshold.
Threshold Range: Range 1 — 0 to 1.00 UI pk-pk in steps of 0.01 UI;
Range 10 — 0 to 10.0 UI pk-pk in steps of 0.1 UI.
Display: as for Error Count.
Sensitivity: typically > 40 ns width to count.

JITTER HIT SECONDS

Method: counts the number of seconds in which at least one jitter hit has occurred.
Display: as for Error Count.

JITTER HIT FREE SECONDS

Method: counts the number of seconds in which no jitter hits have occurred.
Display: as for Error Count.

JITTER HITS OUTPUT (REAR PANEL)

Format: one edge per jitter hit. This is a dual purpose port. The output indicates the receipt of either an error or a jitter hit depending on the selected measurement.

INTERNAL FILTERS

The three internal filters are as specified in CCITT Recommendation 0.171.

Filter	Type	Nominal 3 dB Corner Freq	Nominal Slope Asymptote
HP1	High Pass	200 Hz	20 dB/decade
HP2	High Pass	10 kHz	20 dB/decade
LP	Low Pass	3.5 MHz	60 dB/decade

It is possible to configure these filters in the following ways:

OFF (measurement circuit is connected directly to the jitter demodulator),
LP; HP1; HP2; LP + HP1; LP + HP2;
EXT (to allow connection of external filters between the demodulated jitter output port and the jitter measurement input port).

003 DELAYED DATA OUTPUTS

This option provides three data outputs on the rear panel in addition to the main data output on the front panel.
Format: CMI or binary RZ/NRZ as selected for the main data output.
Delays: Main data O/P to delayed O/P 1 — exactly half a sequence length (on PRBS only.)
Delayed O/P 1 to delayed O/P 2 — ⩾ 1 bit;
Delayed O/P 2 to delayed O/P 3 — ⩾ 1 bit.
Other Parameters: as for the Main Data Output.

010 TAPE CARTRIDGE UNIT

Storage Capacity of Tape: approximately 210 K characters.
Format: 20 data characters per "line".
Buffer Store: approximately 100 lines.
Environment: operating temperature 0°C to 35°C.

MODES

Results Store: measurement results, system messages, time and date information may be recorded on tape.
Results Recall: the data stored on the tape may be read by two methods:
(a) directly in a personal computer. The tape format is compatible with the HP 85 and the cartridge may be read in this machine using a suitable programme.
(b) indirectly via a data transfer through the HP-IB port. HP-IB compatible devices will be able to input this data.
Settings Store: The contents of the measurement pre-set non-volatile memory may be stored on the tape via this control.
Setting Recall: the contents of the measurement pre-set non-volatile memory may be programmed from the tape via this control.

SPECIAL OPTION: ADDITIONAL CRYSTAL FREQUENCY F2

Frequency: any crystal frequency in the range 1 MHz to 170 MHz.
Availability: available on all versions of the 3764A EXCEPT option 001 (four frequency). To special order only.
Format: available at the binary interface only.

Related Hewlett-Packard equipment

3762A Data Generator/3763A Error Detector — Since being introduced in 1977 this useful instrument combination has become an industry standard. The separate generator and receiver illustrate a general purpose design concept for 139 Mbit/s test requirements. Features include: Burst Mode operation, variable input and output thresholds, variable clock frequency offsets, zero substitution and a wide choice of PRBS. This allows them to be used in a wide range of applications from TDMA satellite transmission to digital multiplex, line and radio testing; using both Bell and CCITT hierarchies.

Transit Case — Where a greater degree of protection is needed than is offered by the front panel cover, a glass fibre Transit Case (HP part number 9211-2650) should be used.

Printer — Printers which conform to IEEE 488-1978 Recommendations and which can be manually set to a Listen Only or Listen Always mode are suitable for use with the 3764A.

Ordering information

Instrument Selection Table

Option	Capability
Standard	Error measurement and analysis at 139 Mbit/s
001	Error measurement and analysis at 2, 8, 34 and 139 Mbit/s
002	Error measurement, error analysis, jitter generation and timing jitter measurements at 139 Mbit/s
003	As the standard instrument with the addition of three delayed data outputs at 139 Mbit/s
010	Replaces the standard Printer with a Tape Cartridge Unit

Note: The instrument options, 001/002/003, are mutually exclusive.

Data Logger — Specifying option 010 along with one other option number deletes the built-in Printer and substitutes the Tape Cartridge Unit, e.g. STD/010.

Special Option Crystal Frequency (F2) — This is provided to special order only and is not available on option 001 instruments. Frequencies in the range 1 MHz to 170 MHz can be specified, but the frequency ordered is only available at the binary interface.

HP-IB Operation — This is a standard feature of all versions of the 3764A.

For more information, contact your local HP Sales Office or —
In US: Call • East (301) 258-2000 • Midwest (312) 255-9800 • South (404) 955-1500 • West (213) 877-1282
Or, write Hewlett-Packard, 3000 Hanover Street, Palo Alto, California 94304.
In Europe: Hewlett-Packard S.A., 150 route du Nant-d'Avril, CH 1217 Meyrin 2 - Geneva, Switzerland.
In Japan: Yokogawa-Hewlett-Packard Ltd., 3-29-21 Takaido-Higashi, Suginami-ku, Tokyo, 168, Japan.

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