OPERATING AND SERVICE MANUAL

MODEL 1645A
DATA ERROR ANALYZER

(Including Options 003, 101, 905, and 908)

SERIAL NUMBERS

This manual applies directly to instruments with serial numbers prefixed **2337A**.

With changes described in Seciton VII, this manual also applies to instruments with serial numbers prefixed **1320A** through **1745A**.

For additional important information about serial numbers, see INSTRUMENTS COVERED BY MANUAL in Section I.

© COPYRIGHT HEWLETT-PACKARD COMPANY/COLORADO TELECOMMUNICATIONS DIVISION 1982
P.O. BOX 7050 COLORADO SPRINGS, CO 80933

ALL RIGHTS RESERVED

Manual Part Number 01645-90016
Microfiche Part Number 01645-90017

REVISED: FEBRUARY 1985

WARNING

SAFETY

If this instrument is to be energized via an autotransformer for voltage reduction, make sure the common terminal is connected to the earthed pole of the power source.

BEFORE SWITCHING ON THIS INSTRUMENT, the protective earth terminals of this instrument must be connected to the protective conductor of the (mains) power cord. The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action must not be negated by use of an extension cord (power cable) without a protective conductor (grounding).

Make sure that only fuses with the required rated current and of the specified type (normal blow, time delay, etc.) are used for replacement. The use of repaired fuses and the short-circuiting of fuse holders must be avoided.

Whenever it is likely that the protection offered by fuses has been impaired, the instrument must be made inoperative and be secured against any unintended operation.

GROUNDING

Any interruption of the protective (grounding) conductor (inside or outside the instrument) or disconnecting the protective earth terminal can make this instrument dangerous. Intentional interruption is prohibited.

HIGH VOLTAGE

Any adjustment, maintenance, and repair of the opened instrument under voltage should be avoided as much as possible and, when inevitable, should be carried out only by a skilled person who is aware of the hazard involved.

Capacitors inside the instrument may still be charged even if the instrument has been disconnected from its source of supply.

Adjustments and service described herein are performed with power supplied to the instrument while protective covers are removed. Energy available at many points, if contacted, result in personal injury.

CAUTION

LINE VOLTAGE

BEFORE SWITCHING ON THIS INSTRUMENT, make sure instrument requirements match the voltage of the power source.

GROUNDING

BEFORE SWITCHING ON THIS INSTRUMENT, ensure that all devices connected to this instrument are connected to the protective (earth) ground.

BEFORE SWITCHING ON THIS INSTRUMENT, ensure that the line power (mains) plug is connected to a three-conductor line power outlet that has a protective (earth) ground. (Grounding one conductor of a two-conductor outlet is not sufficient.)

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. This Operating and Service Manual contains information required to install, operate, test, adjust, and service the Hewlett-Packard Model 1645A Data Error Analyzer. The manual part number is listed on the title page. Also listed on the title page of this manual is a Microfiche part number. This number can be used to order 4 x 6-inch microfilm transparencies of the manual. Each microfiche contains up to 96 photo-duplicates of the manual pages. The microfiche package also includes the latest Manual Changes supplement as well as a pertinent Service Notes.

1-3. Supplied with this manual is an Operating Manual which is a copy of the first three manual sections, and should be kept with the instrument for use by the operator. The part number is listed on the title page.

1-4. SPECIFICATIONS.

1-5. Instrument specifications are listed in table 1-1. These specifications are the performance standards or limits against which the instrument is tested. Table 1-2 lists supplemental characteristics. Supplemental characteristics are not specifications but are typical characteristics included as additional information for the user.

1-6. INSTRUMENTS COVERED BY MANUAL.

1-7. Attached to the instrument is a serial number plate. The serial number is in the form: 0000A00000. It is in two parts; the first four digits and the letter are the serial prefix and the last five digits are the suffix. The prefix is the same for all identical instruments; it changes only when a change is made to the

Table 1-1. Specifications

MEASUREMENTS

RATE MEASUREMENTS

Bit Error: provides BER to 1999 with exponent to minus 9.

Carrier Loss: provides rate of data dropouts or number of carrier losses from 0 to 99 with exponent to minus 9. Data dropout or carrier loss detection is selected with an internal switch.

Clock Slip: provides rate of clock slips from 0 to 99 with exponent to minus 9.

Block Error: provides BKER to 998 with exponent to minus 6. A block is 1000 bits.

PERCENTAGE MEASUREMENTS

Skew: provides percentage from 0 to 98% of ones versus zeros errors.

Jitter/Total Peak: jitter provides peak period variation as a percentage (0-63%) of an ideal bit period. Total peak provides the sum effect of jitter and bias distortion also expressed as a percentage of an ideal bit period. Measurements apply only to asynchronous systems. Desired measurement must be selected prior to running a test.

BIT RATE

INTERNAL

Transmitter Bits per Second: selectable 75, 150, 200, 300, 600, 1200, 1800, 2400, 3600, 4800, 7200, 9600.

Crystal Frequency: 5.75 MHz ±0.03%, <0.01% jitter.

Receiver with Bit Synchronizer: same as internal transmitter.

EXTERNAL

Transmitter and Receiver: to 5 MHz.

DATA PATTERNS

PRBS Bit Lengths: 1 048 575, 2047, 511, and 63.

Zero/One Sequences: 7:1, 3:1, 1:1, and MARK (continuous dc level). All patterns can be complemented by DATA/DATA switch.

TEST LENGTH

EXPONENT RANGE switch provides test lengths in bits from 10^2 to 10^9. In AUTO, the 1645A counts the first 98 errors and terminates the test on the next power of ten bits received. In continuous, the 1645A counts errors until the test is manually terminated.

DATA OUTPUTS/INPUTS

FRONT PANEL

Inputs: data input requires TTL levels; maximum input 5.5 V.

Outputs: receiver sync, transmit sync, and events at TTL levels; data output is 2 V into 50 ohms; jitter/total peak is 1 V p-p for each 10% of p-p distortion from waveform causing jitter.

REAR PANEL

Inputs: backward channel data, external transmitter and receiver clocks require TTL levels; maximum input 5.5 V.

Outputs: bits lost at TTL level; internal transmitter clock is >2 V into 50 ohms.

Multipin Connectors: 25 pin female connector for interfacing with standard RS-232C communications systems. 36 pin female printer output at TTL levels in BCD 8421 code.

instrument. The suffix however, is assigned sequentially and is different for each instrument. The contents of this manual apply to instruments with the serial number prefix(es) listed under SERIAL NUMBERS on the title page.

1-8. An instrument manufactured after the printing of this manual may have a serial number prefix that is not listed on the title page. This unlisted serial number prefix indicates the instrument is different from those described in this manual. The manual for this newer instrument is accompanied by a yellow Manual Changes supplement. This supplement contains "change information" that explains how to adapt the manual to the newer instrument.

1-9. In addition to change information, the supplement may contain information for correcting errors in the manual. To keep this manual as current and accurate as possible, Hewlett-Packard recommends that you periodically request the latest Manual Changes supplement. The supplement for this manual is identified with the manual print date and part number, both of which appear on the manual title page. Complimentary copies of the supplement are available from Hewlett-Packard.

1-10. For information concerning a serial number prefix that is not listed on the title page or in the Manual Changes supplement, contact your nearest Hewlett-Packard office.

1-11. DESCRIPTION.

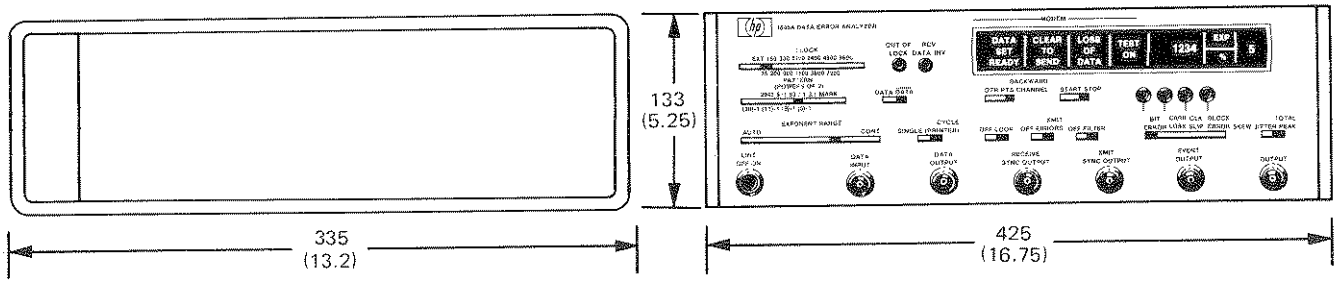
1-12. The 1645A Data Error Analyzer is designed to aid in troubleshooting data communication systems. Data communication link problems are quickly isolated by the 1645A with simultaneous measurements of the following link parameters: bit-error rate, block-error rate, clock-slip rate, carrier-loss rate, skew, jitter and total peak distortion.

Table 1-2. Supplemental Characteristics

INDICATORS

OUT OF LOCK: indicates that receiver synchronization has not occurred or has been lost.
BIT ERROR, CARRIER LOSS, CLOCK SLIP, and BLOCK ERROR: continuous monitors that light each time there is an error.
DATA SET READY (DSR): indicates that modem power is on.
CLEAR TO SEND (CTS): indicates that modem connection to a data line has been established.
LOSS OF DATA: indicates that the Analyzer is not receiving data.
TEST ON: indicates that a test is in progress.
RECEIVED DATA INVERTED: indicates if the 1645A autopolarity circuit has received inverted data.

POWER: 115 or 230 Vac, 48 to 66 Hz, 150 VA max.
DIMENSIONS: see outline drawings.
WEIGHT: net, 8.2 kg (18 lb); shipping, 10.9 kg (24 lb).
OPERATING ENVIRONMENT
Temperature: 0°C to +55°C.
Humidity: to 95% relative humidity at +40°C.
Altitude: to 4600 m (15 000 ft).
Vibration: vibrated in three planes for 15 minutes each with 0.254 mm (0.010 in.) excursion, 10 to 55 Hz.



NOTES

1. DIMENSIONS ARE FOR GENERAL INFORMATION ONLY. IF DIMENSIONS ARE REQUIRED FOR BUILDING SPECIAL ENCLOSURES, CONTACT YOUR HP FIELD ENGINEER.
2. DIMENSIONS ARE IN MILLIMETRES AND (INCHES).

1-13. Containing separate transmitter and receiver sections, the 1645A provides both loop-around and end-to-end system testing capability. Test functions include automatic time base, automatic frame synchronization, automatic polarity selection, and simultaneous measurement of peak distortion and phase jitter with realistic signals. The Model 1645A is also capable of self-test operation.

1-14. The standard Model 1645A is compatible with both TTL and RS-232C logic levels. Test data is transmitted or received by the 1645A through front- and rear-panel BNC connectors for TTL levels, or through a rear panel connector compatible with RS-232C systems. Replaceable logic-interface modules provide test compatibility with data systems having other logic levels.

1-15. All test measurements are taken simultaneously and stored internally for selectable readout. Front-panel digital readouts provide the status of the system under test. Data from the system under test can be further analyzed with an oscilloscope from front- and rear-panel output connectors. In addition, test data is supplied to a rear-panel connector for use with a printer.

1-16. OPTIONS.

1-17. The following options extend the usefulness of the Model 1645A:

Option 003 — provides a power supply for operation from 100/200-volt ac power sources. Slide Switch must be set to read 115 for the 100 Vac range and set to read 230 for the 200 Vac range.

Option 101 — provides a wider phase-locked loop bandwidth which permits the 1645A to be operated with test sets that have up to ±3% variation in clock repetition rates. Circuit changes from the standard instrument are described on schematic 14 in Section VIII. In this configuration, the 1645A becomes part of the 1645S system.

Option 905 — power cord for use in rack-mount installations. Conforms to standard CEE 22-VI.

Option 908 — rack mounting kit.

1-18. ACCESSORIES SUPPLIED.

1-19. The following accessories are supplied with the 1645A:

One 10-foot RS-232C interface cable, HP Part No. 01645-61605.

1-20. ACCESSORIES AVAILABLE.

1-21. The following accessories are available for the 1645A:

10233A Printer Interface Cable: connects the 1645A to HP Model 5055A or 5150A printer; 36 pin male connector on one end and 50 pin male connector on the other.

10235A Interface Cover: provides time interval and voltage measurements, audio monitoring, data set control signal monitoring, and the ability to send control signals to RS-232C data sets.

10387A Type 303 Interface: permits the 1645A to be connected directly to Western Electric Type 303 wideband data station equipment for troubleshooting.

10388A CCITT V35 Interface: permits the 1645A to be used with modems that conform to the CCITT V35 Standard, such as the Western Electric Type 306.

10389A Breakout Box: provides an operator with the capability to manipulate and monitor individual signal lines on an RS-232C data link.

Front Panel Cover (HP Part No. 5060-8767): protects the 1645A front panel during transit and provides a convenient carrying handle. This cover is not needed when a 10235A Interface Cover is ordered.

1-22. RECOMMENDED TEST EQUIPMENT.

1-23. Equipment required to maintain the Model 1645A is listed in Section IV. Other equipment may be substituted if it meets or exceeds the critical specifications listed in the table.

SECTION II

INSTALLATION

2-1. INTRODUCTION.

2-2. This section contains information and instructions for installing and interfacing the Model 1645A. Included are initial inspection procedures, power and grounding requirements, installation instructions, and procedures for repacking the instrument for shipment.

2-3. INITIAL INSPECTION.

2-4. Inspect the shipping container for damage. If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the instrument has been checked mechanically and electrically. Procedures for checking electrical performance are given in Section IV. If the contents are incomplete, if there is mechanical damage or defect, or if the 1645A does not pass the Performance Tests, notify the nearest Hewlett-Packard office. If the shipping container is damaged, or the cushioning material shows signs of stress, notify the carrier as well as the Hewlett-Packard office. Keep the shipping materials for carrier's inspection. The HP office will arrange for repair or replacement at HP option without waiting for claim settlement.

WARNING

Read the Safety Summary at the front of the manual before installing or operating the instrument.

2-5. PREPARATION FOR USE.

2-6. POWER REQUIREMENTS. The instrument requires a power source of either 115 or 230 volts ac ±10%, single-phase, 48 to 66 Hz that can deliver 150 volt-amperes (maximum). The instrument is normally shipped from the factory set to operate from a 115-volt ac power source. To operate the instrument from a 230-volt ac power source, proceed as follows:

a. Remove input power cord (if connected).

b. Replace factory installed line fuse (0.8 A) located on rear of instrument with 0.5-ampere fuse.

c. Move line selector switch to 230 V position.

d. Reconnect input power cord.

2-7. This instrument is equipped with a three-wire power cable. When connected to an appropriate ac power receptacle, this cable grounds the instrument cabinet. The type of power cable plug shipped with each instrument depends on the country of destination. Refer to figure 2-1 for the part numbers of the power cable and plug configurations available.

2-8. INSTRUMENT COOLING. The instrument is adequately cooled by normal air circulation. No special cooling is required.

CAUTION

When rack mounted, the instrument should not be operated in an ambient air temperature that exceeds +50°C.

2-9. RACK-MOUNTING PROCEDURE.

2-10. The instrument is designed for either bench or rack mounting. A rack-mounting kit (Option 908) is available from our HP Sales/Service Office for proper installation of the 1645A. Install mounting hardware as follows (see figure 2-2 for parts identification):

a. Detach tilt stand by pressing it away from front feet. Remove all plastic feet by depressing foot release button and sliding feet free.

b. Remove aluminum trim strip from each side of instrument with thin blade tool.

c. Attach rack mounting flange in space where trim strip was removed (use screws provided with kit). Large notch of flange should be positioned at bottom of instrument.

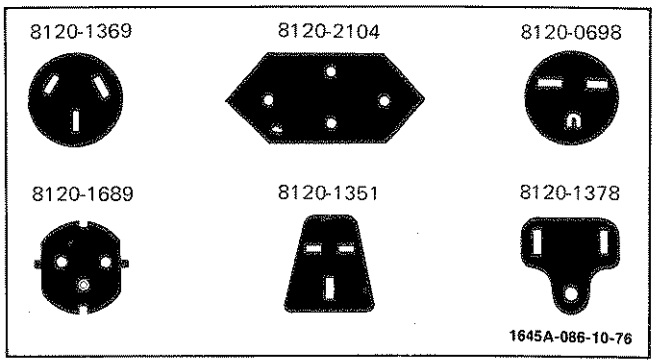
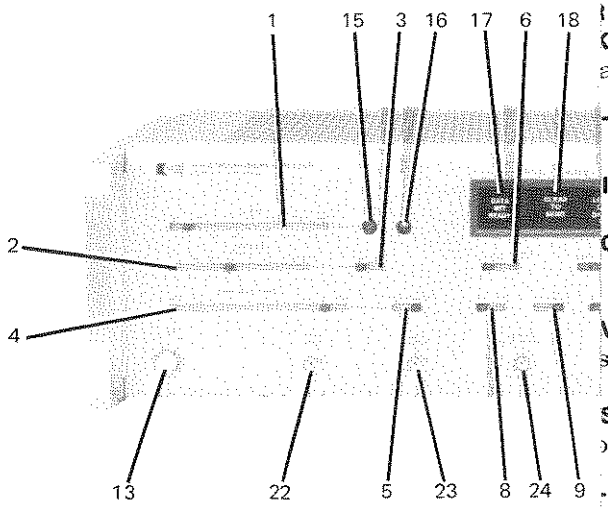


Figure 2-1. Power Cord Configurations



IROR, CARRIER LOSS, CLOCK SLIP, and
K ERROR: continuous monitors that
ach time there is an error.

TORS

INPUT. Test data input, TTL level.

OUTPUT. Transmitted test data at TTL

VE SYNC OUTPUT. Sync pulse for an
scope which is provided once per frame.

SYNC OUTPUT. A sync pulse is pro-
once per transmitted test frame.

OUTPUT. A TTL-level pulse coinci-
vith errors in the test selected by the
y switch.

JT. A waveform representing real-
tter or total peak distortion in the sys-
nder test. Desired output is selected
JITTER/TOTAL PEAK switch.

INTERFACE. Replaceable logic inter-
odule. Standard instrument is compati-
h RS-232C logic levels.

LOST. A gated output of the internal
itter clock coincident with LOSS OF
or CARR LOSS occurrences.

MIT CLOCK. Output of the internal
itter clock as set by the front-panel
K selector.

ER. Output for supplying data to a

MIT CLOCK. Input for a TTL-level ex-
transmitter clock to 5 MHz.

CV CLOCK. Input for a TTL-level ex-
receiver clock.

WARD CHANNEL DATA. Input for
ard (supervisory) channel data.

UT. Power input from AC line.

POWER. Power supply connector for
10235A Interface Cover.

0.8 Amp slow-blow fuse for 115 Vac
on. 0.5 Amp slow-blow fuse for 230
eration.

SELECTOR SWITCHES

1. **CLOCK:** selects 12 internal transmitter clock frequencies or the rear panel input for external clocks up to 5 MHz.

2. **PATTERN:** selects transmitter and receiver test patterns in four pseudo-random sequences of 1 048 575, 2047, 511, and 63, or three zeros/ones sequences of 7:1, 3:1, 1:1, or a continuous dc level in MARK.

3. **DATA/$\overline{\text{DATA}}$:** sets pattern output format. $\overline{\text{DATA}}$ is the complement of DATA and provides the complement of PATTERN.

4. **EXPONENT RANGE:** selects length of receiver test interval. In AUTO, the Analyzer counts the first 98 errors and terminates the test on the next power of 10 bits received. Positions 2 through 9 select test interval length in powers of ten. In CONT (continuous) the receiver counts errors until the test is manually terminated.

5. **SINGLE/CYCLE (PRINTER):** in SINGLE, each test is started manually with all six test results stored. In CYCLE, test results are stored for four seconds and another test automatically started. With a printer connected, four selected test results are printed after each test.

6. **DTR/RTS/BACKWARD CHANNEL:** controls handshake signals from the 1645A to the modem.

tors, and Connectors

SECTION III

OPERATION

3-1. INTRODUCTION.

3-2. This section provides explanations of measurement capabilities and applications, describes operating controls and indicators and operating considerations, and provides step-by-step operating procedures for the 1645A. Figure 3-1 shows the 1645A front and rear panels and provides brief functional descriptions of panel features. Detailed descriptions of more complex controls and features are provided later in this section.

3-3. MEASUREMENT CAPABILITIES.

3-4. Depending on the position of the EVENT switch, the 1645A digital readout indicates event rate (number of events occurring during a given test), or error percentage. The 1645A digital readout indicates rate measurements when the EVENT switch is set to BIT ERROR, CARR LOSS, CLK SLIP, or BLOCK ERROR. The 1645A indicates percent measurements when the EVENT switch is set to SKEW, JITTER, or TOTAL PEAK.

3-5. These statistics can all be measured simultaneously during one test sequence, digitally stored, and read out later at the operator's convenience. They can also be sent to a digital printer for long term unattended monitoring. They can be measured over a fixed test time or the test time can be automated to always give in-range displays with changing error rates. This is especially valuable for unattended monitoring, otherwise high error rates can overflow the display before the measurement is complete.

3-6. RATE MEASUREMENTS. The $\frac{\text{EXP}}{(-)}$ indicator is on for all rate measurements. The number to the right of the $\frac{\text{EXP}}{(-)}$ indicator is a power to 10 (exponent) indicating the number of units the test is based upon. The number to the left of the $\frac{\text{EXP}}{(-)}$ indicator is the number of events that occurred during the test. For example, if 19 events occurred during a 1000 (1×10^3) unit test the event rate would be $\frac{19}{1 \times 10^3}$ or 19×10^{-3}. The readout would be 19 $\frac{\text{EXP}}{(-)}$ 3.

3-7. Bit Error. (Refer to figure 3-2.) A bit error is a one mistaken for a zero or vice versa. Bit error rate (BER), the number of times a bit error occurs during a given test, is an indication of data link quality.

$$\text{BER} = \frac{\text{number of errors}}{\text{number of received bits in a given test}}$$

3-8. For example, if 159 errors occurred during a 10 000 (1×10^4) bit test, the BER is $\frac{159}{1 \times 10^4}$ or 159×10^{-4}. With the EVENT switch placed in the BIT ERROR position, the readout would be 159 $\frac{\text{EXP}}{(-)}$ 4.

3-9. The 1645A computes the error rate by correlating the received bit pattern with a local replica of the transmitted data sequence. The 1645A can generate an ideal error-free replica sequence by sampling a few error-free received bits.

3-10. The bit error rate measurement can be ruined by two common line faults; phase hits (clock slips) and dropouts. Either fault can cause the indicated error rate to increase greatly, quickly overflowing the error counters. When either condition occurs, the 1645A receiver is prevented from counting, and the front panel digital readouts are stopped. When the dropout terminates and data is again supplied to the receiver, the readout is enabled and event counting is resumed.

3-11. Although the Model 1645A does not count bit errors after recognizing a clock slip or data dropout, up to 32 bit errors may be indicated before the Model 1645A recognizes that one of these events has occurred. These false errors can be minimized by using the space/mark PATTERN switch positions 1:1, 3:1, or 7:1. If a high dropout or clock slip rate is suspected, the 1:1 pattern provides the highest accuracy.

3-12. Block Error. (See figure 3-2.) The 1645A divides input data into 1000-bit blocks for test analysis. Block error rate (BKER) is an indication of the number of received blocks in a given test that contains one or more errors.

$$\text{BKER} = \frac{\text{number of blocks with one or more errors}}{\text{number of received blocks in a given test}}$$

3-13. For example, if 49 out of 100 (1×10^2) received data blocks contained one or more errors, the BKER

would be $\frac{49}{1 \times 10^{2}}$ or 49 x 10^{-2}. With the EVENT switch in the BLOCK ERROR position, the readout would be 49 $\frac{\text{EXP}}{(-)}$ 2.

3-14. Block error rates for blocks between 100 and 10 000 bits in length may be determined using the formula

$$BKER_2 \cong BKER \frac{b2}{1000}$$

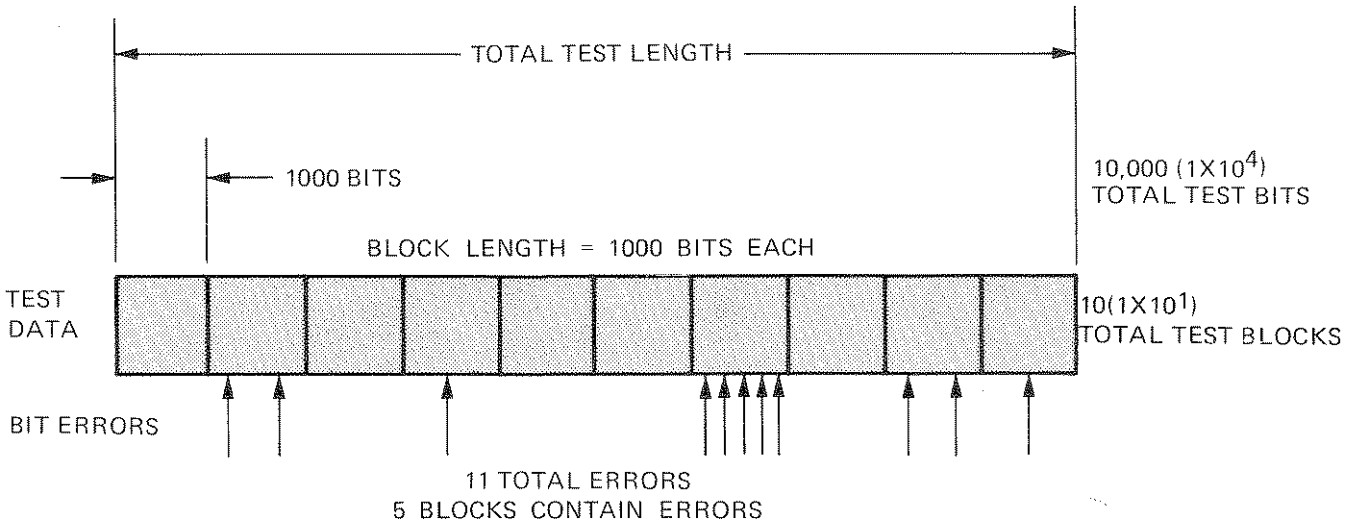
where BKER is the displayed block error, b_2 is the desired block length, and the bit error rate is less than 1 x 10^{-3}.

3-15. Since data is usually transmitted and processed in blocks, block error rate (BKER) is a better indicator of throughput than bit error rate. Throughput is the amount of good data (data not requiring retransmission and not including coding and signal bits) received per unit time.

3-16. Carrier Loss. Carrier Loss indicates a loss of input data to the MODEM under test. With the EVENT switch in the CARR LOSS position, the readout indicates the number of carrier losses occurring during a given test. The 1645A counts the carrier loss signals supplied by the modem.

3-17. The CARR LOSS position can be changed to count dropouts by means of an internal switch. When counting dropouts, the 1645A looks at data transitions. If 16 bits (clock cycles) occur with no transitions, the event is determined to be a dropout. The one exception is when the 2^{20}—1 PRBS sequence is selected. Then a dropout is called only after 32 bits have occurred with no transition.

3-18. Clock Slip. The Clock Slip Rate is an indication of the number of times during a given test the input data has moved backwards or forwards in relation to the data stream clock. The 1645A determines that a burst of errors is due to a clock slip or phase hit rather than just random errors by comparing the error count from an open-loop feedforward register with the error count from a feedback register. If only the feed-



BER (BIT ERROR RATE) = $\frac{\text{TOTAL ERRORS}}{\text{TOTAL TEST BITS}} = \frac{11}{1 \times 10^{4}} = 11 \times 10^{-4}$

BKER (BLOCK ERROR RATE) = $\frac{\text{BLOCKS CONTAINING ERRORS}}{\text{TOTAL TEST BLOCKS}} = \frac{5}{1 \times 10^{1}} = 5 \times 10^{-1}$

BER IS AN INDICATION OF DATA QUALITY.

BKER IS AN INDICATION OF ERROR DISTRIBUTION.

1645A-017-03-76

Figure 3-2. Bit Error Rate vs Block Error Rate

forward register has errors, the errors are not caused by invalid data, but by a phase shift greater than a bit period.

3-19. PERCENTAGE MEASUREMENTS. The % indicator is on for all percent measurements with no exponent displayed.

3-20. Skew. The SKEW measurement is an indication of the percentage of errors which were ones changed to zeros. For example, a display of 75% indicates that 75% of the errors were ones changed to zeros, and the remaining 25% of the errors were zeros changed to ones. Skew provides a sensitive measure of the modem threshold setting. If the modem receiver threshold is biased, one or the other will predominate.

3-21. Jitter or Total Peak. (See figure 3-3.) Jitter is an asynchronous system measurement indicating the maximum peak-to-peak variation in bit periods of the received data due to timing variations expressed as a percent of an ideal bit period. TOTAL PEAK indicates total peak distortion, the sum of peak jitter and bias. Bias is the consistent width variation of a mark with respect to a space. The jitter and total peak measurements are disabled when CLOCK is set to EXT.

3-22. The jitter measuring circuits of the 1645A constantly compute the time in hundreds of a bit period between the data edge and the next clock edge (see figure 3-4). Both the maximum and minimum values are stored. The difference between the two is displayed on the readout as a percentage of an ideal bit period. When JITTER is selected, leading edge variations ($M^+_{MAX} - M^+_{MIN}$) are counted. When TOTAL PEAK is selected, both leading- and trail-edge variations ($M^+_{MAX} - M^+_{MIN}$) and ($M^-_{MAX} - M^-_{MIN}$) are counted.

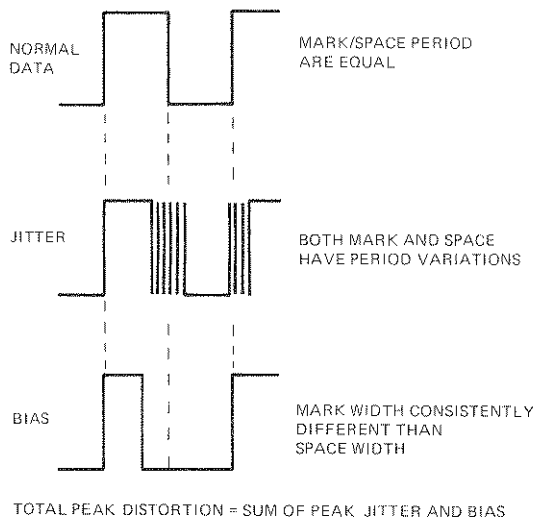


Figure 3-3. Jitter, Total Peak, and Bias

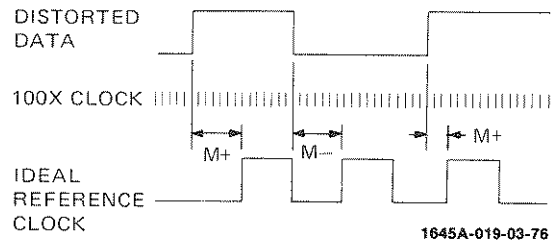


Figure 3-4. Jitter/Total Peak Measurement Method

3-23. The instantaneous analog value of jitter or total peak distortion is available as a continuous monitor at the OUTPUT connector. The output level is 1 volt p-p for each 10% p-p jitter or bias and has a chopped appearance, because it is derived directly from a D/A converter (see figure 3-5). When TOTAL PEAK is selected, the oscilloscope waveform will have two traces. The upper trace represents instantaneous leading-edge jitter, the lower trace trailing-edge jitter and the separation between them is bias distortion. To null bias distortion, adjust the modem until the upper and lower traces overlap.

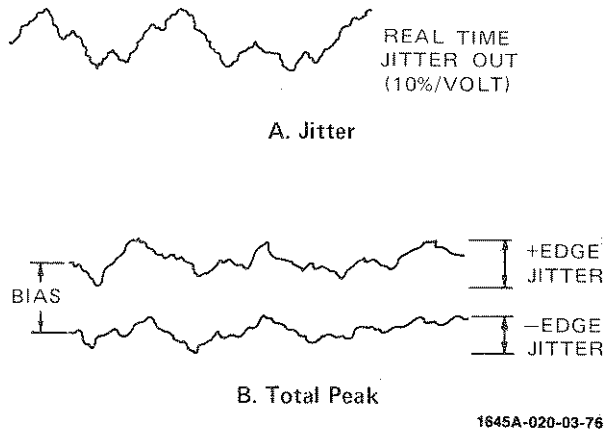


Figure 3-5. Jitter/Total Peak Output Waveforms

3-24. APPLICATIONS.

3-25. The Model 1645A provides a means of testing a data transmission MODEM (Modulator/Demodulator). Testing can be local, end-to-end over a half or a full-duplex data link, or loop-around over a full-duplex data link. Figure 3-6 shows the various test configurations for the 1645A.

3-26. LOCAL MODEM TESTING. A local test requires one Model 1645A connected to the MODEM data terminal input. The MODEM transmitter output is connected to its own receiver input.

3-27. END-TO-END TESTING.

3-28. Half-duplex Data Link. Half-duplex, end-to-end testing requires two instruments, one connected to the data terminal input of each MODEM. One

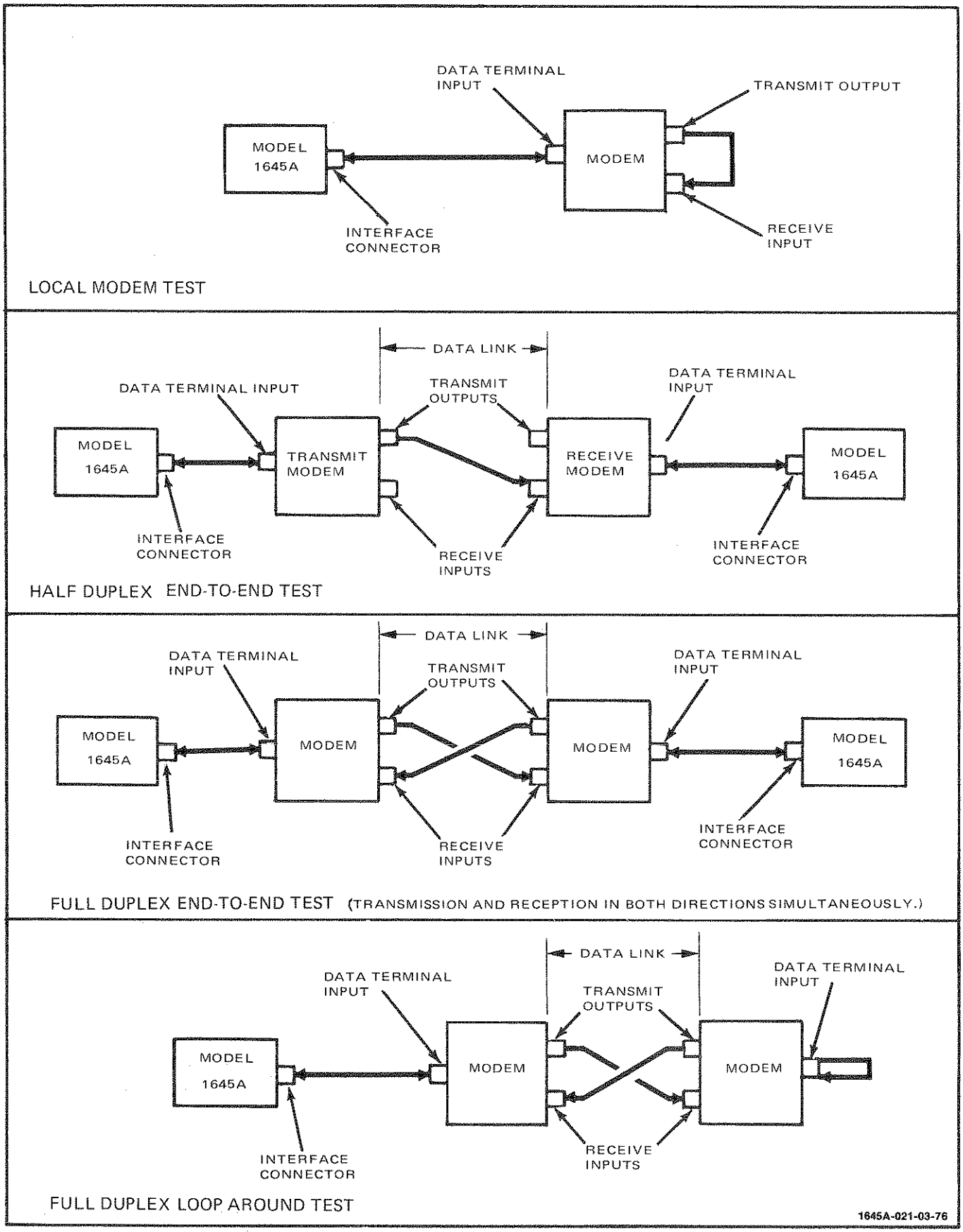


Figure 3-6. Test Configurations

Model 1645A transmits through the system, and the other Model 1645A receives and analyzes the data. To verify results, the direction of transmission can be reversed.

3-29. Full-duplex Data Link. With a Model 1645A connected to both ends of a full-duplex data link, end-to-end testing is simultaneous in both directions. Each instrument receives and analyzes test data transmitted on one channel while transmitting test data on the second channel.

3-30. LOOP AROUND TESTING. Loop-around testing over a full-duplex data link requires one Model 1645A. The remote MODEM receives and retransmits the test data back to the local MODEM for reception and analysis.

3-31. MEMORY SYSTEM TESTING. An additional application area is memory system testing. With suitable interfacing, the PRBS sequences generated by the 1645A can be recorded from the 1645A transmitter and played back to the receiver for the same measurement capability offered for communications applications.

3-32. CONTROLS AND INDICATORS.

3-33. CLOCK. The CLOCK switch setting determines the bit frequency for the 1645A transmitter and receiver. For asynchronous systems, the CLOCK switch is set for the operating frequency of the modem under test. The 1645A provides clock rates of 75 bps, 150 bps, 200 bps, 300 bps, 600 bps, 1200 bps, 1800 bps, 2400 bps, 3600 bps, 4800 bps, 7200 bps, and 9600 bps. For synchronous systems, CLOCK is set to EXT, and the 1645A uses the clock from the modem under test, applied through the rear-panel data interface connector. The 1645A also accepts TTL level clock signals in EXT through a rear-panel BNC connector.

3-34. PATTERN. The PATTERN switch determines the pattern of the transmitter data output. Test data is transmitted in frames. A frame is one complete test pattern or sequence. The PATTERN switch provides eight transmit patterns. The first four positions provide PRBS patterns 2^{20}—1, 2^{11}—1, 2^{9}—1, or 2^{6}—1 bits in length. The next three positions provide the following space/mark patterns; 7:1 (seven zeros followed by a one), 3:1, and 1:1. The last PATTERN position provides a constant MARK output (a dc level). In addition, all output patterns can be inverted by the DATA/$\overline{\text{DATA}}$ switch.

3-35. The test patterns conform to the CCITT International Standards. In addition, the 2^{6}—1 PRBS pattern (63 bits long) allows the 1645A to work with older Bell Telephone test sets. The 2^{20}—1 PRBS pattern (over one-million bits long) provides a very long series of ones for worst case testing of a modem receiver's bit synchronizer.

3-36. EXPONENT RANGE. The EXPONENT RANGE switch selects the desired length (bit count) of the test interval. In AUTO, the 1645A counts the first 98 errors and terminates the test on the next power of 10 bits received. For example, if 98 errors were contained in 1763 (1 x 10^{3} plus) bits, the test would run to 1 x 10^{4} (10 000) bits and then terminate. Positions 2 through 9 select test interval length in powers of ten, i.e., position 4 sets up a test 1 x 10^{4} (10 000) bits long. With the EXPONENT RANGE switch in CONT, the bit errors are totaled on the readout. The $\frac{\text{EXP}}{(-)}$ indicator is disabled, and testing continues until manually terminated by STOP.

3-37. Table 3-1 lists the bit counts and block counts for each numbered switch position.

*Table 3-1. Bit Lengths/Block Lengths**

EXPONENT RANGE POSITION	BIT COUNT	BLOCK COUNT
2	100 (1 x 10^{2})	.1 (1 x 10^{-1})
3	1000 (1 x 10^{3})	1 (1 x 10^{0})
4	10 000 (1 x 10^{4})	10 (1 x 10^{1})
5	100 000 (1 x 10^{5})	100 (1 x 10^{2})
6	1 000 000 (1 x 10^{6})	1000 (1 x 10^{3})
7	10 000 000 (1 x 10^{7})	10 000 (1 x 10^{4})
8	100 000 000 (1 x 10^{8})	100 000 (1 x 10^{5})
9	1 000 000 000 (1 x 10^{9})	1 000 000 (1 x 10^{6})

*The 1645A is supplied with the block length set to 1000. If other block lengths are desired, the block length can be changed. Refer to paragraph 3-62.

3-38. SINGLE/CYCLE (PRINTER). In SINGLE, each test must be started manually. Test results of all six measurements are stored indefinitely for selectable display. In CYCLE, the 1645A displays the selected test results for four seconds and then automatically starts another test.

3-39. Printer Operation. When the CYCLE (PRINTER) position is selected and a printer is connected to the rear-panel PRINTER connector, test results are sent to the printer in standard BCD 8421 format at the end of each test cycle. Test results are printed in the following sequence; Bit Error Rate, Clock Slip Rate, Block Error Rate, and test function selected by the EVENT switch. The measurement selected by the EVENT switch is printed without an exponent for indexing purposes. An omega symbol (Ω) preceding a reading indicates an overrange condition. An optional printer interface cable (HP Model 10233A) is available for interfacing a printer with the 1645A.

NOTE

Regardless of EVENT switch position, the readout and EVENT OUTPUT connector will give bit error only during a test if a printer is connected. At the end of a test cycle, the test results supplied to the printer are also provided to the readout and to the EVENT OUTPUT connector.

3-40. DTR/RTS/BACKWARD CHANNEL. This switch controls handshake signals from the 1645A to the modem under test and enables backward channel operation. The handshake signals allow the 1645A to operate through any modem system. DTR (Data Terminal Ready) signals the modem that the 1645A is on line and ready. RTS (Request To Send) indicates that the 1645A transmitter is ready to begin sending test data. The BACKWARD CHANNEL position provides access to the backward channel through the rear-panel BACKWARD CHANNEL DATA connector. This allows the operator to insert signals so that the effects of crosstalk from backward channel data on error rates can be observed.

3-41. EVENT. The EVENT switch selects which error measurement is displayed on the digital readout and applied to the EVENT OUTPUT connector. The EVENT switch permits selection of the following test results:

BIT ERROR - Readout indicates bit error rate to 1999 with exponent to minus 9.

CARR LOSS - Readout indicates rate of carrier loss signals from modem or data dropouts to 99 with exponent to minus 9.

CLK SLIP - Readout indicates rate of clock slippages occurring during test to 99 with exponent to minus 9.

BLOCK ERROR - Readout indicates block error rate to 998 with exponent to minus 6.

SKEW - Readout indicates percentage (0-98%) of ones versus zeros errors per test.

JITTER/TOTAL PEAK - JITTER indicates percentages (0-63%) of period variation of a mark or space in asynchronous systems. TOTAL PEAK indicates percentage sum (0-63%) of total peak distortion, the sum of jitter and bias (width variation between a mark and a space). CLOCK must be set to an internal transmitter clock frequency when measuring jitter or total peak.

3-42. COUNT D/O - COUNT C/L SWITCH. When the EVENT switch is set to CARR LOSS, an internal switch mounted on the A1 board between A1J10 and A1J11 (see figure 3-7) determines whether the 1645A counts carrier loss signals from the modem under test or data dropouts detected by the 1645A. The 1645A counts dropouts in the COUNT D/O position or carrier losses in the COUNT C/L position.

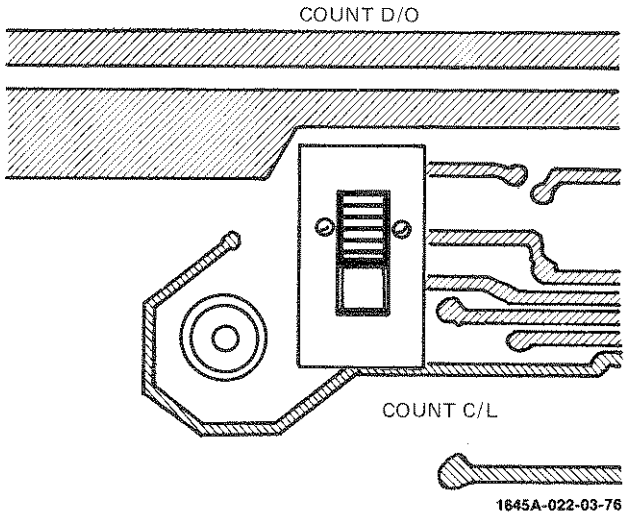


Figure 3-7. COUNT D/O - COUNT C/L Switch

3-43. OFF/FILTER. This switch permits a digital matched filter to be switched in or out ahead of the error detection circuits. Used with asynchronous systems, the filter removes noise and prevents data sampling on glitches. This feature allows the 1645A to operate in the presence of high noise levels on data. Also, if switching in the filter reduces the error rate, it indicates the modem filter is not doing an adequate job.

3-44. INDICATORS. Error monitor lights are provided for bit error, block error, clock slip, and carrier loss. The monitor lights flash any time an error occurs, whether or not a measurement is in process. This provides a continuous visual indication of the test situation to supplement the actual data taken in the measurements.

3-45. In addition to the error monitor lights, several other indicators provide status information for the 1645A and modem. The OUT OF LOCK light indicates that receiver synchronization has not occurred or has been lost. RCV DATA INV indicates that the 1645A autopolarity circuit has received inverted data. DSR (Data Set Read) indicates that modem power is on. CTS (Clear To Send) indicates that modem connection to a data line has been established. LOSS OF DATA indicates that the 1645A is not receiving data. The TEST ON light indicates that a test is in progress.

3-46. OPERATING FEATURES.

3-47. SIMULTANEOUS MEASUREMENTS WITH STORAGE. All measurements by the 1645A are made simultaneously on the same data base. Each measurement is then stored inside the unit and can be referred to by simply moving the EVENT switch to the measurement position. This allows comparison-type measurements relating the different kinds of measurements made under the same test conditions.

3-48. AUTOMATIC SYNCHRONIZATION. The 1645A receiver automatically locks on to the received signal in a minimum amount of time. It relocks to the signal when synchronization is lost or momentarily interrupted. The 1645A required no manual syncing. The automatic synchronization feature allows the unit to be left unattended for long periods of time.

3-49. AUTOMATIC POLARITY DETECTION. In some systems the transmitted data may be inverted by the system. The 1645A automatically detects this phase inversion and corrects for it before making error measurements.

3-50. AUTOMATIC MEASUREMENT MODE. With the EXPONENT RANGE switch set to AUTO, a test is automatically terminated at the next integer value of 10 data bits after detecting at least 98 bit errors. In this mode, the readout provides a direct, auto-ranged measurement of error rate with no operator interaction.

3-51. SELF-TEST MODE. A self-test mode is included in the 1645A where errors are automatically injected into the transmitted data stream which is internally connected to the receiver. The receiver then can measure this predetermined error rate. This mode tests bit errors and block errors. The self-test mode verifies instrument performance, and reduces test and calibration time because the verification can be performed in a few seconds on site.

3-52. REPLACEABLE INTERFACES. The entire modem interface is contained on one plug-in board. This allows the instrument to be easily configured for use with logic levels other than RS-232C. Refer to Section I for other standard interfaces available. Specially-tailored interfaces can be ordered through HP Sales/Service Offices.

3-53. AUXILIARY OUTPUTS. Real time jitter or total peak distortion for use with an oscilloscope or RMS meter is provided through a BNC connector on the 1645A. An output of each error pulse is provided for further analysis of error characteristics. During drop-outs or carrier losses, while the error rate is blanked, the internal clock is gated to the BITS LOST connector, so that lost bits can be counted. The BITS LOST output enables the operator to keep track of downtime caused by system failures.

3-54. OPERATING CONSIDERATIONS.

3-55. PROPER INTERFACE. Before conducting a test, verify that the 1645A interface circuitry (A15) matches the MODEM under test (i.e., if MODEM operates with an RS-232C convention, the 1645A must have an RS-232C interface board installed).

3-56. OUT OF LOCK/TEST ON INDICATORS. Under some operating conditions, the OUT OF LOCK or TEST ON indicator may be on prior to starting a test. Should this occur, push the START/STOP switch to STOP and hold until the indicator goes out. The STOP position unlocks the autopolarity circuit and allows the instrument to synchronize with the received data. It also clears an internal flip-flop controlling the TEST ON indicator.

3-57. FLASHING DIGITAL READOUT. If the event count overranges, the readout digits will flash on and off. A pulse is generated at the EVENT OUTPUT connector for each error whether the readout is flashing or not. In SKEW, a flashing display indicates insufficient data to make a reading.

3-58. FRONT AND REAR PANEL BNC CONNECTORS. When conducting tests with the following front- and rear-panel data input/output BNC connectors, the DATA INTERFACE connector must be disconnected to prevent data interference.

DATA INPUT (front panel)
EXT XMIT CLOCK (rear panel)
EXT RCV CLOCK (rear panel)

3-59. MODEMS WITH AUTOMATIC ANSWERING. Testing systems having an automatic answering feature must be done with the MODEM connected to the data-link telephone lines and set for manual operation.

3-60. TESTING WITH TWO INSTRUMENTS. When conducting a data-link test with two instruments (end-to-end testing), the CLOCK and PATTERN switch positions on both instruments must be identical. For half-duplex end-to-end testing, the transmit Model 1645A DTR/RTS/BACKWARD CHANNEL switch is set to RTS, and the receive Model 1645A switch is set to DTR. For full-duplex end-to-end testing, both instruments are set to RTS.

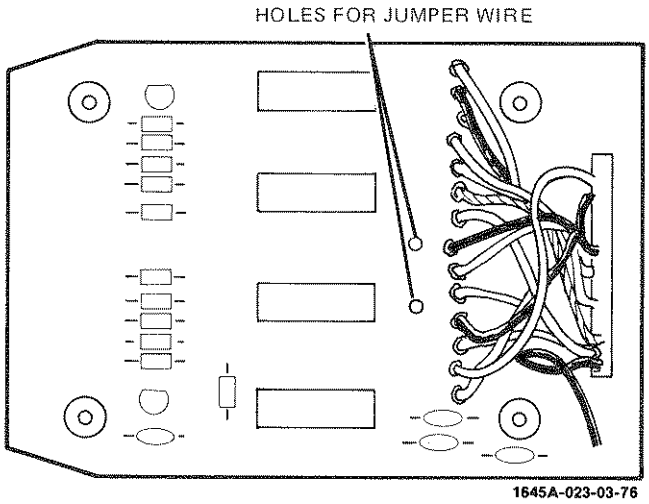


Figure 3-8. Data Transmission Inhibit Modification

3-61. HANDSHAKE SIGNALS. When the 1645A DTR/RTS/BACKWARD CHANNEL switch is in the RTS position, the instrument transmits data continuously, not waiting for CTS (Clear To Send) from the modem. To inhibit data transmission until CTS is received, a jumper or 10-ohm resistor must be inserted between pin 8 of U4 and pin 5 of U2 on the RS-232C interface board, A15. Holes are supplied near the middle of the board, parallel to the square pins, for this purpose (see figure 3-8).

NOTE

When operating two 1645A's in full duplex testing with the jumper inserted, a CLEAR TO SEND can be generated by moving the DTR/RTS/BACKWARD CHANNEL from the DTR to the RTS position. When CLEAR TO SEND is not present, the receiving 1645A will indicate OUT OF LOCK, CARRIER LOSS and LOSS OF DATA.

3-62. BLOCK LENGTH. The block length for the block error measurement is set to 1000 at the factory. To change the block length, modify the A8 board as follows:

a. Remove R1 and connect a jumper wire from point BE (between U3 and U4) to the point specified in figure 3-9.

b. Remove A8R2 through A8R5 and connect jumpers in the corresponding circuit arrangement for the block length desired (see figure 3-9).

3-63. TEST CONDITION SELECTION. The CLOCK, PATTERN, and EXPONENT RANGE switches set up the basic conditions for a test. CLOCK and PATTERN set up both the transmitter and the receiver for the desired test conditions, and the EXPONENT RANGE switch sets up the receiver for the desired test length.

3-64. Test Length. Test length is a function of bit count and clock frequency. The bit count of a test is determined by the EXPONENT RANGE switch. The time of a test is the bit count divided by the CLOCK rate (bits/sec). Table 3-2 lists bit counts and time lengths available with front-panel settings.

3-65. Frame Vs Block. Test data is transmitted in frames. A frame is a complete test pattern or sequence. For example, with the PATTERN switch in 511, the transmitter sends a 2^9—1 or 511 bit PRBS (Pseudorandom Binary Sequence). The complete PRBS sequence constitutes a frame of data.

3-66. Regardless of frame length, the standard 1645A receiver divides input data into 1000-bit blocks for analysis. For example, if the transmitted PRBS sequence (frame) is 511 bits long, a 1000-bit input data block would contain 1.96 frames. If the transmitted frame is 2047 bits long, an input data block would contain 0.488 frame. Table 3-3 lists the frame content and block counts available with front-panel settings.

3-67. OPERATING PROCEDURES.

3-68. SELF TEST. To verify proper operation of the Model 1645A, proceed as follows:

a. Set the Model 1645A front panel controls as follows:

LINE	ON
CLOCK	9600
PATTERN	63
EXPONENT RANGE	4
DATA/$\overline{\text{DATA}}$	DATA
SINGLE/CYCLE (PRINTER)	SINGLE
OFF/LOOP	LOOP
OFF/XMIT ERRORS	XMIT ERRORS
OFF/FILTER	OFF
DTR/RTS/BACKWARD CHANNEL	DTR
EVENT	BIT ERROR
JITTER/TOTAL PEAK	JITTER

NOTE

Momentarily set the START/STOP switch to STOP and observe that the OUT OF LOCK indicator is out.

b. Momentarily set the START/STOP switch to START and observe that the TEST ON indicator is ON while readout is counting, and OFF when counting stops.

c. Set the EVENT switch to the indicated positions and observe the following indications.

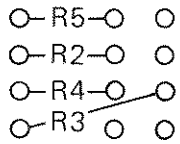
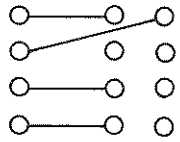
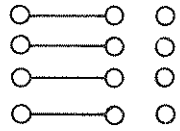
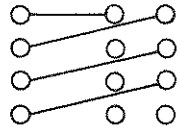
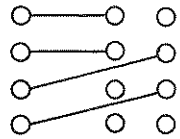
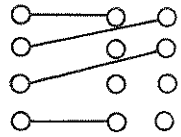
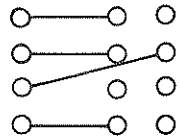
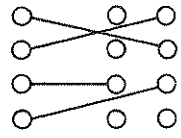
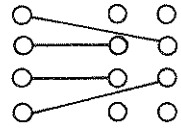
BLOCK LENGTH	BLOCK END (REMOVE R1)	BLOCK SUBTRACT INPUT TO A8U20 (REMOVE R2, R3, R4 OR R5 AS NEEDED)
10	BE to BE1	
10^2	BE to BE2	
10^3 (STANDARD)	BE to BE3	
10^4	BE to BE4	
10^5	BE to BE5	
10^6	BE to BE6	
10^7	BE to BE7	
10^8	BE to BE8	
10^9	BE to BE9	

Figure 3-9. A8 Jumper Connections for Different Block Lengths

Table 3-2. Test Lengths

CLOCK SETTING (BITS/SEC)	EXPONENT RANGE SETTING (BITS/SEC)							
	2	3	4	5	6	7	8	9
75	1.33 sec	13.33 sec	2.22 min	22.22 min	3.70 hrs	37.04 hrs	370.36 hrs	3703.61 hrs
150	.667 sec	6.67 sec	66.67 sec	11.11 min	1.85 hrs	18.52 hrs	185.19 hrs	1851.94 hrs
200	.50 sec	5.0 sec	50 sec	8.33 min	1.39 hrs	13.89 hrs	138.89 hrs	1388.89 hrs
300	.333 sec	3.33 sec	33.33 sec	5.55 min	55.55 min	9.26 hrs	92.59 hrs	925.92 hrs
600	.167 sec	1.67 sec	16.67 sec	2.78 min	27.78 min	4.63 hrs	46.29 hrs	462.96 hrs
1200	.083 sec	.833 sec	8.33 min sec	1.39 min	13.89 hrs	2.31 hrs	23.15 hrs	231.48 hrs
1800	.056 sec	.556 sec	5.56 sec	55.56 sec	9.26 min	1.54 hrs	25.43 hrs	154.32 hrs
2400	.042 sec	.417 sec	4.17 sec	41.67 sec	6.94 min	1.16 hrs	11.57 hrs	115.74 hrs
3600	.028 sec	.278 sec	2.78 sec	27.78 sec	4.63 min	46.30 min	7.72 hrs	77.16 hrs
480	.021 sec	.208 sec	2.08 sec	20.83 sec	3.47 min	34.72 min	5.79 hrs	57.87 hrs
7200	.014 sec	.138 sec	1.39 sec	13.89 sec	2.31 min	23.14 min	3.86 hrs	38.58 hrs
9600	.010 sec	.104 sec	1.04 sec	10.42 sec	1.74 min	17.36 min	2.89 hrs	28.93 hrs

EVENT Position	Indication	
BIT ERROR	158 (±1)	EXP (—) of 4
CARR LOSS	0	EXP (—) of 4
CLK SLIP	0	EXP (—) of 4
BLOCK ERROR	10 (+2, —1)	EXP (—) of 1
SKEW		98%

Table 3-4 lists the BIT ERROR and BLOCK ERROR self-test indications for other settings of PATTERN and EXPONENT RANGE.

d. Set the Model 1645A front-panel controls as follows:

CLOCK	75
PATTERN	2^{20}—1
EXPONENT RANGE	2
DATA/DATA	DATA
SINGLE/CYCLE (PRINTER)	CYCLE
OFF/LOOP	LOOP
OFF/XMIT ERRORS	OFF
OFF/FILTER	OFF
EVENT	JITTER

e. Momentarily set the START/STOP switch to START. After 60 seconds, readout should indicate less than or equal to 3% (for Option 101, less than or equal to 5%).

Table 3-3. Block Counts/Frame Contents

EXPONENT RANGE (BLOCKS)	PATTERN						
	PRBS PATTERNS (SEQUENCE BIT LENGTH)				SPACE/MARK PATTERNS		
	$2^{20}-1$ (1048575)	$2^{11}-1$ (2047)	$2^{9}-1$ (511)	$2^{6}-1$ (63)	7:1	3:1	1:1
2 (.1)	9.54×10^{-5}	.049	.196	1.59	12.50	25	SQUARE WAVE
3 (1)	9.54×10^{-4}	.488	1.96	15.87	125	250	SQUARE WAVE
4 (10)	9.54×10^{-3}	4.885	19.57	158.73	1250	2500	SQUARE WAVE
5 (100)	.095	48.85	195.69	1587.30	12 500	25×10^{3}	SQUARE WAVE
6 (1000)	.954	488.5	1956.95	15 873.02	12.5×10^{4}	25×10^{4}	SQUARE WAVE
7 (10 000)	9.54	4885.2	19 569.47	158730.16	12.5×10^{5}	25×10^{5}	SQUARE WAVE
8 (100 000)	95.37	48 852	195 694.72	1587301.59	12.5×10^{6}	25×10^{6}	SQUARE WAVE
9 (1 000 000)	953.67	488 519.8	1956 947.16	15873015.87	12.5×10^{7}	25×10^{7}	SQUARE WAVE

3-69. MODEM TEST PROCEDURE.

a. Connect Model 1645A rear panel DATA INTERFACE connector to the MODEM data terminal or computer connector using the appropriate cable (HP P/N 01645-61605 for RS-232C connections).

b. If system is asynchronous, set CLOCK to frequency of MODEM under test. If system is synchronous, set CLOCK to EXT.

c. Set PATTERN to 1:1 and EXPONENT RANGE to AUTO.

d. Set Model 1645A front panel controls as follows:

DATA/$\overline{\text{DATA}}$ ..... DATA
SINGLE/CYCLE (PRINTER) ..... SINGLE
OFF/LOOP ..... OFF
OFF/XMIT ERRORS ..... OFF
OFF/FILTER ..... OFF
DTR/RTS/BACKWARD CHANNEL .. DTR
EVENT ..... BIT ERROR

e. When MODEM is able to accept data, the DATA SET READY indicator will go on. After DATA SET READY is on, set DTR/RTS/BACKWARD CHANNEL to RTS.

f. When MODEM is ready to transmit, the CLEAR TO SEND indicator will go on.

g. Momentarily push START/STOP to STOP and wait until the OUT OF LOCK and TEST ON indicators go out. When these indicators are out, synchronization has occurred and testing can continue.

h. Set up required test conditions by selecting the appropriate positions of the following switches (refer to tables 3-1, 3-2, and 3-3):

PATTERN
EXPONENT
DATA/$\overline{\text{DATA}}$
SINGLE/CYCLE (PRINTER)

Table 3-4. Self Test Indications

SWITCH SETTINGS		READOUT INDICATIONS			
PATTERN	EXPONENT RANGE	BIT ERROR		BLOCK ERROR	
		Readout	EXP (—)	Readout	EXP (—)
63	3	15 (±1)	3	1 (±1)	0
2^6-1	4	158 (±1)	4	10 (±1)	1
	5	1587 (±1)	5	98 (±1)	2
511	3	1 (±1)	3	1 (±1)	0
2^9-1	4	19 (±1)	4	10 (±1)	1
	5	195 (±1)	5	100 (±1)	2
	6	1956 (±1)	6	998 (±1)	3
2047	4	4 (±1)	4	5 (±1)	1
$2^{11}-1$	5	48 (±1)	5	49 (±1)	2
	6	488 (±1)	6	489 (±1)	3
$2^{20}-1$	6	1 (±1)	6	1 (±1)	3
	7	9 (±1)	7	10 (±1)	4
	8	95 (±1)	8	96 (±1)	5
	9	953 (±1)	9	954 (±1)	6

Note: Refer to table 3-2 for test lengths

NOTE

Known errors can be injected into the transmitted data stream by setting OFF/XMIT ERRORS to XMIT ERRORS. When XMIT ERRORS the Model 1645A injects one error per transmitted PRBS frame. Refer to table 3-3 for an indication of the frame and block counts for various combinations of PATTERN and EXPONENT RANGE switch settings.

i. Start a new test by momentarily pushing START/STOP to START.

3-70. MODEM TROUBLESHOOTING. The flowchart given in figure 3-10 summarizes how the 1645A pinpoints troublesome elements of a communications systems. The algorithm lists the error measurement and error with its probable source.

3-71. The bit error rate test is used to measure the overall link quality. Block error rate, when compared to bit error rate on the same data base, provides an indication of the burst characteristics of the errors. If errors occur in a distributed fashion (high block error rate) then review skew, jitter, or total peak distortion tests. Conversely, high bit error rate coupled with low block error rate indicates that phase hits and dropouts should be checked.

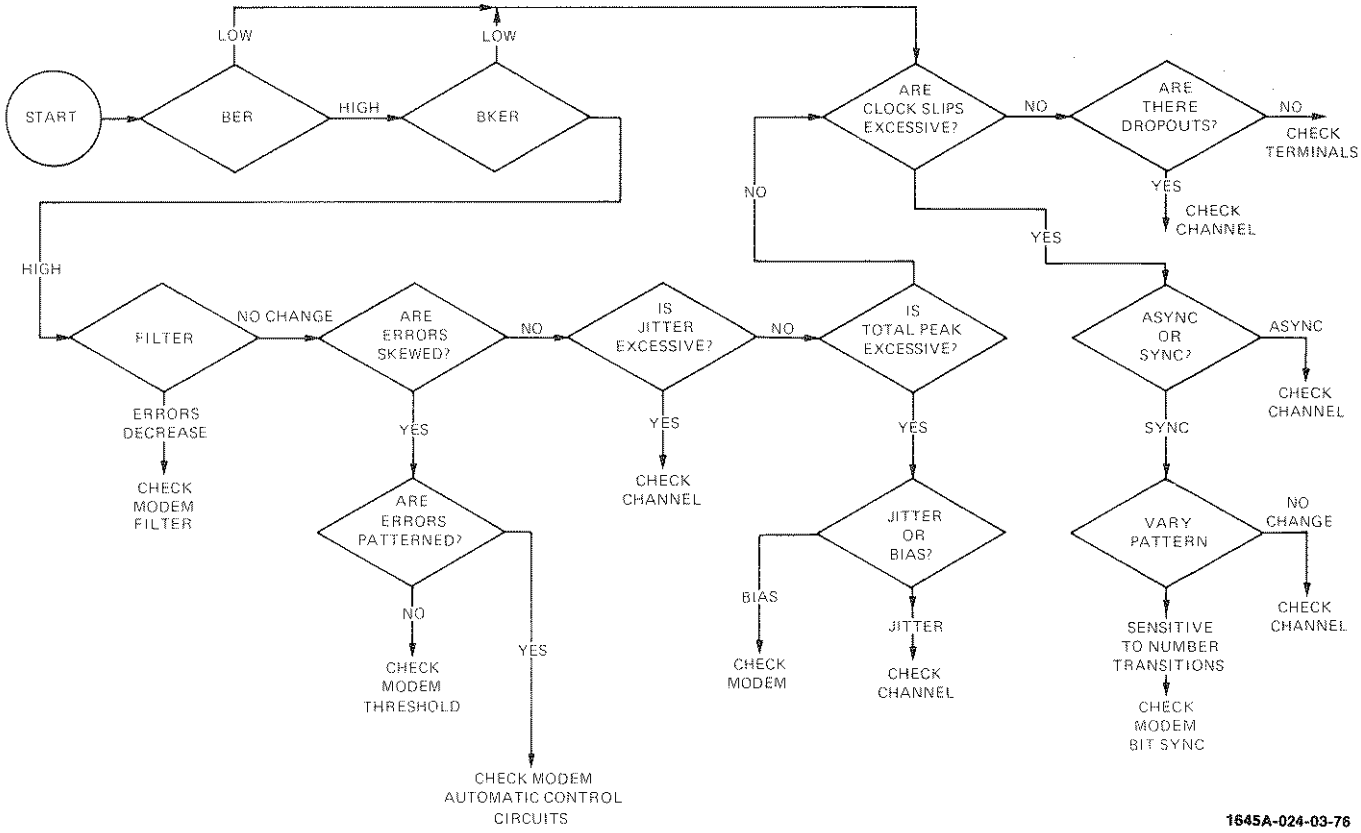


Figure 3-10. Modem Troubleshooting Algorithm

3-72. If switching in the Analyzer's Digital filter reduces BER and BKER, then the modem filter is suspect.

3-73. Ideal Skew characteristics of erroneous data is 50%, that is, errors should be equally distributed between ones being mistaken for zeros and vice-versa. If errors are skewed, then there are two possible causes: errors are being repeated (patterned) or a decision threshold is set wrong with errors being weighted in one direction or another. In the latter case, total peak distortion probably indicates the presence of bias distortion.

3-74. Excessive jitter indicates phase hits are occurring in the channel because the 1645A transmitting terminal is known to be stable (if in doubt, a self test will verify stability). An excessive total peak measurement (the sum of peak jitter and peak bias distortion) indicates that the modems are suspect. If bias is excessive, there will probably also be skew if the digital filter is turned off.

3-75. Excessive clock slips indicate that data may be valid but has shifted relative to the clock. Clock slips in asynchronous systems generally occur from switching transients. In synchronous systems, clock slips can also be caused by bit synchronizer problems. To determine if clock slips are caused by channel or modem problems in a synchronous system, the modem bit synchronizer can be exercised with repetitive test patterns having long periods without transitions (pseudorandom sequence of 2^{20}—1) and patterns with many transitions (2^6—1).

3-76. Dropouts (lack of transitions in the data) or carrier losses indicate channel problems such as radio fades or other severe amplitude hits.

3-77. If, after a thorough analysis of data, the erroneous terminal outputs can not be determined to be caused by the channel or modem, then the terminals should be checked.

Table 4-1. Recommended Test Equipment

Instrument Type	Recommended Model	Required Characteristics	Required For
Multimeter	HP 34740A with HP 34702A	Measure resistance and voltage	Performance Check and Troubleshooting
Monitor Oscilloscope	HP 1740A	General Purpose 50 MHz	Performance Check, Adjustments, and Troubleshooting
Counter	HP 5300A/5302A	Frequency measurement 0 to 10 MHz, with 0.01% accuracy	Performance Check and Troubleshooting
Pulse Generator	HP 8013B	Adjustable 0-50 MHz, External trigger input.	Performance Check, Adjustments, and Troubleshooting
Recorder	HP 5055A	Paper Printout capability	Performance Check
Logic-state Analyzer	HP 1600A	Monitor TTL levels	Troubleshooting
Logic Probe	HP 10525T	Monitor TTL IC's	Troubleshooting
Logic Pulser	HP 10526T	Pulse TTL Circuits	Troubleshooting
Logic Clip	HP 10528A	Connect to DIP packages	Troubleshooting
BNC "T" Conn. and BNC to BNC Connector	HP 1250-0781 HP 1250-0080		Performance Check, Adjustments, Troubleshooting

SECTION IV

PERFORMANCE CHECK

4-1. INTRODUCTION.

4-2. This section contains step-by-step procedures for checking instrument specifications listed in table 1-1.

4-3. TEST EQUIPMENT.

4-4. Test equipment required for procedures in this section is listed in table 4-1. Test equipment equivalent to that recommended may be substituted, provided it meets the required characteristics listed in the table. For best results, use recently calibrated test equipment.

4-5. PERFORMANCE CHECK.

4-6. The performance check can be used as part of an incoming inspection, as a periodic operational test, or to check calibration after repair or adjustments have been made. Specific checks can be made separately if desired. If the instrument does not perform as specified, refer to adjustment procedures in Section V.

4-7. Performance check record forms are provided at the end of this section for recording measurements obtained in the first running of the procedure. This record may be used to compare measurements taken at later dates with the original. The first time the performance check is made, enter the results on the performance check record. Remove the record from the manual and file it for future reference. Be sure to include the instrument serial number on the record for identification.

4-8. PHASE LOCK LOOP.

a. Remove top cover and connect monitor oscilloscope to A14TP1, LOOP FILTER.

b. Set Model 1645A controls as follows:

CLOCK 9600
PATTERN 1:1
EXPONENT RANGE 2
SINGLE/CYCLE (PRINTER) ..... CYCLE (PRINTER)
OFF/LOOP ..... LOOP
OFF/XMIT ERRORS ..... OFF
OFF/FILTER ..... OFF
EVENT ..... JITTER/TOTAL PEAK
JITTER/TOTAL PEAK ..... JITTER

c. Adjust controls to view one complete cycle of waveform and observe that waveform has a 50% duty cycle.

d. Set PATTERN to 2^{20}—1 and CLOCK to 75.

e. Momentarily push START/STOP to START, observe JITTER readout for one minute, and verify that readout indication is less than or equal to 3%. (If readout is greater than 3% or if greater than 5% for option 101, refer to Section V for Phase Lock Loop Adjustment.)

4-9. INT XMIT CLOCK.

a. Connect counter B 10 MHz input to 1645A rear panel INT XMIT CLOCK connector.

b. Set 1645A OFF/LOOP switch to LOOP.

c. Remove top cover and set COUNT D/O-COUNT C/L switch (A1S1) to COUNT D/O.

d. Set counter to indicate frequency.

e. Set 1645A CLOCK switch to the following positions (table 4-2) and observe the indicated frequencies on the counter:

Table 4-2. Clock Frequencies

CLOCK Position	Frequency (Hz)
9600	9600 ±0.03% (9597.12 Hz to 9602.88 Hz)
7200	7200 ±1%
4800	4800 ±1%
3600	3600 ±1%
2400	2400 ±1%
1800	1800 ±1%
1200	1200 ±1%
600	600 ±1%
300	300 ±1%
200	200 ±1%
150	150 ±1%
75	75 ±1%

f. Set CLOCK to 9600 and connect rear panel INT XMIT CLOCK connector to oscilloscope input. With oscilloscope input terminated in 50 ohm, observe that waveform amplitude is greater than or equal to 2 V (peak).

g. Set PATTERN to 1:1, OFF/LOOP to OFF, and connect rear panel BITS LOST connector to oscilloscope input. With oscilloscope input terminated in approximately 1 megohm, observe that waveform amplitude is greater or equal to 1.5 V (peak).

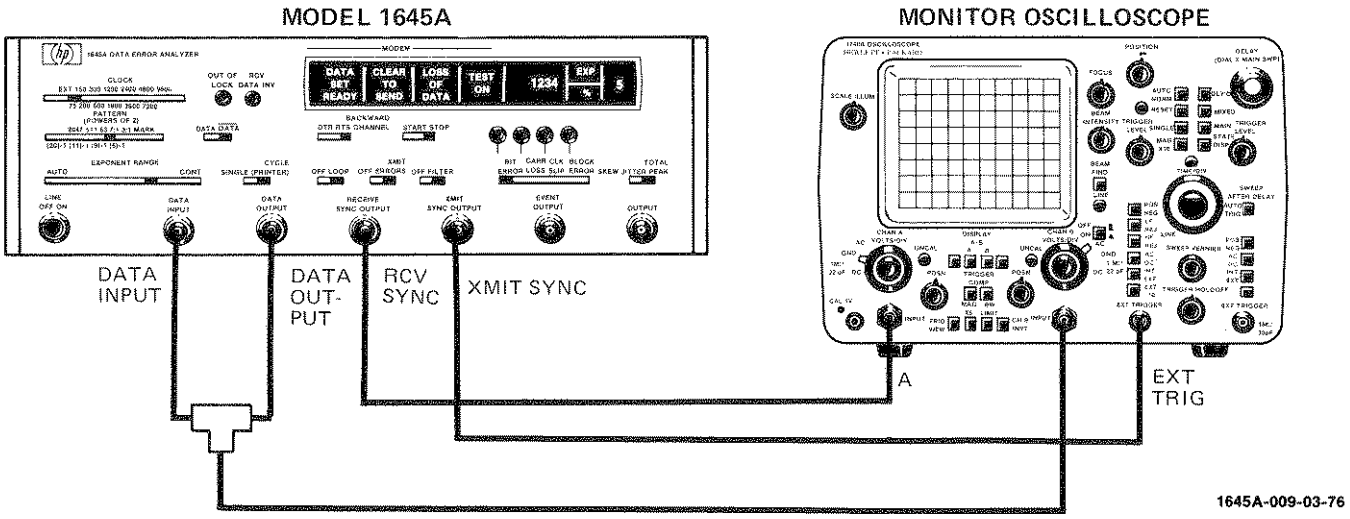


Figure 4-1. Transmit Pattern Test Setup

h. Connect counter to rear panel BITS LOST connector.

i. Set CLOCK to 75, and observe the following indications:

counter indication	70 Hz to 80 Hz
OUT OF LOCK indicator	on
LOSS OF DATA	on

j. Set OFF/LOOP switch to LOOP and observe that counter indication is 0 Hz (+1).

4-10. TRANSMIT PATTERN.

a. Connect test equipment as shown in figure 4-1.

b. Set front panel controls as follows:

Model 1645A:

CLOCK	9600
EXPONENT RANGE	AUTO
SINGLE/CYCLE (PRINTER)	SINGLE
OFF/LOOP	OFF
OFF/XMIT ERRORS	XMIT ERRORS
OFF/FILTER	OFF
EVENT	BIT ERROR

Remove top cover and set COUNT D/O-COUNT C/L switch (A1S1) to COUNT D/O.

Monitor Oscilloscope:

Volt/Div (Channel B)	1 V
Vernier	CAL
AC/GND/DC/50Ω	50Ω
DISPLAY	B
POLARITY (Channel B)	+UP
AUTO/NORM	NORM
VERNIER	CAL
INT/EXT	EXT
TRIGGER SLOPE	POS

c. Set PATTERN and DATA/$\overline{\text{DATA}}$ to positions indicated in table 4-3. For each setting, momentarily push START/STOP to START and observe that TEST ON indicator is on while readout is counting, and then goes off. After TEST ON goes off, observe proper indications on Model 1645A readout and oscilloscope Channel B (see figure 4-2).

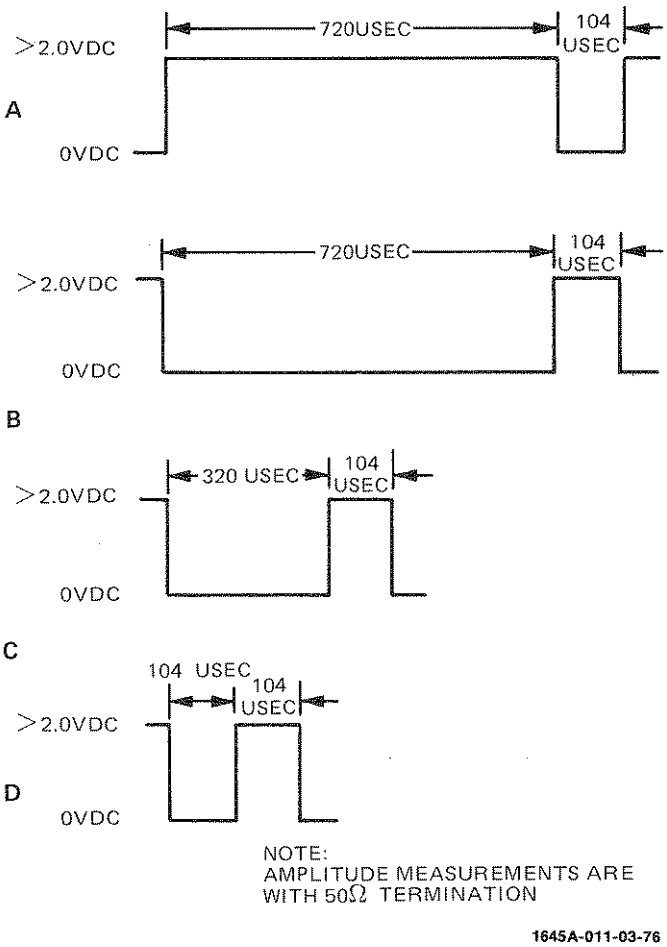


Figure 4-2. Transmit Pattern Test Waveforms

d. Set PATTERN to MARK, DATA/$\overline{\text{DATA}}$ to DATA and observe a +2.5 Vdc level on oscilloscope and that OUT OF LOCK and LOSS OF DATA indicators are on.

e. Set DATA/$\overline{\text{DATA}}$ to $\overline{\text{DATA}}$ and observe 0 Vdc level on oscilloscope.

f. Set PATTERN to 1:1.

g. Switch oscilloscope to channel A and observe that waveform amplitude is greater than or equal to 1.5 V (peak) with approximately 1 megohm input termination.

4-11. JITTER/TOTAL PEAK.

NOTE

Insert Standard RS-232C interface board for this check. The following procedure does not work with certain special interface boards.

a. Connect test equipment as shown in figure 4-3.

b. Set 1645A front panel controls as follows:

CLOCK 9600
PATTERN 1:1
DATA/$\overline{\text{DATA}}$ ..... DATA
EXPONENT RANGE 2
SINGLE/CYCLE (PRINTER) ..... CYCLE (PRINTER)
OFF/LOOP ..... OFF
OFF/XMIT ERRORS ..... OFF
OFF/FILTER ..... OFF
EVENT ..... JITTER/TOTAL PEAK
JITTER/TOTAL PEAK ..... TOTAL PEAK

c. Remove top cover and set COUNT D/O-COUNT C/L switch (A1S1) to COUNT D/O.

d. Set pulse generator for externally triggered (+) operation, adjust output amplitude for +3 V (peak), and adjust pulse width for a 40% duty cycle.

e. Observe that Model 1645A digital readout indicates 18% to 22% and that oscilloscope channel A waveform is a 2 V p-p square wave.

Table 4-3. Transmit Pattern Check Indications

SWITCH SETTINGS		READOUT INDICATIONS					OSCILLOSCOPE
PATTERN	DATA/$\overline{\text{DATA}}$	BIT ERROR	CARR LOSS	CLK SLIP	BLOCK ERROR	SKEW	CHANNEL A INDICATION
2047	DATA	EXP 488 (±1) (—) 6	EXP 0 (—) 6	EXP 0 (—) 6	EXP 488 (±1) (—) 3		fixed PRBS bit pattern
511	DATA	EXP 196 (±1) (—) 5	EXP 0 (—) 5	EXP 0 (—) 5	EXP 100 (±1) (—) 2		fixed PRBS bit pattern
63	DATA	EXP 159 (±1) (—) 4	EXP 0 (—) 4	EXP 0 (—) 4	EXP 10 (±1) (—) 1	98%	fixed PRBS bit pattern
63	$\overline{\text{DATA}}$	EXP 159 (±1) (—) 4	EXP 0 (—) 4	EXP 0 (—) 4	EXP 10 (±1) (—) 1	0%	fixed bit pattern inverted from above
Set EXPONENT RANGE to 4							
7:1	$\overline{\text{DATA}}$	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 1	FLASHING	See fig. 4-2A
7:1	DATA	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 1	FLASHING	See fig. 4-2B
3:1	DATA	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 1	FLASHING	See fig. 4-2C
1:1	DATA	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 4	EXP 0 (—) 1	FLASHING	See fig. 4-2D

f. Set JITTER/TOTAL PEAK switch to JITTER. Observe that 1645A digital readout indicates less than 2% (5% - Option 101).

g. Set 1645A controls as follows:

CLOCK	75
PATTERN	2^{20}—1
OFF/LOOP	LOOP

h. Momentarily set START/STOP to START. Observe that digital readout indicates less than 2%, and test TEST ON indicator flashes on and off (5% - Option 101).

i. Set 1645A controls as follows:

CLOCK	9600
PATTERN	1:1
OFF/LOOP	OFF
JITTER/TOTAL PEAK	TOTAL PEAK

j. Adjust pulse generator output amplitude to +5 V (peak). Observe that digital readout indicates 18% to 22% and that channel A waveform is a 2 V p-p square wave.

k. Set JITTER/TOTAL PEAK to JITTER. Observe that digital readout indicates less than 3% (5% - Option 101).

4-12. EXTERNAL DRIVE.

a. Connect test equipment as shown in figure 4-4.

b. Set front panel controls as follows:

Model 1645A:

CLOCK	EXT
PATTERN	2^{20}—1
DATA/DATA	DATA
SINGLE/CYCLE (PRINTER)	SINGLE
OFF/LOOP	LOOP
OFF/XMIT ERRORS	XMIT ERRORS
OFF/FILTER	OFF
EVENT	BIT ERROR

Remove top cover and set COUNT D/O-COUNT C/L switch (A1S1) to COUNT D/O.

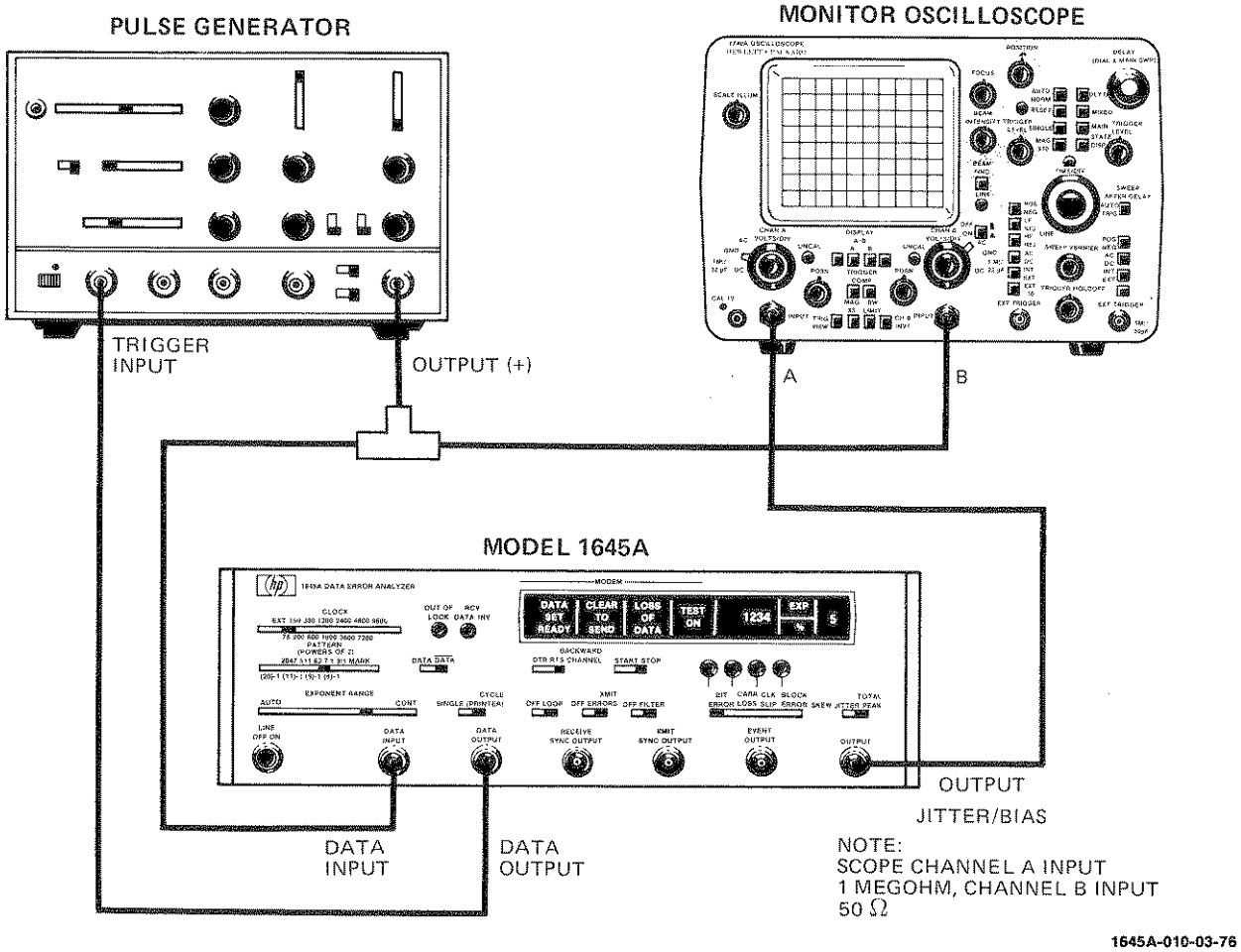


Figure 4-3. Jitter/Total Peak Test Setup

Monitor Oscilloscope:

Volts/Div (Channel A)	1 V
Vernier	CAL
AC/GND/DC/50Ω	DC
DISPLAY	A
TRIGGER	A
Time/Div	2 μS
VERNIER	CAL
INT/EXT	INT
TRIGGER SLOPE	POS
All other pushbuttons	OUT

c. Set pulse generator output for a 5 ±.5 MHz square wave with an amplitude of +4 V (peak).

d. Set EXPONENT RANGE to the positions indicated in table 4-4. For each position, momentarily push START/STOP to START and observe that TEST ON indicator is on while the readout is counting, and then goes off. After TEST ON goes off, observe the proper indication on the 1645A readout. (Note that EXP indicator is on and BIT ERROR indicator is flashing.)

e. Set PATTERN switch to 63 and observe that bit pattern on Channel A of oscilloscope is stable and repeats with each EVENT output pulse.

f. Set EXPONENT RANGE to CONT. Observe that EXP indicator is off and that oscilloscope amplitude is ≥1.5 V (peak).

4-13. DROP-OUT.

NOTE

Pin numbers listed in step d are for RS-232C interface only. For other interfaces, ensure that appropriate signals are jumpered togather.

a. Disconnect all test equipment and set 1645A front panel controls as follows:

CLOCK	9600
PATTERN	63
EXPONENT RANGE	CONT
SINGLE/CYCLE (PRINTER)	SINGLE
DTR/RTS/BACKWARD CHANNEL	DTR
OFF/LOOP	OFF
OFF/XMIT ERRORS	XMIT ERRORS
OFF/FILTER	OFF
EVENT	BIT ERRORS
DATA/DATA	DATA

b. Remove top cover and set COUNT D/O-COUNT C/L switch (A1S1) to COUNT C/L.

c. Set loop ON, then OFF.

d. Verify the following indicator status on the 1645A front panel:

OUT OF LOCK	on
LOSS OF DATA	on
DATA SET READY	off
CLEAR TO SEND	off
TEST ON	off

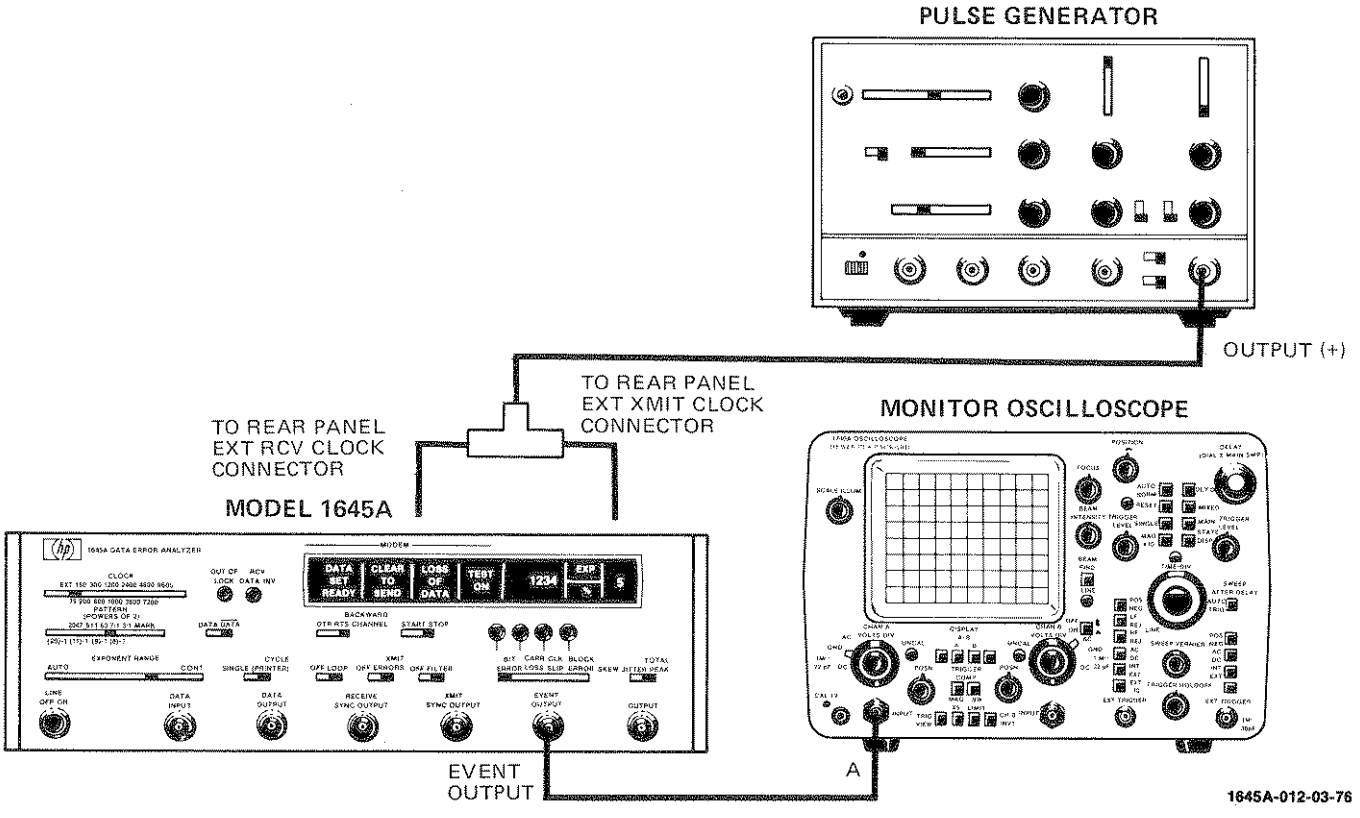


Figure 4-4. External Drive Test Setup

BIT ERROR ..... on
CARR LOSS ..... off
BLOCK ERROR ..... on
CLOCK SLIP ..... off

e. Set LINE to OFF and jumper the following pins on rear panel RS-232C DATA INTERFACE connector:

pin 4 to pin 5 (RTS to CTS)
pin 6 to pin 20 (DSR to DTR)
pin 8 to pin 19 (CAR. ON to SECOND RTS)

f. Set LINE to ON and observe the following indicator status on 1645A front panel:

OUT OF LOCK ..... on
LOSS OF DATA ..... on
DATA SET READY ..... on
CLEAR TO SEND ..... off
TEST ON ..... off
BIT ERROR ..... on
CARR LOSS ..... on
CLK SLIP ..... off
RCV DATA ..... on

Table 4-4. External Drive Bit Error Indications

EXPONENT RANGE SETTING	BIT ERROR READOUT			
AUTO	953	(±1)	EXP (—)	9
9	953	(±1)	EXP (—)	9
8	95	(±1)	EXP (—)	8
7	9	(±1)	EXP (—)	7
6	0	or 1	EXP (—)	6
5	0	or 1	EXP (—)	5
4	0	or 1	EXP (—)	4
3	0	or 1	EXP (—)	3
2	0	or 1	EXP (—)	2

g. Set DTR/RTS/BACKWARD CHANNEL switch to RTS and observe that CLEAR TO SEND indicator is on.

h. Set DTR/RTS/BACKWARD CHANNEL switch to BACKWARD CHANNEL and observe that CARR LOSS indicator is off.

i. Set LINE to OFF and remove jumpers from rear panel RS-232C DATA INTERFACE connector.

j. Set DTR/RTS/BACKWARD CHANNEL to DTR, set LINE to ON, and monitor voltage between pin 4 of rear panel RS-232C DATA INTERFACE connector and chassis ground. Observe an indication of —5 Vdc to —12 Vdc.

k. Set DTR/RTS/BACKWARD CHANNEL switch to BACKWARD CHANNEL and monitor voltage between pin 4 of rear panel RS-232C DATA INTERFACE connector and chassis ground. Observe an indication of +5 Vdc to +12 Vdc.

l. Set pulse generator output as shown in figure 4-5A, and apply to rear panel BACKWARD CHANNEL connector.

m. Using oscilloscope monitor pin 14 of rear panel DATA INTERFACE connector and observe waveform shown in figure 4-5B.

4-14. CARRIER LOSS/CLOCK SLIP.

a. Disconnect all test equipment and set 1645A front panel controls as follows:

CLOCK 9600
PATTERN 1:1
EXPONENT RANGE ..... CONT
SINGLE/CYCLE (PRINTER) ..... SINGLE
OFF/LOOP ..... LOOP
OFF/XMIT ERRORS ..... XMIT ERRORS
OFF/FILTER ..... OFF
EVENT ..... CARR LOSS

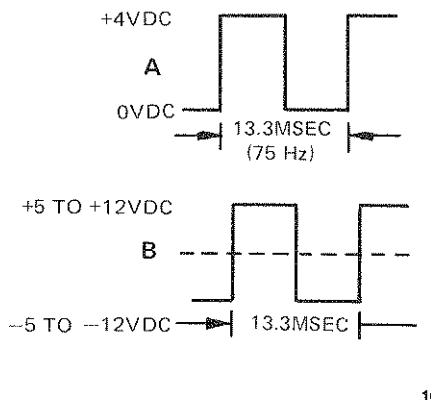


Figure 4-5. Drop-out Test Waveforms A+B

b. Remove top cover and set COUNT D/O-COUNT C/L switch (A1S1) to COUNT D/O.

c. Momentarily set START/STOP switch to START.

d. Switch OFF/LOOP from LOOP to OFF and back ten times, ending at LOOP position. Readout should indicate 10.

e. Set EVENT switch to CLK SLIP and momentarily set START/STOP to START.

f. Switch DATA/$\overline{\text{DATA}}$ from DATA to $\overline{\text{DATA}}$ and back ten times, ending at DATA position. Readout should indicate 20.

4-15. PRINTER INTERFACE.

a. Connect recorder to 1645A rear panel PRINTER connector with inter-connecting cable (HP Model 10233A).

b. Set 1645A front panel controls as follows:

CLOCK 9600
PATTERN 63
DATA/$\overline{\text{DATA}}$ ..... DATA
EXPONENT RANGE 4
SINGLE/CYCLE (PRINTER) ..... SINGLE
DTR/RTS/BACKWARD CHANNEL .. RTS
OFF/LOOP ..... LOOP
OFF/XMIT ERRORS ..... XMIT ERRORS
OFF/FILTER ..... OFF
EVENT ..... CARR LOSS

c. Remove top cover and set COUNT D/O-COUNT C/L switch (A1S1) to COUNT D/O.

d. Apply power to recorder and set for print operation.

e. Momentarily set START/STOP to START, and set SINGLE/CYCLE (PRINTER) to CYCLE (PRINTER).

f. Verify that recorder prints the following numbers in the indicated sequence:

1. 159 4
2. 000 4
3. 010 1
4. 000

NOTE

The above sequence is repeated after the 4th reading. 1 is bit error, 2 is clock slip, 3 is block error, and 4 is the event selected by the EVENT switch. No exponent is provided for the fourth item.

PERFORMANCE CHECK RECORD
MODEL 1645A

Instrument Serial Number _____ Date _____

Check	Specification	Measured
PHASE LOCK LOOP		
Waveform	50% duty cycle	_____
INT XMIT CLOCK		
Clock Frequencies		
9600	9600 ±0.03% (9597.12 Hz to 9602.88 Hz)	_____
7200	7200 ±1%	_____
4800	4800 ±1%	_____
3600	3600 ±1%	_____
2400	2400 ±1%	_____
1800	1800 ±1%	_____
1200	1200 ±1%	_____
600	600 ±1%	_____
300	300 ±1%	_____
200	200 ±1%	_____
150	150 ±1%	_____
75	75 ±1%	_____
Bits Lost	Amplitude is >1.5 V	_____
	70 - 80 Hz	_____
	0 Hz	_____
TRANSMIT PATTERN		
2047	See Table 4-2	_____
511	See Table 4-2	_____
63	See Table 4-2	_____
63 ($\overline{\text{DATA}}$)	See Table 4-2	_____
7:1 ($\overline{\text{DATA}}$)	See Table 4-2	_____
7:1	See Table 4-2	_____
3:1	See Table 4-2	_____
1:1	See Table 4-2	_____
JITTER/TOTAL PEAK		
+3V (peak) input	18% to 22%	_____
	less than 3%	_____
	less than 3%	_____
+5V (peak) input	18% to 22%	_____
	less than 3%	_____
	less than 3%	_____

PERFORMANCE CHECK RECORD (Cont'd)
MODEL 1645A

Instrument Serial Number _____ Date _____

Check	Specification	Measured
EXTERNAL DRIVE		
EXPONENT RANGE		
AUTO	953 (±1) (—) 9	_____
9	953 (±1) (—) 9	_____
8	95 (±1) (—) 8	_____
7	9 (±1) (—) 7	_____
6	0 or 1 (—) 6	_____
5	0 or 1 (—) 5	_____
4	0 or 1 (—) 4	_____
3	0 or 1 (—) 3	_____
2	0 or 1 (—) 2	_____
CONT	OVER-RANGING	
DROP OUT		
INDICATOR STATUS	CLEAR TO SEND on	_____
	CARR LOSS out	_____
Voltage at pin 4	—5 to —12 Vdc	_____
	+5 to +12 Vdc	_____
Waveform at pin 4	See figure 4-5B	_____
CARRIER LOSS/CLOCK SLIP		
Carrier Loss indication	10 (±1)	_____
Clock Slip indication	20 (±1)	_____
PRINTER INTERFACE		
Recorder indication	159 4	_____
	000 4	_____
	010 1	_____
	000	_____