FONIX®

FA-10

MAINTENANCE MANUAL

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FRYE

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FA-10 HEARING EVALUATOR (220V)

The following changes apply only to the 220V version of the FONIX FA-10:

1.11.1 Mains Supply Cord

Delete the first sentence of this section.

1.11.3 Power Entry Module

Change section to:

The power entry module is Schurter type KD14.4101.107 2 pole snap-in for 2.0 mm panel thickness. The power entry module also contains an IEC type male mains connector and mains power switch. The mains fuses for 220V/240V operation are two each 0.16A / 250V IEC type T.

Appendix E

Rear Panel Safety Markings

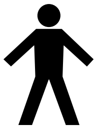
Change warning to:

CAUTION: FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE ONLY WITH T 0.16A / 250V FUSE

Never replace a fuse with a fuse which has a rating higher than specified.

The fuses are 0.16A / 250V IEC type T.

Change text next to symbol:



For purpose of safety classification under UL2601-1/IEC601-1, the FA-10 is class 1, type B, ordinary equipment suitable for continuous operation

1. SERVICE AND REPAIR GUIDE

1.1 Opening the FA-10 for Service

1. Remove the two screws on the FA-10 front plastic panel.

2. Remove the five screws on the FA-10 rear panel.

3. Gently lift the FA-10 front plastic panel.

There is a hinge mechanism which allows the FA-10 case to be opened for servicing with all interconnect cables connected. The hinges are located at the bottom rear of the FA-10.

Most circuit boards are accessible for easy inspection and probing. Some areas of the VU METER BOARD are difficult to probe and inspect. With the FA-10 open in this manner, the FA-10 top section is not solidly connected to the chassis baseplate. If analog circuit testing is planned, connect the FA-10 top and bottom half with a jumper wire. This will minimize pickup of CPU related noise. Note that the inside surface of the plastic top half is coated with conductive paint. Copper tape is installed on the FA-10 plastic top half to prevent electostatic discharges from entering the FA-10. Do not remove the copper tape.

1.2 Separating Top and Bottom Half

If it is necessary to separate the FA-10 top section from the FA-10 chassis baseplate:

1. Unplug the FA-10 mains power plug.

2. Disconnect the four cables connecting the FA-10 top half and the FA-10 chassis baseplate. Cables always mate with circuit board connectors having the same "J" number. Observe that the color stripe on each cable goes to pin 1 on the mating circuit board connector. The three connector flat cable mates with CPU/KEYBOARD J4, OUTPUT BOARD J4, and FILTER BOARD J4. If cables are not properly reinstalled, the FA-10 will be damaged.

3. Gently bend the plastic top half at the right hinge pin toremove the hinge pin from the hole in the chassis baseplate.

1.3 CPU/Keyboard Removal

1. Using a 5/32" Allen (hexagon) wrench, remove the three large front panel knobs: Left Hearing Level, Frequency, Right Hearing Level.

2. Disconnect the flat ribbon cables connected to the CPU/KEYBOARD.

3. Remove 9 screws, #4-40 x 1/2".

4. Catch the 10 push button caps and 10 silicon rubber inserts which fall out with the circuit board.

1.4 CPU/Keyboard Installation

1. Place the FA-10 front panel plus plastic top housing face down on a table.

2. Install the 10 push button caps and silicon rubber inserts in the FA-10 front panel.

3. Place the FA-10 CPU/KEYBOARD on the front panel.

4. Check that the LEDs are properly seated in the front panel LED locating cut outs.

5. Install the 9 screws, #4-40 X 1.2", do not tighten yet.

6. Check that the Left Hearing Level, Frequency, and Right Hearing Level control shafts rotate freely. If necessary, reposition the CPU/KEYBOARD.

7. Tighten the 9 screws. Check that the three control shafts still rotate freely.

8. Install the three large knobs. The large knobs should have 1/32" to 1/16" (0.8mm to 1.6mm) clearance to the front panel. Be certain that the correct knob is on each shaft.

9. Connect the flat ribbon cables to J8L, J8R, J4, and J3.

1.5 Auxiliary Keyboard Removal

1. Disconnect J8

2. Rotate the three knobs to a known position.

3. Remove the three knobs with a 0.050" (1.27mm) Allen (hexagon) wrench. Note the relationship between the flatted shaft tip and the knob index mark. The set

screw will on the same side of the shaft as the flattened area on the shaft tip. You will need these positions during re-installation.

4. Remove the 1/2" hex nuts holding the rotary controls to the FA-10 front panel. The AUXILIARY KEYBOARD should fall free.

1.6 Auxiliary Keyboard Installation Notes

1. If you have replaced any of the controls on the AUXILIARY KEYBOARD, trim the solder leads of the control so that the solder leads are just long enough to pass through the circuit board. This will prevent the leads from shorting to the FA-10 chassis when the AUXILIARY KEYBOARD is installed.

2. When tightening the bushing nuts on the rotary controls, check that each rotary control rotates freely. If the control bushing does not lie flat on the FA-10 front panel, the control will bind after the bushing nut is tightened. Overtightening may also deform the bushing and cause binding; try loosening the bushing nut slightly.

3. The set screw on each knob goes on the same side of the shaft as the flattened area at the tip of the shaft.

4. Reassemble the FA-10. Connect the FA-10 to mains power. Turn on the FA-10.

5. Verify that each position of the Input selector selects that input.

6. Set the Input Selector to Mic; Verify that the Hearing Aid Simulator LED turns on continuously when the Hearing Aid Simulator switch is set to 6dB 12dB 18dB and HFE.

7. Set the Hearing Aid Simulator to 6dB.

8. Verify that the Hearing Aid Simulator LED is:

   •ON when the Input Selector is set to Left Ext, Right Ext, and Mic;

   •OFF when the Input Selector is set to Tone, Stenger, White Noise, Speech Noise, and Narrow Band Noise.

1.7 VU Meter Board Removal

1. Pull off the 7 small knobs on the FA-10 front panel. (No tool required)

2. Remove six screws on the VU METER BOARD.

3. Unplug all connectors.

1.8 Output Board Removal

1. Remove the ten 3/8" hex nuts on FA-10 rear panel (use a 1/2 inch nut driver).

2. Remove 3 screws in line along the bottom of the OUTPUT BOARD. It is not necessary to remove the screws holding the heat sinks to the power amplifiers unless you intend to replace the power amplifiers.

1.9 Filter Board Removal

1. Remove the screw at the FILTER BOARD mecca.

2. Remove the screw at the FILTER BOARD shield.

3. Unsnap the FILTER BOARD from 7 snap on (metallic) board retainers.

4. Unsnap the FILTER BOARD shield. (The copper side is supposed to be up.) A screwdiver may be used to pry the circuit board from the chassis.

1.10 Power Supply Board Removal

1. Remove the screw at mecca.

2. Unsnap the POWER SUPPLY BOARD from the 4 metallic circuit board retainers. A screwdiver may be used to pry the circuit board from the chassis.

1.11 Primary Wiring

1.11.1 Mains Supply Cord

The FA-10 was designed as a 115 Volt only instrument and is equipped with a power entry module and a removable hospital grade mains supply cord. The mains supply cord should be replaced if it shows cracking or abrasion of the outer jacket. For safety, the mains supply cord should only be connected to a properly grounded mains power outlet.

1.11.2 Terminals

The crimped on “quick disconnect” (spade lug) terminals have exact sizes and may be difficult for end users to obtain in small quantities.

Important are: correct wire size, correct quick disconnect width, and correct quick disconnect mating thickness. Use of the wrong size quick disconnect terminal may result in a loose, intermittent fit. Arcing may occur, leading to overheating and charring of the terminal.

The transformer uses “quick disconnect”, female, fully insulated, #18 wire, .020" x .187" for single wire connections and “quick disconnect”, female, fully insulated, #14 – #16 wire, .020" x .205" for two wire connections. The correct crimping tool for these terminals and wire sizes is required.

The power entry module uses ”quick disconnect”, female, fully insulated, #18 wire, .032" x .187". The correct crimping tool for this terminal and #18 wire is required.

Note that the terminal thicknesses are not the same. The terminals are not interchangeable.

1.11.3 Power Entry Module

The power entry module is Schurter type KD14.4101.107 2 pole snap-in for 2.0 mm panel thickness. The fuse drawer is Schurter type 4303.2904 medical grade for two 3AG fuses. The power entry module also contains an IEC type male mains connector and mains power switch. The mains fuses for 115 volt operation are two each 0.5 A/250V 3AG slow and must be UL recognized.

1.12 Hints

The CPU/KEYBOARD can be tested by itself, only connected to J3 of the POWER SUPPLY BOARD. Connection of the AUXILIARY KEYBOARDs to the CPU/KEYBOARD is optional during “minimum system” testing.

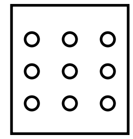
The POWER SUPPLY BOARD can be tested by itself with J2 and J3 disconnected. J2 and J3 have different pinouts. Do not interchange the cables going to J2 and J3.

The VU METER BOARD, FILTER BOARD, and OUTPUT BOARD are tightly interconnected. It is not practical to test these boards independently. The CPU/KEY-

BOARD should be connected and operating, otherwise the controls on the above three boards will be at random positions.

The cable going between FILTER BOARD J9 and OUTPUT BOARD J9 is the only cable in the FA-10 that twists between connectors.

For most circuit boards, the central ground point, called MECCA, is identified by its shape.



The VU METER BOARD and AUXILIARY KEYBOARD have no MECCAs. The MAIN MECCA is located on the POWER SUPPLY BOARD. Chassis ground connects to circuit grounds at the POWER SUPPLY BOARD. To suppress high frequency noise, chassis ground is also connected to the circuit grounding system at the FILTER BOARD MECCA.

1.13 Cleaning the FA-10

For your safety, disconnect the FA-10 from mains power while cleaning. Wipe the FA-10 case with a slightly moist but not dripping cloth. Use plain water or water with mild dishwashing detergent. Wipe away any detergent with a slightly moist cloth, then dry the FA-10.

Solvents and abrasives can cause permanent damage to the FA-10.

Never allow fluid to enter:

- the electronics module
- the power switch
- the power entry module
- the electrical connectors
- the keyboard push buttons or rotary controls

Cleaning the earphones:

Although the danger of spreading disease through the audiometric earphones is low, it is not non-existent. The manufacturer of the ear cushions recommends the use of any OSHA (Occupation Safety and Health Agency) recommended anti-bacterial soap. Disposable acoustically transparent covers are also available commercially.

2. CIRCUIT DESCRIPTION

2.1 Introduction

The FA-10 audiometer consists of 5 major circuit boards and two minor circuit boards.

2.1.1 Major Circuit Boards

2.1.1.1 Power Supply Board

Converts AC power from the transformer to six DC voltages and generates power on reset.

2.1.1.2 CPU/Keyboard

CPU/KEYBOARD controls the FA-10 via clocked serial I/O; generates clocks for left and right channel filters; generates raw tone square waves and noise signals; contains front panel LEDs; contains front panel Hearing Level controls and front panel Frequency control; contains front panel push buttons; generates tone used for Patient Response signal.

2.1.1.3 Filter Board

Electronically selects input source; provides smooth turn-on and turn-off of noise and tone; converts tone square waves into sine waves; bandwidth limits noise signal for white noise, speech noise, and narrow band noise; provides Hearing Aid Simulator filters for external and microphone inputs; derives +5A and -5A power for FILTER, VU, and OUTPUT BOARDS; includes some VU METER switching logic. The various functions are controlled by shift registers connected to the system serial bus.

2.1.1.4 VU Meter Board

Contains VU METER LEDs, LED drivers, circuitry to cause LED meter to have “VU” ballistic response; holds Microphone level pot, External level pot; Talkback pot; Monitor Phones level pot; Monitor Phones signals summing circuits; Patient Response LED; and Power LED.

2.1.1.5 Output Board

Holds input connectors and input buffer amplifiers for Left External, Right External, Talkback; input connector for Patient Response; system main attenuators; output connectors for Bone Vibrator and Monitor Phones; amplifiers and output connectors for Left Speaker, Right Speaker, Left Earphone, and Right Earphone. Contains 9 JFET switches to route output signals to their destinations; contains level translators and logic to drive the JFET switches. Board functions are controlled by shift registers connected to the system serial bus.

2.1.2 Minor Circuit Board

2.1.2.1 Auxiliary Keyboard

There are two identical AUXILIARY KEYBOARDS per FA-10, one for the left channel, one for the right channel. The AUXILIARY KEYBOARD holds a Hearing Aid Simulator control, an Input control, an Output control, and a Hearing Aid Simulator LED.

2.1.2.2 RS232 Board

The RS232 computer interface is optional. The RS232 board contains TTL level to RS232 level translators and static discharge protection circuitry.

2.2 Power Supplies

2.2.1 Mains Fuses

The mains fuse is rated at 0.5 amps. Under worst case normal 115 volt operation, a current of about 0.4 amps RMS will pass through the mains fuses. (0.4 amps through a 0.5 amp fuse calculates to a 20% fuse derating.) The worst case during normal operation occurs when the speaker outputs are driven to maximum power from the FA-10 internal tone generator. If both speaker amplifiers are driven to full power simultaneously from microphone or external inputs, or if the speaker outputs are shorted to ground, then higher current may pass through the mains fuses, possibly causing the fuses to open. If a mains fuse opens at FA-10 power- on, an internal fault has occurred.

2.2.2 Power Transformer

Transformer input voltage: 115 Volts AC.

Transformer nominal output voltage: 14 Volts AC per winding, maximum load.

The FA-10 Power transformer uses a split bobbin design which has two major advantages:

1. Safety—the primary is isolated from the rest of the transformer by a very robust 4000 volt insulation system.

2. Radio frequency interference suppression—the stray capacitance between primary and secondary windings is very small; a line input filter is not required. Necessary filtering is done at the transformer secondary circuit by the secondary side RFI filter. A primary winding line input filter would require high voltage components, would require safety agency approvals, and as a result would have a substantial cost.

2.2.3 Secondary Side RFI Filter

Purpose: To prevent interference caused by external radio frequency signals conducted into the FA-10 by the mains supply cord.

Circuit elements:

Stray capacitance, transformer primary to secondary: 35 pF
Stray capacitance, transformer primary to core: 30 pF
power supply board C12: .01UF
C13: .01UF

These result in a supression ratio of 55-60 db

2.2.4 Rectifiers:

Function: convert transformer AC output to unregulated DC voltage.

Input, nominal, maximum load: 15 VAC
Output, nominal, minimum load: +20 VDC, -20 VDC
Output, nominal, maximum load: +18 VDC, -18 VDC
Ripple, +rectifier: 0.6V peak to peak
Ripple, -rectifier: 0.6V peak to peak

2.2.5 +5V Regulator

U4 is a 7805 three terminal regulator. U4 regulates unregulated DC voltage from C11 down to +5 volts for use by the logic ICs on the CPU/KEYBOARD, the FA-10 front panel LEDs, (during factory calibration the RS232 board) , and the VU meter circuits. Analog circuits have a separate +5V supply originating on the FILTER BOARD. The 7805 requires at least 7.5 volts input to operate. The 7805 can output more than 1.0 amps with output shorted to ground. The 7805 has internal current limiting and thermal protection. U4 is mounted to a chassis heat sink using an insulator to avoid a chassis-mecca ground loop. In normal operation, the +5V supply should measure between +4.800V and +5.200V at U4 pin 3 to power supply mecca.

2.2.6 +12V Regulator

U6 is a 7812 three terminal regulator. U6 regulates unregulated DC voltage from C11 down to +12 volts for use by operational amplifiers, the +5 volt analog power supply on the FILTER BOARD, the optional RS232 BOARD and the VU METER circuits. The 7812 requires at least +14.6 volts input to operate. The 7812 can output more than 1.0 amps with output shorted to ground. The 7812 has internal current limiting and thermal protection. U6 is mounted to a chassis heat sink using an insulator to avoid a chassis-mecca ground loop. In normal operation, the +12V supply should measure between +11.5V and +12.5V at U6 pin 3 to power supply mecca.

2.2.7 -12V Regulator

U3 is a 7912 three terminal regulator. U3 regulates unregulated DC voltage from C11 down to -12 volts for use by operational amplifiers, the -5 volt analog power supply on the FILTER BOARD, and the optional RS232 BOARD. The 7912 requires at least -13.6 volts input to operate. The 7912 can output more than 1.0 amps with output shorted to ground. The 7912 has internal current limiting and thermal protection. U3 is mounted to a chassis heat sink using an insulator since U3 case is not at ground potential. In normal operation, the -12V supply should measure between -11.5V and -12.5V at U3 pin 3 to Power Supply MECCA.

2.2.8 +11V Volt Regulator

Minimum voltage input required for regulation: +14.5 volts
Acceptable Output Voltage: +10.241 to +11.588 Volts

U5, an LM350T, is a 3-Ampere adjustable regulator. U5 converts unregulated DC voltage to +11 volts regulated for use by the speaker amplifiers. One speaker amplifier, when shorted to ground, can draw enough current to cause a regulated supply to fall out of regulation. The ± 11 volt and ± 12 volt supplies are kept separate so that speaker shorts will not affect the rest of the audiometer, especially the patient earphones. Note that if a speaker output is shorted to ground, the LM350T can output 3 amps. The LM350T has an internal current limit and thermal overload protection; however 3 amps of additional secondary current may cause the FA-10 mains fuses to open. U5 is mounted to the chassis heat sink using an insulator since U5 case is not at ground potential.

The current through R14 must be greater than 10mA, otherwise if the +11 volt power supply were operated without load, the LM350T output would rise above +11 volts towards the unregulated supply connected to the LM350T input.

When operating, the LM350T will regulate its output so that it is Vref (=1.25V) above Vout. The voltage across R14 will be Vref. The voltage (referred to ground) at the ADJ pin is set by R11.

Vadj = (R14 current + Iadj) x R11
Vout = Vadj + Vref

FOR +11 VOLTS: Vout = (Vref x (1 + (R11/R14))) + (Iadj x R11)
Vref = 1.25V typical
Iadj = 0.000050 amp typical, increases with load
R11 = 953 ohms
R14 = 124 ohms

C17 reduces high frequency noise. Assume that Vref is noisy.
From above: Vout = (Vref x (1 + (R11/R14))) + (Iadj x R11)

If C17 = 0:
Noise out = Ref noise x (1 + 7.69) + (I noise x 953Ω)
Noise out = ref noise x (8.69) minimum.

If C17 has zero impedance at high frequencies, the parallel combination of C17 and R11 will have zero impedance at high frequencies:
Noise out = (ref noise x (1 + 0Ω/R14)) + (I noise x 0Ω)
Noise out = ref noise.

C10 provides high frequency bypassing.

2.2.9 -11V Volt Regulator

Minimum voltage input required for regulation: -14.5 volts Acceptable Output Voltage: -10.241 to -11.588 Volts

U2, an LM333T, is a 3-Ampere adjustable regulator. U2 converts unregulated DC voltage to -11 volts regulated for use by the speaker amplifiers. One speaker amplifier, when shorted to ground, can draw enough current to cause a regulated supply to fall out of regulation. The ± 11 volt and ± 12 volt supplies are kept separate so that speaker shorts will not affect the rest of the audiometer, especially the patient earphones. Note that if a speaker output is shorted to ground, the LM333T can output 3 amps. The LM333T has an internal current limit and thermal overload protection; however 3 amps of additional secondary current may cause the FA-10 mains fuses to open. U2 is mounted to the chassis heat sink with an insulator since U2 case is not at ground potential.

The current through R15 must be greater than 10mA, otherwise if the -11 volt power supply were operated without load, the LM333T output would rise above -11 volts towards the unregulated supply connected to the LM333T input.

When operating, the LM333T will regulate its output so that it is Vref (= 1.25V) above Vout. The voltage across R14 will be Vref. The voltage (referred to ground) at the ADJ pin is set by R12.

Vadj = (R15 current + Iadj) x R12 Vout = Vadj + Vref

FOR -11 VOLTS: Vout = (Vref x (1 + (R12/R15))) + (Iadj x R12)
Vref = 1.25V typical
Iadj = 0.000070 amp typical, increases with load
R12 = 953 ohms
R15 = 124 ohms

C19 reduces high frequency noise. Assume that Vref is noisy.
From above:

Vout = (Vref x (1 + (R12/R15))) + (Iadj x R12)

If C19 = 0:
Noise out = Ref noise x (1 + 7.69) + (I noise x 953Ω)
Noise out = ref noise x (8.69) minimum.

If C19 has zero impedance at high frequencies, the parallel combination of C19 and R12 will have zero impedance at high frequencies:
Noise out = (ref noise x (1 + 0Ω/R15)) + (I noise x 0Ω)
Noise out = ref noise.

C6 provides high frequency bypassing.

2.2.10 Voltage Doubler

The -22.3V regulator requires at least -24 volts at its input in order to operate. Since the power transformer peak output voltage may be as low as 16.5 volts, the VOLTAGE DOUBLER is required between the power transformer and -22.3V regulator.

Circuit operation: Assume C2 and C3 are discharged. Let the first cycle from the power transformer (J1 pin 4) be -20 volts. D3 conducts, protecting C2 from reverse voltage. D2 conducts and charges C3 to about -20 volts. Next half cycle, J1 pin 4 goes to +20 volts. D4 conducts. C2 is charged to about +20 volts. Next half cycle, J1 pin 4 goes to -20 volts. The voltage on C2 adds to the voltage on J1 pin 4. The voltage at D2 cathode is -30 volts, C3 is charged to a voltage greater than the peak input voltage. After a number of cycles, the voltage on C3 will equalize to about -40 volts.

2.2.11 -22.3V Regulator

Acceptable output range: -21.516V to -22.997V

U1 is a TL431ACLP programmable shunt regulator. If pin 1 is positive by the amount Vref (about 2.495 volts) with respect to pin 2, then U1 will conduct current from pin 3 to pin 2. This current will increase rapidly as the voltage between U1 pins 1 and 2 increases. R1 and R2 establish a voltage divider so that 2.495 volts will exist between pins 1 and 2 when pin 3 is at 22.3 volts. R3 forms a ballast to limit current into U1. -22.3 volts is used to power “low power” opamps on the OUTPUT BOARD.

-Vout = (Vref x (1 + (R2/R1))) + (Iref x R2)
Vref = 2.495 volts typical
R1 = 8.06K
R2 = 63.4K
Iref = 2 µA typical

2.2.12 Power On Reset

2.2.12.1 Introduction

The power on reset circuit will activate under any of three conditions:

1. The FA-10 has just been turned on.
2. Mains voltage is less than 90% of rated input and is not high enough for the power supply voltage regulators to operate.
3. An over current condition has occurred and the unregulated supplies are unable to supply enough voltage to operate the power supply voltage regulators. Perhaps a speaker is shorted to ground or perhaps both speakers are driven to clipping from Mic or Ext inputs.

When a power on reset condition is detected, the POR line is set to logical “1”, +5 volts. This signal is used to:

- halt and reset the system microprocessor,
- cause hardware logic to reset the watchdog timer,
- reset the CPU/KEYBOARD parallel port to logical “0”,
- (reset of parallel port causes “silence” line to disable all patient signal outputs—earphones, bone vibrator, and speaker),

- reset CPU/KEYBOARD U23, RS232 UART (if RS232 option is installed).

The power on reset circuit operates by detecting the voltage level on the positive unregulated supply at C11.

The POR signal will be “1” if C11 is below Vtr-: (14.152 to 14.518 volts). This voltage level is critical if the FA-10 is used at low mains voltage since Vtr- determines the low mains voltage shut down point.

The POR signal will be “0” if C11 is above Vtr+: (15.098 to 15.599 volts). Vtr+ is not as critical as Vtr-.

The POR signal has hysteresis: if C11 is between threshold voltages Vtr+ and Vtr- then the POR line will maintain the logic level from the last threshold voltage occurrence.

2.2.12.2 Power On Reset Circuit Operation
(See FA-10 Power Supply Schematic)

Assume that the FA-10 mains switch has been turned off long enough for all internal capacitors to discharge. The mains switch is then turned on. The AC voltage may be at any phase in its cycle when the mains switch is turned on. It may take several cycles for C11 to reach full charge. The +5 volt supply will be stable for considerable time before C11 reaches +15 volts since the +5 volt supply regulator can fully regulate when C11 is at +7.5 volts.

U8 will conduct current from U8 pin 3 to U8 pin 2 when the voltage between U8 pin 2 and U8 pin 1 exceeds a threshold of about 2.495 volts. This threshold is specified most accurately when 10 milliamps is flowing into U8 pin 3. R4, R5, and (D5+R4) establish a voltage divider to feed U8 pin 1. Assume that the voltage across D5 = 0.5V to 0.7V when D5 is conducting.

Initially, the current through U8 is zero. There is no current through R6 and R7 so the voltage at Q1 base = +5V. Current through Q1 and R9 is zero. Voltage at U7A pin 1 is zero, U7A pin 2 = +5V, and U7F pin 12 = 0V.

When the voltage on C11 reaches Vtr+, about +15.35 volts, voltage divider R4, R5, and (D5+R4) outputs about 2.495 volts and U8 begins to conduct. When the current into U8 pin 3 reaches 10 mA, the voltage across R7 reaches 0.7 volts and Q1 begins to conduct current. The voltage across R9 ramps to +5 volts but not in zero time. U7A pin 1 is a schmidt trigger input so the small amount of noise voltage present at its input is rejected without causing the POR signal to chatter between “0” and “1”. U7F pin 12 switches to “1”, +5 volts. D5 is reverse biased so current through D5 goes to zero. R5 and R4 alone now form the U8 pin 1 voltage divider. The voltage divider formed by R4 and R5 will cause current to flow through U8 as long as C11 stays above Vtr-, about 14.3 volts. When U7F pin 12 switches positive, the signal is delayed about 20 to 50 microseconds by R13 and C15. This delay insures adequate time for the system microprocessor to reset. The microprocessor normally requires about 1 microsecond to fully reset.

2.3 CPU/Keyboard

(Refer to the 2 pages of CPU/KEYBOARD schematics)

2.3.1 Introduction

The following circuits are located on the CPU/KEYBOARD:

- MASTER CLOCK
- WATCHDOG TIMER
- CPU
- PAL
- EPROM
- RAM
- EEROM
- PARALLEL PORT
- MASTER SHIFT REGISTER
- LEFT CHANNEL FILTER CLOCK DIVIDER
- RIGHT CHANNEL FILTER CLOCK DIVIDER
- NOISE AND TONE GENERATORS
- PATIENT RESPONSE TONE GENERATOR
- UART (present only if RS232 option is installed)
- LEDs
- PUSH BUTTON SWITCHES
- ROTARY ENCODER SWITCHES

2.3.2 Master Clock

The Master Clock generates
9216000 Hz used by the noise and tone generator
4608000 Hz used by the Z80 CPU and also the filter clock dividers
2304000 Hz used by the optional UART
1125 Hz used by the Z80 CPU for non-maskable interrupt,
by the patient response monitor as an audio tone,
and by the Watchdog Timer as its time reference.

The FA-10 has one master frequency reference. This assures that all circuitry that exists within the FA-10 has fixed frequency ratios to all other circuitry within the FA-10. Heterodyning caused by drifting of multiple frequency references will not be heard from any FA-10 signal output.

U14 is a 74AC7060 oscillator/ripple counter. This IC contains the circuitry to make a crystal oscillator and then divide the crystal oscillator frequency by 2, 4, 8, 16, 32 ...., 16432. That is 14 frequencies each 1/2 the previous frequency. The 74AC7060 is capable of counting at 110 Megahertz. The outputs have rise and fall times of about 3 nanoseconds. In order to operate an IC with very high speed outputs on a two layer board, the input and output leads must have minimum length and the IC power and ground leads must be bypassed. The bypassing requires C29, 0.03µF, a specialized capacitor with minimum lead inductance. C29 is located directly on the power and ground pins of U14, between U14 and the circuit board. C29 must be installed and U14 must be connected directly to C29.

U14 must not be placed in an IC socket.

If the bypassing is not properly connected, there will be interaction of the outputs of U14. For example, U14 pin 1, normally a well formed 36000 Hz square wave, would have higher frequency impulses superimposed on the signal. In addition, these impulses which will be at lower frequencies than the crystal, will affect the crystal frequency.

The crystal oscillator is simply a CMOS inverter inside U14. The inverter input is at U14 pin 11. The inverter output is at U14 pin 13. R22 and C19 form a low pass filter which prevents the crystal from oscillating at a harmonic or overtone of the fundamental 18.432 megahertz. R21 biases the inverter for linear amplification; without the crystal, the inverter would stabilize with input and output near 2.5 volts. The oscillator circuit is a Pierce circuit, the crystal is operated in parallel (antiresonant) mode. The crystal can be considered to be a capacitor, an inductor, and a resistor all connected in parallel. C19 and C18 combine in the parallel structure and can actually vary the oscillation frequency slightly. In this resonant circuit, a virtual ground “appears” in the middle of the crystal. The phases of the signals at crystal terminals are about 180° apart in timing. As long as the inverter has more gain than the loss in the crystal, the oscillator will oscillate. The availability of the full gain of the inverter depends upon bypass capacitor C29.

2.3.3 Watchdog Timer

2.3.3.1 Watchdog Timer Introduction

If the CPU program goes out of control the Watchdog issues a logical “1” on signal DOG. DOG resets the Z80 CPU, resets parallel port outputs to logical “0”, and causes the patient audio outputs to silence. In addition, after the DOG signal clears to allow the Z80 CPU to restart, another signal, DOUBLEDOG, is issued which the Z80 CPU can examine to determine that the CPU has just recovered from a WATCHDOG RESET.

In order to prevent the Watchdog Timer from timing out and causing a reset, the Z80 CPU must write to signal DOGSTROBE to clear the Watchdog Timer counter to zero. DOGSTROBE must be addressed in intervals of less than 227 milliseconds or else signal DOG will be asserted. DOGSTROBE is normally logic “0” and goes to logic “1” for about 500 nanoseconds when the CPU addresses DOGSTROBE.

2.3.3.2 Watchdog Timer Circuit Operation

U16 is a 74HC4040 12 bit binary counter. The counter is clocked by the 1125 Hz output of the master clock. If the counter gets 256 counts of 1125 Hz without getting reset by DOGSTROBE, the output representing 2^8, U16 pin 12, will go to logic “1”, thus asserting signal DOG.

At the moment AC mains power is applied, signal POR is asserted to the PAL which asserts DOGSTROBE. The CPU then has 227 milliseconds to initialize and clear the counter for the first time.

Nor gate U22A causes the FA-10 to reset if a power on reset (POR) takes place from the power supply, OR if DOG is asserted by the Watchdog Timer.

The PAL logic insures that DOGSTROBE is asserted by CPU command or else by power on reset (POR); not by signal DOG. This allows U16 to retain information at U16 pin 14 to indicate that the CPU has been reset in past time by a Watchdog reset. The CPU reads DOUBLEDOG by examining master shift register U18 pin 20 with U9 the EEROM disabled. If U18 pin 20 is logic “0”, then a watchdog reset happened in the past. The CPU program should then issue a front panel error code, and halt all FA-10 operation since the CPU program is faulty.

2.3.4 CPU

U15, the Central Processing Unit, is a CMOS 6 MHz Z80. Detailed operation of the Z80 is beyond the scope of this circuit description. For detailed information on the Z80, see the ZILOG Z80 FAMILY DATA BOOK published January 1989.

All peripheral circuits in the FA-10 are controlled by the CPU. All FA-10 front panel controls are read by the CPU. The CPU determines any action required and then issues appropriate control signals to peripheral circuits. The FA-10 rear panel power switch is the only switch not read directly by the CPU.

The CPU is clocked at 4.608 MHz by the master clock/divider. It may take the CPU several clock cycles to execute an instruction.

The non-maskable interrupt, 1125 Hz, also generated by the master clock/divider, initiates NMI cycles. An NMI cycle is a set of instructions which must be finished before the next NMI cycle. At the time of this writing, the FA-10 programming is based on a repeating sequence of nine NMI cycles. At the beginning of each NMI cycle, the program checks to see that the previous NMI cycle finished. If the previous NMI cycle did not finish, an error code is flashed on FA-10 front panel LEDs. The CPU itself cannot prevent interruption of the program by a new NMI cycle.

Maskable Interrupt (INT\) is generated by U23, the optional UART. INT\ is normally asserted to the CPU when an 8 bit character has been received by the UART. If the UART is not installed, R25 pulls U22C pin 8 low; U22C pin 10 (INT\) goes to logical “1”, no interrupt. During time critical sections of CPU program, the CPU masks INT\.

SYSRES\ (system reset) resets the CPU to begin execution at program step zero and also resets internal CPU registers. SYSRES\ will occur: when mains power is first turned on, when mains power is turned off, if the watchdog timer has timed out, or if the FA- 10 power supply has been overloaded (perhaps by a short circuit at a speaker amplifier output).

2.3.5 PAL

U10, a 16V8, is an electrically erasable Programmable Array of Logic.
The PAL:

- establishes the location in CPU address space of RAM, U18
- establishes the location in CPU address space of EPROM, U13
- establishes the port address of shift registers
- establishes the port address of the tone generator, U21
- establishes the port address of the 8 bit parallel port, U19
- establishes the port address of the watchdog timer, U16
- resets the Watchdog Timer, U16, during power on reset.
- establishes the port address of the UART, U23

2.3.6 EPROM

The EPROM (Erasable Programmable Read Only Memory) U13 contains program instructions and data for the CPU. The contents of the EPROM are established by Frye Electronics Engineering and cannot be changed by the user. The EPROM contents are retained without need of power. At the time of this writing, the program for the FA-10 fits into a 27C256. The 27C256 can hold 262,144 bits of data stored as 32,768 8 bit bytes.

The binary code placed by the CPU on to the address bus [A0...A14] determines exactly which of the 32,768 bytes is selected. The selected byte is presented on to the data bus [D0...D7] by the EPROM. The EPROM disables (open circuits) its data bus connections unless "output enable not" (OE\) and "chip enable not" (CE\) pins are at logical "0".

The CPU requires valid data from the EPROM 200.5 nanoseconds after the last control signal is delivered to the EPROM. A 200 nanosecond EPROM would probably suffice, however the FA-10 uses a 150 nanosecond EPROM, a 50 nanosecond derating.

For 27C256 (or 27C512) note that a jumper connects JP2 pins 1 and 2. Note that the 27C512 will fit and function in the FA-10 but the FA-10 can only access half of the 65,536 bytes stored in the 27C512. For 27C128 and smaller EPROMS, generally used only by Frye Engineering, a jumper connects JP2 pins 2 and 3. 27C64 and smaller EPROMS are smaller than the socket at U13. These smaller EPROMS would be mounted with socket pins 1,2,27,28 empty.

2.3.7 RAM

The RAM (Random Access Memory) U18 contains 8192 8 bit bytes. The CPU can write a byte to RAM or read a byte from RAM. The RAM fits in the lower portion of the U18 socket. Socket pins 1,2,31,32 are empty. A jumper connects JP3 pins 2 and 3. The larger socket at U18 allows a larger RAM to be used by Frye Engineering for software development.

In order for the RAM to read or write data, U18 pin 30, CS2 must be logical "1" and pin 22, CS1\ must be logical "0".

If U18 pin 9 W\, "write not" is logical "0", then the byte on the data bus is stored at the RAM location coded by the address bus.

If U18 pin 9 "W\" is logical "1" and U18 pin 24 "OE\"is logical "0", then a byte stored in RAM is placed on the data bus. The byte is the one stored at the RAM location coded on the address bus.

The RAM contains temporary; if power is disconnected, the contents of RAM are lost.

2.3.8 EEROM

U9 is a 93C66 Electrically Erasable Read Only Memory with storage for 4096 bits organized as 256 words of 16 bits each. The contents of EEROM are retained by the IC even if FA-10 power is off. The user alters the contents of EEROM during FA-10 calibration.

U9 takes the place of mechanical potentiometers in a conventional audiometer. U9 is used to store earphone, speaker, and bone vibrator calibration data. Stored in U9 are two copies of the user's calibration data and two copies of the calibration data obtained at the factory.

The 93C66 is a serial input/output device and fits in an 8 pin package with two pins unused. Input data is organized as a "1" start bit, a two or four bit operation code, an 8 bit address if required, and data for input if the operation code is "write to EEROM".

Pin 1, CS (chip select) enables the IC for input or output. U9 pin 1 is connected to signal EECS which is generated by U19 pin 2, the CPU parallel port. Power on reset signal SYSRES\ sets the parallel port to all logical "0" bits. This insures that the EEROM contents are not disturbed by erratic CPU operation when +5V is not within acceptable operating range.

Pin 2, SK (serial clock) is used to shift data into or out from the 93C66. Data is read into the 93C66 on the rising edge of the clock signal and shifted out on the rising edge of the clock signal. The output data is stable on the falling edge of the clock signal. U9 pin 2 is connected to signal EECLK which is generated by the CPU parallel port U19 pin 5.

Pin 3, DI (data in) is the serial input to the 93C66 for operation codes, addresses, and data. U9 pin 3 is connected to signal SOUT. SOUT is generated by the master shift register U20.

Pin 4, DO (data out) is the data output for the 93C66. This pin is an open circuit if pin 1 (CS) is logical "0". Pin 4 generates signal EEOUT which connects to U20 pin 18, the master shift register. R30, 5.1K connected to U8E pin 10, is a pull-up resistor to insure that U9 pin 4 swings to +5 volts when at logical "1". This also allows the master shift register to examine the watchdog timer. If the watchdog timer has timed out and later allowed the FA-10 to restart, U8E pin 10 will be logical "0". If U9 is not enabled then: pin 4 is open circuit; the watchdog status signal (inverted DOUBLEDOG) will pass through R30 unaffected and match U8E pin 10.

2.3.9 Parallel Port

U19, a 74HCT273, is an octal “D” flip flop with clear. Uf U19 pin 1 is set to logical “0” by signal SYSRES\, then all U19 outputs Q1..Q8 will be reset to logical “0”. The SYSRES\ feature prevents erratic FA-10 operation if the power supplies are under voltage.

If the CPU sends a byte to U19, the following sequence takes place:

- U19 pin 1 is logical “1” (the CPU is running, SYSRES\ is logical “1”).
- The CPU places the byte on the data bus.
- The CPU sends control signals to the PAL (U10) indicating that the parallel port is addressed.
- The PAL (U10) strobes signal P PORT from logical “0” to logical “1” for a short period of time, about 0.5 microseconds.
- On the rising edge of signal P PORT at U19 pin 11, U19 flip flops assume the logic levels on the data bus and pass the logic levels to U19 outputs Q1..Q8.

2.3.10 Master Shift Register

By using a serial bus to control the FA-10, we minimized electrical noise within the FA-10. The serial bus is used to control items which change state infrequently.

U20 is a 74HCT299 8 bit universal shift register with bus interface. The 74HCT299 can convert serial data to 8 bit parallel data to send to the CPU and convert 8 bit parallel data from the CPU to serial data. It has a shift left input, pin 18 and a shift right input, pin 11. The 74HCT299 can shift data either left to right or right to left. U20 is connected so that data can be output to the LED shift registers as data is read back from the pushbutton and rotary encoder shift registers.

If 74HCT299 is set to logical “0” then all shift registers are set to logical “0”.

If both pin 2 G1, and pin 3 G2 are set to logical “0” then QA QB QC QD QE QF QG QH are all enabled. Otherwise these outputs are high impedance.

Pin 8 QA’ and pin 17 QH’ are always enabled.

The exact mode of the 74HCT299 is determined by pin 1 (S0) and pin 19 (S1).

S1	S0	CHANGE AFTER NEXT CLOCK POSITIVE CLOCK EDGE:
0	0	no change
0	1	serial shift left SL —> QH, old QH —> QG, etc.
1	0	serial shift right SR —> QA, old QA —> QB, etc.
1	1	parallel load: D0 —> QA . . . . D7 —> QH

2.3.11 Left Channel Filter Clock Divider U11
Right Channel Filter Clock Divider U12

U11 and U12 are identical independent CDP68HC68W1E circuits. The CDP68HC68W1E is a serial programmable frequency divider which can divide an input frequency (4.608 MHz) by any integer between 2 and 256 or else any even integer between 2 and 512. The signals produced by U11 and U12 are used on the filter board as reference frequencies for switched capacitor filters.

A CDP68HC68W1E requires 3 bytes of 8 bits each = 24 bits from the master shift register U20. Bytes are entered most significant bit first, least significant bit last. Pin 2, CS\, must be logical "0" during transmission of the 3 bytes.

The first byte controls the operation of the CDP68HC68W1E. The 6 most significant bits are "don't care". Bit #7 will disable the CDP68HC68W1E. Bit #8, "CD", if CD=1, enables a divide by 2 prescaler which acts on the input clock. CD is equal to either 0 or else 1 for the equations following.

The second byte contains the frequency divide number "N".

FrOut = FrIn/((N+1)(CD+1))

The third byte "W" sets the pulse width "PW", in input clock counts, of the Fout pulse, during the FrOut cycle. This is the number of FrIn counts that FR OUT will be logical "1".

PW = (W+1) x (CD+1)

In order for a FrOut to operate, N>W and N>0. It is possible for the CPU to send either 1,2, or all 3 bytes to alter the contents of the CDP68HC68W1E:

- pulse width alone may be sent,
- frequency divide number and pulse width may be sent,

- control, frequency divide number, and pulse width may be sent.

For reliability, the FA-10 CPU always sends all 3 bytes.

2.3.12 Noise and Tone Generators U21

U21, SAA1099, is a stereo music synthesizer with 6 voices. The FA-10 uses only a small portion of the capabilities of this IC. The outputs of U21 are sent to the FILTER BOARD envelope generator for further processing.

The SAA1099 contains 32 control registers. To change the contents of a register:

- the register is first selected using the data bus with A0 = “1”
- the selected register new contents are entered using the data bus with A0 = “0”.
- Both pin 1 WR\ and and pin 2 CS\ must be at logical “0” to enter data into the SAA1099.

The 9.216 MHz clock fed to pin 8 is the reference for all frequencies generated by the SAA1099.

The SAA1099 has crude analog outputs on pins 4 and 5. The attack and decay characteristics of the tones are not suitable for use in an audiometer. The SAA1099 is used only as a source of square waves to be filtered into sine waves and as a source of digital noise.

U21 pin 6 is a current reference input.

Iref = (5.0V - 0.7V) / 10.0K = 430 μA

Each voice of the SAA1099 is capable of placing Iref on an output pin. Since R28 and R29 are 49.9K, 430 μA through one of these resistors will produce a 21 volt drop. Obviously, with only a 5 volt supply, the two output channels are clipped signals . C24 and C25 reduce the size of amplitude control artifacts introduced by the SAA1099. U18C and U18F, schmidt trigger input inverters, fully convert the SAA1099 output signals into logic level signals with fast rise and fall times.

2.3.13 Patient Response Tone Generator

The patient response tone is a 1125 Hz 50 millivolt peak to peak signal placed on logic signal “RESPONSE”. The 1125 Hz signal is fed to the FA-10 operator’s monitor headphones when “RESPONSE” is at logical “0”.

The following three items are in series: U14 pin 15 (1125 Hz); R2, 10,000 ohms; and OUTPUT BOARD R8, (100 ohms to ground when patient response switch is closed). This forms a 100:1 voltage divider for the 1125 Hz signal when the patient response switch is closed. The 1125 Hz signal is ignored by logic circuits connected to the RESPONSE signal.

2.3.14 UART

U23 (present if RS232 option is installed) is a 16C450 Universal Asynchronous Receiver-Transmitter. The 16C450 forms a serial interface between the FA-10 and an external computer or external computer terminal. The 16C450 is connected to +5V and ground and does not provide the ± 12.0 volt logic levels used in RS232 communications. That level translation takes place on the RS232 BOARD. The 16C450 can take a byte from the data bus, add a start bit, add stop bit(s), convert to a serial bit stream, and send out the from the SOUT pin. The serial data rate is programmed via the on chip baud rate generator.

Serial input data arrives at pin 10, SIN. The start and stop bits are removed and the serial input is converted into a parallel byte to be read by the data bus. The 16C450 will interrupt the CPU with signal INT to cause the CPU to read the data.

JP1 pin 2 is a status bit that the CPU can read. JP1 pin 2 does not directly affect 16C450 operation.

2.3.15 LEDs

FA-10 front panel status LEDs D1, D2, D3, D5, D7, D11, D12, D16, D17, LEFT AUXILIARY KEYBOARD D1, and RIGHT AUXILIARY KEYBOARD D1 are connected to serial to parallel shift registers U6 and U7 74HC595. The current per LED I = (5.0V -2.2V) / 330 Ω = 10 mA There are 6 LEDs connected to U6 and 5 LEDs connected to U7. The absolute maximum allowable current for a supply pin on a 74HC595 is 70 mA. In order to obtain some derating and enhance reliability, about half of the FA-10 LEDS are connected to ground and about 1/2 of the LEDs are connected to +5V. This limits 74HC595 Vcc supply current to about 30 mA and GND current to about 30 mA. Data is shifted from the CPU into U6 and U7 at the same time data is shifted from U1, U2, U3, U4, and U5 into the CPU. U6 and U7 are double buffered so that data can be shifted into the IC without flashing the LEDs. Signal KEYSTROBE is held at logical “1” during the shifting process and then KEYSTROBE is returned to logical “0”.

2.3.16 Push Button Switches

These are simple single pole single throw normally open switches.

2.3.17 Rotary Encoder Switches

These controls are rotary absolute gray code encoders. An encoder reports a unique (absolute) binary code for each encoder switch position. Between adjacent encoder switch positions, only one bit changes (gray code).

2.4 Auxiliary Keyboard

There are two identical AUXILIARY KEYBOARDS per FA-10, one for the left channel, one for the right channel. The AUXILIARY KEYBOARD holds a Hearing Aid Simulator control, an Input control, an Output control, and a Hearing Aid Simulator LED. These controls are rotary absolute gray code encoders. The encoder reports a unique (absolute) binary code for each switch position. Between adjacent encoder switch positions, only one bit changes (gray code).

2.5 RS232 Board

This board is included with the RS232 option.

2.5.1 Static Protection

D1, D2, D3, and D4 are transzorbs. The transzorbs do not conduct at voltages below ± 14 volts; conduct at voltages above ± 15.6 to ± 19.1 volts. 1 turn inductors L1, L2 and 300 pF transzorb capacitance provide a small amount of delay to insure that the transzorbs have time to conduct after an electrostatic discharge to the pins of J12.

2.5.2 Level Translator

U2, LT1039CN16, translates ± 12 volt RS232 signal levels from J12 to 0 to 5 volt logic levels for use by the UART on the CPU/KEYBOARD.

2.6 Filter Board

(see FILTER BOARD schematic, 3 pages)

2.6.1 Introduction

The filter board:

- Selects the audiometer input signal
- Ramps square wave amplitude between zero amplitude and full amplitude
- Filters square waves into sine waves (11 frequencies)
- Filters logic level random noise into narrow band noise (11 frequencies)
- Filters logic level random noise into speech weighted noise
- Filters voice signals to simulate hearing aid slopes: 6dB 12dB 18dB HFE

2.6.2 Filter Board Function Table

AUDIOMETER INPUT SELECTED	U5, U20 MODE LINES C B A	VU METER SOURCE	FILTER CLOCK, Hz	FILTER TYPE	POLES	Q	FILTER FREQ(s)
WHITE NOISE	0 0 0	INT REF	0	NONE	X	X	X
SPEECH NOISE	0 0 1	INT REF	115200	LP	2	.957	1050
NBN/TONE 8000	0 1 0	INT REF	768000	BP	4	4.915	6927, 9241
NBN/TONE 6000	0 1 0	INT REF	576000	BP	4	4.915	5195, 6931
NBN/TONE 4000	0 1 0	INT REF	384000	BP	4	4.915	3464, 4621
NBN/TONE 3000	0 1 0	INT REF	288000	BP	4	4.915	2598, 3465
NBN/TONE 2000	0 1 0	INT REF	192000	BP	4	4.915	1732, 2310
NBN/TONE 1500	0 1 0	INT REF	144000	BP	4	4.915	1299, 1733
NBN/TONE 1000	0 1 0	INT REF	96000	BP	4	4.915	866, 1155
NBN/TONE 750	0 1 0	INT REF	72000	BP	4	4.915	649, 866
NBN/TONE 500	0 1 0	INT REF	48000	BP	4	4.915	433, 578
NBN/TONE 250*	0 1 1	INT REF	24000	BP	4	4.915	216, 289
NBN/TONE 125*	0 1 1	INT REF	12000	BP	4	4.915	108, 144
6 dB simulator	1 0 0	INPUT	85333	HP	1	X	774
12 dB simulator	1 0 1	INPUT	96000	HP	2	.56	866
18 dB simulator	1 1 0	INPUT	82286**	HP	3	X, .82	1530, 1530
HFE simulator	1 0 1	INPUT	209454**	HP	2	.56	3778
MIC or EXTERNAL (simulator off)	1 1 1	INPUT	0	NONE	X	X	X

*470 Hz low pass filter enabled (at U17A or U8A)

**LMF100 set to “÷ 50” mode for 18 dB and HFE (otherwise “÷ 100” mode). The acutal divide ratio is set with resistors

HP = high pass

BP = Chebyshev band pass with 2 each 2 pole filter; 4.915 Q at each 2 pole filter

LP = low pass

The following descripton uses the left channel schematic, the right channel is identical.

2.6.3 Envelope Generator

When the front panel left stimulus switch is pressed, the CPU issues signal L TONEON. U24A, U24B, and U6A generate a pair of signals that ramp almost linearly between 0 volts and +5V for U6A, between 0 volts and -5V for U24B. The ramp time is about 30 milliseconds. Square waves representing tone or noise from the CPU board are connected to U1B pin 10. U1B pin 15 switches between the two reference voltages generating a ramping square wave.

2.6.4 Input Multiplexer

The input multiplexer U2 selects the input signal for the left channel. Signals LF TONE and LF NBN are attenuated to different levels. The equivalent impedance from U1C pin 4, C6, R2, and C1 form a 2KHz low pass filter used for anti-aliasing. This filter is used for 125, 250, 500, and 750 Hz.

2.6.5 Input Anti-aliasing Filters

U4A, LMF100, is a switched capacitor filter. It will produce unwanted output signals for input frequencies higher than 1/2 the filter clock. Square waves contain many high frequency components. U7B is active for frequencies below 1 KHz, U7A is effective for frequencies 1 KHz and above. U7B filter is rated flat to 8 KHz. Both anti aliasing filters actually roll off at about twice the rated frequency in order to allow loose tolerance parts to be used. In the unused frequency span, the response of the filter need not be perfectly flat.

2.6.6 Switched Capacitor Filters

U4A is the core of the left channel filters. The characteristics of the filter are set by the feedback resistors. These characteristics are Q, gain, ratio of filter frequency to filter clock frequency, and type of filter. Precision capacitors are not used in the FA-10.

2.6.7 Output Switch

U5 connects the switched capacitor filter output selected by the CPU.

2.6.8 Output Anti-aliasing filter

For most configurations, R40 and C5, a 19 KHz low pass filter is all that is required to round off the signal edges caused by the switched capacitor filter. For 125 Hz and

250 Hz tones and noise, more filtering is required since the filter clock is at an audible frequency. The additional filtering is provided by the 470 Hz low pass filter at U8A.

2.6.9 +5A -5A

U9 and U10 are 3 terminal linear regulators which convert ± 12 volt supplies to ± 5 volt supplies for use by the FILTER, OUTPUT, and VU METER BOARDS.

2.6.10 Shift Registers

U12 and U13 receive FILTER BOARD switch setting information from the CPU via the serial bus. These are buffered shift registers so outputs do not change due to the normal system updating. The the serial bit stream from U13 pin 9 continues to the OUTPUT BOARD.

2.6.11 VU Meter Switching Logic (partial)

U22B prevents tone or noise signals from reaching the left channel VU meter. The tone or noise signal could charge up the AC to DC converter. When the front panel stimulus switch is released, the charge buildup would cause a double bounce of the VU meter as the VU meter went to zero deflection.

2.7 VU Meter Board

(see FA-10 VU METER BOARD schematic)

2.7.1 Introduction

The VU meter board contains:

- VU meter LEDs, drivers and circuits to imitate mechanical VU meters
- Input level potentiometers
- Talk forward potentiometer
- Buffer amplifier for each potentiometer wiper to minimize crosstalk
- Speech microphone preamplifiers
- Monitor phones circuits

2.7.2 VU Meters

This description is for the left channel VU meter. Operation of the right channel VU meter is identical. For this circuit description, assume a 287 millivolt RMS (0 VU) 1000 Hz sine wave at U10 pin 5.

2.7.3 Input Amplifier

U10C has a gain of +3.80 typical. 287mV x 2 x 3.80 = 1.543 V peak at U10C pin 8. Positive peak +1.543V; Negative peak -1.543V.

2.7.4 Absolute Value Detector

U10D has a gain of +0.667 for positive inputs and -0.667 for negative inputs. In other words, Vout = 0.667 x |Vin |.

The amplitude of the rectified sine wave peaks should be 1.029V typical.

2.7.5 Filter

U10B converts the rectified sine wave into a DC voltage and also adds mechanical VU meter characterisitics. Assume that input amplifier U10C initially has no input. The 0 VU sine wave is suddenly applied. The DC voltage at U10B pin 7 will first rise to 99% of "deflection" in 300 ± 30 milliseconds and then overshoot by 1% to 1.5%.

The DC gain for U10B is 1.383. The input is not DC but a rectified sine wave. The filter performs a time average (NOT an RMS average). The average value integrated over 1/2 cycle of a sine wave is $2/\pi$ x peak voltage. For a rectified sine wave input, the gain of U10B is 1.383 x $2/\pi$ = 0.880 x peak voltage.

For the 387mV RMS 0VU reference input sine wave, U10B pin 7 will be at 0.906 VDC typical.

U10B has ± 12V supplies. R20 limits current to U13B pin 2 if U10B pin 7 exceeds ± 5V.

2.7.6 TONEON Switch

When the FA-10 is operated with TONE or NOISE inputs selected, the VU meters respond instantly rather than with the mechanical VU meter characteristic. L METER input to U10C pin 10 is connected to ground by the FILTER BOARD. U13B pin 2 is very near ground. When the front panel stimulus switch is pressed, the CPU issues signal L TONEON which causes U13B to switch to a voltage calculated to slightly exceed 0 VU; U13 pin 1 is at about 0.955 VDC typical.

2.7.7 VU LED Driver

U7 is a VU meter LED driver. U7 pin 7 reference voltage is 1.28 VDC typical. The current out of pin 7 sets LED segment current; LED segment current (10 mA) is about 10 times reference amplifier output current (1 mA). The reference amplifier output voltage sets the VU meter sensitivity for +3 VU.

U7 contains a chain of voltage comparators and a resistor divider to determine the VU equivalent of the voltage at U7 pin 5. U7 contains logic so that only one LED segment will light at one time. If JP1 is shorted, all of the LEDs below the illuminated output LED will also be illuminated. This would waste power; also the patient could see the VU meter reflected in the FA-10 operator's glasses. Leave JP1 open.

2.7.8 VU LEDs

U8 is a package of red yellow and green intensity matched LEDs. If replacing U8, be sure to observe polarity, a dot on the side of the package indicates pin 1.

2.7.9 Power On LED

Green, illuminated when the FA-10 is ON.

2.7.10 Mic Ref Supply

All microphones used with the FA-10 are 2 terminal electret microphones. The FA-10 provides power to each microphone via a 5 volt power supply and a 10K resistor. The VU meter board provides power (U6) and connections for the left and right panel microphones.

2.7.11 Left Mic Preamp
Right Mic Preamp
Talk Forward Amplifier
Left External Buffer
Right External Buffer

These are gain amplifiers and buffers.

The microphone cables connecting to the mic preamps include a jack with a switch. The switch disables the panel speech microphone when an external speech microphone is installed.

2.7.12 Monitor Headphones

The FA-10 has a very complete monitor system. The monitor headphones allow the FA-10 operator to listen to 3 items:

- Signals presented to the patient; presented to operator in stereo.
- Patient talkback microphone; in operator's center channel.
- Patient response switch; tone + click in operator's center channel.

If the operator is hearing impaired in one ear and wishes to have a monaural monitor headphone, short the tip and ring terminals together in the headphone's stereo plug. There is no change required to the FA-10 itself. The monitor amplifiers have series resistors which will prevent damage if headphone signal connections are shorted to each other or ground.

2.7.13 Patient Signals

The patient signals are sampled just before the attenuators.

The monitor headphones do not exactly monitor the channel mixing feature. For example, if the front panel left channel OUTPUT switch is set to RIGHT CHANNEL, the monitor headphones will still present the left channel attenuator input to the operator's left ear and the right channel attenuator input to the operator's right ear.

The monitor headphones properly present the OUTPUT REVERSE feature.

2.7.14 Patient Response Tone

The RESPONSE logic level signal also includes a 1125 Hz tone. RESPONSE originates on the OUTPUT board at the patient response switch jack, is monitored by the CPU, gets 1125 Hz from the CPU master clock divider, and then goes to the VU meter board to light the Responce LED and activate the monitor headphones RESPONSE tone/click. The 1125 Hz tone is always superimposed on RESPONSE.

When the Patient Response switch is pressed, RESPONSE goes to logical "0". R34 and R35 have maintained C5 near the RESPONSE logical "0" DC level. The response tone is summed with the TALKBACK audio at the talkback amplifier U4B and is then summed with the main monitor channels at U1. The loudness of the response tone is preset and not adjustable by the operator. The response tone loudness is optimized for walkman style monitor headphones.

2.7.15 Patient Response LED

Green, illuminated when the Patient Response switch is pressed.

2.7.16 Talkback Microphone

The talkback microphone preamp and and reference voltage supply are located on the OUTPUT BOARD. The talkback microphone preamp output, signal "TALKBACK", is connected to pot R9.

2.8 Outbput Board

(See OUTPUT BOARD schematics, 4 pages.)

2.8.1 Shift Registers

U5 and U6 are serial input, parallel latched output shift registers. These shift registers are in a chain starting the shift registers on the FILTER BOARD and ending with the shift registers internal to digital potentiometers U12 and U19.

2.8.2 Level Translators

U8, U9, U10 translate 9 control signals from 0V-5V CMOS logic levels to -22.3V & +12V (approximate) logic levels required by the switching FETs.

2.8.3 Switching JFETs

Q1, Q2, Q3, Q6, Q7, Q8, Q11, Q12, Q13 (Nine JFETs)

These devices are used as switches to control audiometer output signals. The "J108" is an N channel JFET. The gate is essentially a diode junction to the source. If the gate is 10 volts or more negative with respect to the source, the JFET will not conduct. If the gate is at zero volts with respect to the source, the JFET will conduct. The gate will conduct current if positive about 0.5V with respect to the source. Source and drain terminals are interchangeable; the most negative terminal acts as source.

Source to drain resistance with gate at 0V : 8 Ω
Source to drain resistance with gate at +0.5V : typically 6 Ω

In the FA-10, JFET gate current is limited by 22 megohm resistors. There is a circuit board guard run around the 22 megohm resistor to gate connection to prevent circuit board leakage currents from reaching the gate.

2.8.4 Attenuators

This description uses the left channel attenuator. The Right channel attenuator is identical in function.

The FA-10 Attenuator control signals:

L ATTN	E	D	GAIN / ATTENUATION
	0	0	80 dB attenuation
	0	1	40 dB attenuation
	1	0	0 dB attenuation
	1	1	40 dB GAIN

U11:	C	B	A	ATTENUATION
	0	1	1	35 dB attenuation
	1	0	1	30 dB attenuation
	0	0	0	25 dB attenuation
	1	1	1	20 dB attenuation
	0	0	1	15 dB attenuation
	1	1	0	10 dB attenuation
	0	1	0	5 dB attenuation
	1	0	0	0 dB attenuation

The non-standard coding of "L ATTN C", "L ATTN B", and "L ATTN A" allows for close placement of R35, R41, R36, R37, R38, R42, R39, and R40 around U11. The 74HC4051 is not optimized for attenuator layout.

2.8.5 Attenuator Logic

2 bit demultiplexer U7B provides decoding of the above attenuation table. Signal "L -80" switches the attenuator at U15C and U15B between 40dB attenuation and 80dB attenuation. U15B and U15C cannot produce 120dB of attenuation; only 0dB, 40dB, or 80dB of attenuation. This attenuator is set to 0 dB attenuation when the bilateral current source at U16A is set for 40 dB of gain.

U7B pin 9, signal "L ISRC MODE" when logicial "0" sets the bilateral current source for +40dB of gain. Level translator U8B pin 7 turns on JFET Q8 as part of the +40dB of gain.

2.8.6 Digital Pots

Attenuation steps less than 5 dB are provided by dual digital pot U12. U12 contains 2 strings of 255 equal value resistors. The output taps are selected by the 17 bit shift register contained in U12. The CPU uses U12 to provide attenuation steps of 0.1dB each.

2.8.7 Bilateral Current Source

The use of bilateral current sources on the FA-10 outputs allows both bilateral current sources to be connected to one output for accurate channel summing; and allows the use of JFET switches for output routing. The bilateral current source outputs are not appreciably affected by JFET on resistance.

The bilateral current source has two modes of operation:

2.8.7.1 MODE 0) 40 dB Gain Mode

$$
\begin{aligned}
Iout &\approx -Vin \times ((R59+R58) / (R56 \times (R49+0.5\Omega))) \\
&\approx -31.2 \text{ mA per volt in} \\
&= -30.861 \text{ mA per volt in; exact calculation}
\end{aligned}
$$

In this mode, R49 acts as a current sensing resistor. The opamp regulates its output voltage so that the current through R49 matches the above equation independent of the value of the load impedance.

The output impedance of an ideal bilateral current source would be infinite. In reality, the FA-10 bilateral current source would oscillate if the conditions for infinite output impedance were met.

If $((R57 + R49) / R56) < ((R59 + R58) / R60)$:
then the bilateral current source may oscillate.
(Output impedance negative)

The output impedance for the bilateral current source is approximately:

$$Rout \approx R49 \times (R/\partial R)$$

where $R/\partial R$ is the inverse of mismatch of resistor ratio.

$$Rout \approx R49 / (1 - (((R57+R49)/R56) / ((R59+R58)/(R60))))$$

The above illustrates the reason for the 0.1% resistor tolerance for R56, R57, R59, and R60.

If not connected to a load, the bilateral current source output will swing from power supply rail to power supply rail even with small input voltages. The fast rise and fall times of the output signal will cause it to radiate into outputs other than the one selected. When testing, be sure to use a 100 ohm load.

2.8.7.2 MODE 1) 0 dB Gain Mode:

U16 forms a long tail current source. U16A is a simple voltage output amplifier with large series resistor R50 = 1780Ω. R50 is much larger than the 100Ω load. Small changes in the 100Ω load do not affect output current.

At Q5 pin 1:
$V(Q5) = -Vin \times (R59 + R58) / R60 = -Vin \times .598469$

Rload = 100Ω; R(C29) = 0.5Ω; Rfet = 6Ω

At J26:

$$Iout = \frac{V(Q5)}{R49 + R(C29) + Rfet + R50 + Rload}$$

Across Rload, 100Ω:
I out = –0.3141 mA / volt in

2.8.8 Power Supplies

(± 5A power supplies originate on the FILTER BOARD.)

2.8.9 Cables

The two shielded cables on the OUTPUT BOARD carry signals that are high level analog signals (first cable with W1 and W2) or electrically noisy (second cable with W3, W4, and W5).

2.8.10 Rear Panel Inputs

2.8.10.1 L Ext Input J14; R Ext Input J15

These are intended as external compact disk or as external cassette player inputs. The signals are fed through voltage followers to reduce the signal impedance and thus limit crosstalk from other FA-10 circuits. The buffered signals are connected to the VU METER BOARD.

2.8.10.2 Talk Bac Mic J16

J16 is intended for connection to a Frye provided electret condenser microphone. The microphone is powered by U2A (+5 volts decoupled). The +5 volts decoupled is fed through R2, 10K to form a "long tail" current source.

The voice signal from the microphone is amplified by U2B and routed to the VU meter board.

2.8.10.3 Patient Response J13

The patient response input is intended for connection to a single pole single throw normally open switch which the patient presses when he/she hears a tone. D1 5.6V zener, R8 100Ω resistor, and C7 2.2 µF capacitor provide electrostatic discharge protection. C7 also provides some filtering for the patient response signal originating on the CPU BOARD.

2.8.11 Rear Panel Output Connectors

2.8.11.1 Stereo Monitorr Headphones J17

The left and right monitor signals originate at U14 pin 7 and U22 pin 7 respectively. The monitor signals, talkback microphone, and patient response click/tone are added together on the VU METER BOARD. The combined signals are returned as "C LMON" and "C RMON". R27 and R28 provide short circuit protection. D14 and D15, transzorbs, provide electrostatic discharge protection. The left channel is connected to J17 "tip" terminal, the right channel is connected to J17 "ring" terminal.

2.8.11.2 Patient Earphone Output J20, J26

J20 and J26 are for connection to Telephonics TDH 39 100 Ω earphones. D3 and D6, transzorbs, provide electrostatic discharge protection. C11 and C28, 0.1 µF capacitors, provide protection against external sources of radio frequencies.

2.8.11.3 Bone Vibrator Output J18

J18 is for connection to a 100 Ω Radioear B71 bone vibrator. Transzorb D2 provides protection against electrostatic discharge. C72 0.1 µF capacitor, provides protection against external sources of radio frequencies. C72 also suppresses a parasitic oscillation which involves the bilateral current source and the inductance of the bone vibrator.

2.8.11.4 Speaker Amplifiers J19, J25

J19 and J25 are intended for connection to 8 Ω loudspeakers. These connectors can also be used for connection to an external power amplifier. Input impedance of the external power amplifier is not critical; J16 and J25 can operate without load resistors.

This description is for the left channel. Operation or the right channel is identical:

D5, transzorb, provides electrostatic discharge protection. D10, D11, 1 amp rectifiers protect U13 from voltage spikes caused by overdriving U13 into an inductive (loudspeaker) load. R45 and C55 suppress high frequency oscillations. R9 and R53 present a 100 Ω load to bilateral current source at U16A. R9 and R53 form a voltage divider. The voltage division ratio is set so that U16A and U13 will clip simultaneously. To insure stability, U13 must be configured for a voltage gain of at least 10. A non- inverting amplifier has a gain:

A = 1 + (R45 / R44).

If A =10 then , R45 = 9 x R44. For stable operation, U13 must be bypassed, especially at high frequencies. Bypassing is provided by C41, C42, C53, and C54.

2.9 Complex Signal Paths

2.9.1 Tone

Originates as square waves on the CPU/KEYBOARD. Square wave amplitude made to increase to 100% or fall to 0% in 30 milliseconds by the FILTER BOARD envelope generator. Turned into sine waves by the filter board switched capacitor bandpass filters. Amplitude controlled by attenuators on the OUTPUT BOARD. Fed to bilateral current source amplifier. Sent to earphone, bone vibrator, speaker amplifier and speaker, or other channel.

2.9.2 Patient Response

This is a multifunction signal combining a 5 volt logic level and a small analog 1125 Hz tone on one wire. This logic level signal originates on the OUTPUT BOARD at the patient response jack. The tone originates at the CPU/KEYBOARD master clock. The patient response logic level signal is available as a signal to the CPU at a shift register on the CPU/KEYBOARD. The patient response logic level lights an LED on the VU METER BOARD when the patient presses the patient response switch. The patient response logic level enables a CMOS switch on the VU METER BOARD which sums the patient response analog 1125 Hz tone into the monitor earphones circuit.

3. CALIBRATION

3.1 Equipment Required

a. A 1000 Hz sine wave generator (calibration not critical).

b. A sound level meter*.

c. An artificial mastoid with calibration table. If you are following this procedure for the first time and/or you have only a curve for your artificial mastoid, see appendix A.

d. A scientific or engineering calculator for establishing the artificial mastoid calibration table in appendix A.

e. An AC-millivoltmeter * RMS responding, NOT average responding for measuring the output of the artificial mastoid.

f. Type 9A (6cc) earphone coupler with earphone weight or spring.

* The sound level meter and the millivoltmeter must be traceable to a government standards laboratory such as, in the U.S., the National Institute of Technology and Science (used to be called the National Bureau of Standards). There should be a sticker from a calibration laboratory on the sound level meter and on the voltmeter showing: the name of the calibration laboratory and the date that next calibration is due.

3.2 Introduction

The FA-10 can be calibrated without opening the enclosure. Calibration is enabled by setting the controls to a “secret” code, holding down two keys, then turning power on. The **-2.5 dB** and **Reverse** keys then function as “adjust .5 dB downward” and “adjust .5 dB upward” keys respectively. One simply sets the FA- 10 controls for a particular function. That function can then be calibrated. There are a total of 75 steps to be completed in a full calibration. Calibration values are stored and calibation mode exited by another “secret” setting of controls plus pressing two keys.

This calibration procedue is the minimum required to fully calibrate an FA-10. This procedure assumes that the FA-10 is fully functional. This procedure is not intended as an instrument performance check.

The FA-10 is intended to be used with 100Ω patient earphones, 100Ω bone vibrator, and 8Ω speakers. Use of other impedance devices will reduce available output and may slightly degrade FA-10 accuracy.

Since the frequencies are crystal controlled, there is no frequency drift and no need to calibrate the frequencies on the Hearing Evaluator.

Only one channel needs to be calibrated for the Bone Vibrator. Both channels use the same calibration table values.

If you intend to skip steps, be aware of the following. These effects are limited to channel calibrated (left or right) and limited to the output calibrated (earphone, bone vibrator, or speaker):

- **Tone** must be calibrated before **Narrow Band Noise**.
- If 1 **KHz Tone** is changed, **1 KHz Narrow Band Noise** must be recalibrated.

You may exit calibration at any time and resume later where you left off. If you have unreliable mains power, exiting calibration several times through the calibration procedure may be of benefit.

3.3 Hints

Especially low frequencies, with **Stimulus** pressed, wiggle the earphone against the 9A coupler to check that there are no acoustic leaks.

With **Stimulus** pressed,wiggle the bone vibrator against the artificial mastoid to be certain that it is seated properly.

You may increase the sound levels as needed (within FA-10 capabilities) to reduce the effects of ambient noise. Increase the calibration point at the sound level meter or millivolt meter by the same amount that you increase the Hearing Level control. It is desirable that background noise be 20 dB less than measured signal. Check background noise frequently.

If the **red LEDs flash**, one or more of four conditions exists:

- ALL THREE RED LEDs FLASH: The left **Output** switch set to **Right Channel** plus right **Output** switch set to **Left Channel** (part of switch combination used to enter and exit calibration).

- ONE Hearing Level LED FLASHES plus FREQUENCY LED FLASHES: The Frequency setting for the output selected has been disabled by holding -2.5 dB until the calibration has reached zero output.
- ONE Hearing Level LED flashes rapidly: You have exceeded the maximum output capabilities of the FA-10. Decrease the Hearing Level control setting.
- One Hearing Level LED flashes slowly **(POTENTIAL OPERATOR TRAP!)**: You have adjusted the calibration level above a software safety limit. The Hearing Level LED will flash slowly at all Hearing Level control settings. To clear this condition, (in calibration mode) hold **Stimulus** and simultanously press **-2.5 dB** once.
- Compensate for any frequency response error in your sound level meter. If the frequency response of the meter is low at a frequency, your expected measurements at that frequency will be low by the same amount.

3.4 Procedure: Start

3.4.1 Enter Calibration Mode

Turn the Hearing Evaluator power off.

1. Set the left and right **Input** switches to **Tone**.
   Set the right **Output** switch to **Left Channel**.
   Set the left **Output** switch to **Right Channel**.
   Set the left and right **Hearing Aid Simulator** switches to **Off**.

2. Press and hold down the **Pulse** and **Warble** buttons.
   Turn the audiometer rear panel **POWER** switch **ON**.

   The audiometer will indicate that it is in the calibration mode by rapidly flashing the left **Hearing Aid Simulator LED** at a 1/10 second rate.

3. Set the left **Output** switch to **Phone**.
   Set the right **Output** switch to **Phone**.

3.4.2 Calibration

To calibrate the external source in the Cal steps 15, 30, 45, 60, and 75 below:

- Connect the 1000 Hz sine wave generator to the External Source Input being calibrated.

- Set the sine wave generator for about 1 volt output (not critical!)
- Set the FA-10 **Input** to **External**.
- Press FA-10 Stimulus and adjust the FA-10 front panel **External** control so that the VU meter reads “0 VU”. Perfect adjustment occurs with the “-1 VU” and “0 VU” LEDs both lit.

For complete FA-10 calibration, make all **adjustments** listed in tables 1 through 5 below. Calibrate to the values shown in **bold**.

For each step:

- Set up the FA-10 for the calibration step.
- Press and hold down the channel **Stimulus** button to present sound and simultaneously press the **-2.5** dB key to decrease amplitude or press the **Reverse** key to increase amplitude.
- Release the **Stimulus** key and go to the next step.
- Disable the channel at calibration steps 16, 26, 31, 41, 61, and 71. Press and hold the **Stimulus** key and the **-2.5** dB key until the Hearing Level LED flashes plus the Frequency LED flashes. This indicates that the channel is off.

TABLE 1
Left Channel Earphone Calibration for TDH39 100Ω Earphones

CAL step	Left Input	Left Output	Frequency	Left Hearing Level	Sound Level Meter plus 6 cc coupler
1	TONE	Phone	125	70 dB	**115.0 dB SPL**
2	TONE	Phone	250	70 dB	**95.5 dB SPL**
3	TONE	Phone	500	70 dB	**81.5 dB SPL**
4	TONE	Phone	750	70 dB	**77.5 dB SPL**
5	TONE	Phone	1K	70 dB	**77.0 dB SPL**
6	TONE	Phone	1.5K	70 dB	**76.5 dB SPL**
7	TONE	Phone	2K	70 dB	**79.0 dB SPL**
8	TONE	Phone	3K	70 dB	**80.0 dB SPL**
9	TONE	Phone	4K	70 dB	**79.5 dB SPL**
10	TONE	Phone	6K	70 dB	**85.5 dB SPL**
11	TONE	Phone	8K	70 dB	**83.0 dB SPL**
12	Narrow Band Noise	Phone	1K	70 dB	**83.0 dB SPL**
13	Speech Noise	Phone	—	70 dB	**89.5 dB SPL**
14	White Noise	Phone	—	70 dB	**70.0 dB SPL**
15	L External Source (Ext 1 KHz; set OVU)	Phone	—	70 dB	**89.5 dB SPL**

For Eartone 3A Earphones (formerly ER3A), calibrate the same as for TDH39 Earphones, but use the following table.

TABLE 1A
Left Channel Earphone Calibration for Eartone 3A and 5A 50Ω Earphones

CAL step	Left Input	Left Output	Frequency	Left Hearing Level	Sound Level Meter plus 6 cc coupler
1a	TONE	Phone	125	70 dB	**96.0 dB SPL**
2a	TONE	Phone	250	70 dB	**84.0 dB SPL**
3a	TONE	Phone	500	70 dB	**75.5 dB SPL**
4a	TONE	Phone	750	70 dB	**72.0 dB SPL**
5a	TONE	Phone	1K	70 dB	**70.0 dB SPL**
6a	TONE	Phone	1.5K	70 dB	**72.0 dB SPL**
7a	TONE	Phone	2K	70 dB	**73.0 dB SPL**
8a	TONE	Phone	3K	70 dB	**73.5 dB SPL**
9a	TONE	Phone	4K	70 dB	**75.5 dB SPL**
10a	TONE	Phone	6K	70 dB	**72.0 dB SPL**
11a	TONE	Phone	8K	70 dB	**70.0 dB SPL**
12a	Narrow Band Noise	Phone	1K	70 dB	**76.0 dB SPL**
13a	Speech Noise	Phone	—	70 dB	**82.5 dB SPL**
14a	White Noise	Phone	—	70 dB	**70.0 dB SPL**
15a	L External Source (Ext 1 KHz; set OVU)	Phone	—	70 dB	**82.5 dB SPL**

TABLE 2
Bone Vibrator Calibration
WATCH OUT FOR NOISE

CAL step	Left Input	Left Output	Frequency	Left Hearing Level	Mastoid + Millivoltmeter from Table 6 See Appendix A
16	TONE	Bone	125		**Cal to minimum (disable)**
17	TONE	Bone	250	20 dB	———(Table 6)
18	TONE	Bone	500	40 dB	———(Table 6)
19	TONE	Bone	750	40 dB	———(Table 6)
20	TONE	Bone	1K	40 dB	———(Table 6)
21	TONE	Bone	1.5K	40 dB	———(Table 6)
22	TONE	Bone	2K	40 dB	———(Table 6)
23	TONE	Bone	3K	40 dB	———(Table 6)
24	TONE	Bone	4K	40 dB	———(Table 6)
25	TONE	Bone	6K	40 dB	———(Table 6)
26	TONE	Bone	8K	40 dB	———(Table 6)
27	Narrow Band Noise	Bone	1K	40 dB	———(Table 6)
28	Speech Noise	Bone	—	40 dB	———(Table 6)
29	White Noise	Bone	—	40 dB	———(Table 6)
30	L External Source (Ext 1 KHz; set OVU)	Bone	—	40 dB	———(Table 6)

TABLE 3
Left Channel Speaker Calibration

CAL step	Left Input	Left Output	Frequency	Left Hearing Level	Sound Level Meter at 3 feet
31	TONE (warble on)	Speaker	125	50 dB	**73.5 dB SPL**
32	TONE (warble on)	Speaker	250	70 dB	**82.0 dB SPL**
33	TONE (warble on)	Speaker	500	70 dB	**73.0 dB SPL**
34	TONE (warble on)	Speaker	750	70 dB	**70.5 dB SPL**
35	TONE (warble on)	Speaker	1K	70 dB	**70.0 dB SPL**
36	TONE (warble on)	Speaker	1.5K	70 dB	**69.0 dB SPL**
37	TONE (warble on)	Speaker	2K	70 dB	**67.5 dB SPL**
38	TONE (warble on)	Speaker	3K	70 dB	**61.0 dB SPL**
39	TONE (warble on)	Speaker	4K	70 dB	**61.5 dB SPL**
40	TONE (warble on)	Speaker	6K	70 dB	**67.0 dB SPL**
41	TONE (warble on)	Speaker	8K	70 dB	**78.0 dB SPL**
42	Narrow Band Noise	Speaker	1K	70 dB	**76.0 dB SPL**
43	Speech Noise	Speaker	—	70 dB	**82.5 dB SPL**
44	White Noise	Speaker	—	70 dB	**70.0 dB SPL**
45	L External Source (Ext 1 KHz; set OVU)	Speaker	—	70 dB	**82.5 dB SPL**

TABLE 4

Right Channel Earphone Calibration for TDH39 100Ω Earphones

CAL step	Right Input	Right	Frequency	Right Hearing Level	Sound Level Meter plus 6 cc coupler
46	TONE	Phone	125	70 dB	**115.0 dB SPL**
47	TONE	Phone	250	70 dB	**95.5 dB SPL**
48	TONE	Phone	500	70 dB	**81.5 dB SPL**
49	TONE	Phone	750	70 dB	**77.5 dB SPL**
50	TONE	Phone	1K	70 dB	**77.0 dB SPL**
51	TONE	Phone	1.5K	70 dB	**76.5 dB SPL**
52	TONE	Phone	2K	70 dB	**79.0 dB SPL**
53	TONE	Phone	3K	70 dB	**80.0 dB SPL**
54	TONE	Phone	4K	70 dB	**79.5 dB SPL**
55	TONE	Phone	6K	70 dB	**85.5 dB SPL**
56	TONE	Phone	8K	70 dB	**83.0 dB SPL**
57	Narrow Band Noise	Phone	1K	70 dB	**83.0 dB SPL**
58	Speech Noise	Phone	—	70 dB	**89.5 dB SPL**
59	White Noise	Phone	—	70 dB	**70.0 dB SPL**
60	R External Source (Ext 1 KHz; set OVU)	Phone	—	70 dB	**89.5 dB SPL**

For Eartone 3A Earphones, calibrate the same as for TDH39 Earphones, but use the following table.

TABLE 4A

Right Channel Earphone Calibration for Eartone 3A and 5A 50Ω Earphones

CAL step	Right Input	Right Output	Frequency	Right Hearing Level	Sound Level Meter plus DB0138 coupler
46a	TONE	Phone	125	70 dB	**96.0 dB SPL**
47a	TONE	Phone	250	70 dB	**84.0 dB SPL**
48a	TONE	Phone	500	70 dB	**75.5 dB SPL**
49a	TONE	Phone	750	70 dB	**72.0 dB SPL**
50a	TONE	Phone	1K	70 dB	**70.0 dB SPL**
51a	TONE	Phone	1.5K	70 dB	**72.0 dB SPL**
52a	TONE	Phone	2K	70 dB	**73.0 dB SPL**
53a	TONE	Phone	3K	70 dB	**73.5 dB SPL**
54a	TONE	Phone	4K	70 dB	**75.5 dB SPL**
55a	TONE	Phone	6K	70 dB	**72.0 dB SPL**
56a	TONE	Phone	8K	70 dB	**70.0 dB SPL**
57a	Narrow Band Noise	Phone	1K	70 dB	**76.0 dB SPL**
58a	Speech Noise	Phone	—	70 dB	**82.5 dB SPL**
59a	White Noise	Phone	—	70 dB	**70.0 dB SPL**
60a	R External Source (Ext 1 KHz; set OVU)	Phone	—	70 dB	**82.5 dB SPL**

TABLE 5
Right Channel Speaker Calibration

CAL step	Right Input	Right Output	Frequency	Right Hearing Level	Sound Level Meter at 3 feet
61	TONE (warble on)	Speaker	125	50 dB	**73.5 dB SPL**
62	TONE (warble on)	Speaker	250	70 dB	**82.0 dB SPL**
63	TONE (warble on)	Speaker	500	70 dB	**73.0 dB SPL**
64	TONE (warble on)	Speaker	750	70 dB	**70.5 dB SPL**
65	TONE (warble on)	Speaker	1K	70 dB	**70.0 dB SPL**
66	TONE (warble on)	Speaker	1.5K	70 dB	**69.0 dB SPL**
67	TONE (warble on)	Speaker	2K	70 dB	**67.5 dB SPL**
68	TONE (warble on)	Speaker	3K	70 dB	**61.0 dB SPL**
69	TONE (warble on)	Speaker	4K	70 dB	**61.5 dB SPL**
70	TONE (warble on)	Speaker	6K	70 dB	**67.0 dB SPL**
71	TONE (warble on)	Speaker	8K	70 dB	**78.0 dB SPL**
72	Narrow Band Noise	Speaker	1K	70 dB	**76.0 dB SPL**
73	Speech Noise	Speaker	—	70 dB	**82.5 dB SPL**
74	White Noise	Speaker	—	70 dB	**70.0 dB SPL**
75	R External Source (Ext 1 KHz; set OVU)	Speaker	—	70 dB	**82.5 dB SPL**

3.4.3 Alternate Earphone Calibration

If the alternate earphone option is installed, the audiometer may be calibrated for two separate earphone types.

To select the alternate earphone, place the left Hearing Aid Simulator switch in the Option A position. If the alternate earphone calibration is available, the Hearing Aid Simulator LED will flash rapidly, indicating that the alternate earphone calibration is being used.

You may now repeat the normal earphone calibration procedure to calibrate the alternate earphones.

Remember to clearly mark on the audiometer which earphones are the primary earphones and which ones are the alternate earphones. Mismatching of the earphone calibration will result in incorrect thresholds being measured.

3.4.4 Exit Calibration Mode (and Store Calibration Data)

The calibration you have just performed will be automatically stored into the internal EEROM (electrically Erasable Read Only Memory) when leaving the calibration mode. Two copies of the data are stored in “field calibration tables”. This step may be performed at any point you choose during the calibration procedure. You may later resume where you left off.

1. Set the left **Input** switch to **Tone**.

2. Set the right **Input** switch to **Tone**.

3. Set the right **Output** switch to **Left Channel**.

4. Set the left **Output** switch to **Right Channel**.

5. Set the left **Hearing Aid Simulator** switch to **HFE**.

6. Set the right **Hearing Aid Simulator** switch to **HFE**.

7. Press and hold the **Pulse** and **Warble** buttons at the same time and hold them down until the Hearing Aid Simulator LEDs go out. This indicates that the calibration data has been stored and you are out of calibration mode. This process will take about 5 seconds.

***** FLASHING RED OK *****

Note that the red Level error LEDs will be flashing rapidly because the Output switches are set to an invalid output selection. This is normal. Change the Output switch settings to stop the flashing.

**** ERROR ** WARNING ** FLASHING GREEN ****

If the calibration did not take because you did not properly set the switch combination to exit the calibration mode or because of FA-10 circuit problems: then the left GREEN Hearing Aid Simulator LED will remain flashing. Recheck the switch combination items 1) through 7) above. If the switch combination is correct, then: sorry! You must repeat the calibration. First replace U9, the 93C66 on the CPU/KEYBOARD.

End of procedure. Your FA-10 is now calibrated.

3.5 Other Calibration Options

3.5.1 How to Discard Calibration Values

While still in the calibration mode, simply turn off the power switch and all calibration information modifications will be discarded.

3.5.2 To Enter Calibration Mode with Original Factory Calibration

Should you make a mistake in calibration and want to restore the original factory calibration tables for your FA-10:

1. Turn FA-10 Power switch off.

2. Set the left and right **Input** switches to **Tone**.
   Set the right **Output** switch to **Left Channel**.
   Set the left **Output** switch to **Right Channel**.
   Set the left and right **Hearing Aid Simulator** switches to **Off**.

3. Press and hold down the **Output Reverse** and **Talk Forward** buttons.

4. Turn the audiometer rear panel **POWER** switch **ON**.

At this point, the FA-10 is in calibration mode. Make any calibration changes necessary, then go to step 3.4.3 to save the calibration data and exit calibration.

3.5.3 To Enter Calibration Mode with an Average of Factory Calibrations

This is an average of the calibration tables for the first few FA-10smanufactured. These steps will be useful if all ofthe EEROM tables are defective. Possible uses might include:

- ERROM has been replaced.
- Troubleshooting an FA-10 which has multiple electrical problems including a replaced EEROM (not yet calibrated).
- Establishing a "calibration deviation report" for an FA-10 with totally damaged EEROM calibration tables. This FA-10 might have been used to collect patient data. (The user operated the FA-10 while the Hearing Aid Simulator green LEDs were flashing in groups of 6 or 7 flashes.)

Unless you know for certain that the data in the EEROM were destroyed by technician's calibration errors, the EEROM should be replaced. The cost of the EEROM is small compared to the cost of recalibration.

START:

1. Turn FA-10 Power switch off.

2. Set the left and right **Input** switches to **Tone**.
   Set the right **Output** switch to **Left Channel**.
   Set the left **Output** switch to **Right Channel**.
   Set the left and right **Hearing Aid Simulator** switches to **Off**.

3. Press and hold down all 4 of the following buttons:
   Output Reverse, Pulsed, Warble, Talk Forward. (Use a ruler or pencil.)

4. Turn the FA-10 rear panel **POWER** switch **ON**.

At this point, the FA-10 is in calibration mode.

Continue with all the calibration steps and then go to item 3.9 (following) to save the calibration data and exit calibration.

3.5.4 Exit Calibration Mode (Store Calibration Data and Store New Factory Calibration Data)

Don't do this unless:

- you have replaced the EEROM, or
- FA-10 transducer(s) have been changed, or else
- you know that the factory calibration tables were destroyed by technician error.

The calibration you have just performed will be automatically stored into the internal EEROM (electrically Erasable Read Only Memory) when leaving the calibration mode. This step may be performed at any point you choose during the calibration procedure. You may later resume where you left off.

1. Set the left **Input** switch to **Tone**.
2. Set the right **Input** switch to **Tone**.
3. Set the right **Output** switch to **Left Channel.**
4. Set the left **Output** switch to **Right Channel.**
5. Set the left **Hearing Aid Simulator** switch to **HFE**.
6. Set the right **Hearing Aid Simulator** switch to **HFE**.
7. Press and hold the left **Stimulus**, right **Stimulus**, **Pulse**, and **Warble** buttons at the same time; and hold them down until the Hearing Aid Simulator LEDs go out. This indicates that the calibration data has been stored and you have exited calibration mode. This process will take about 10 seconds.

FLASHING RED OK

Note that the red Level error LEDs will be flashing rapidly because the **Output** switches are set to an invalid output selection. This is normal. Change the **Output** switch settings to stop the flashing.

** ERROR ** WARNING ** FLASHING GREEN **

If the calibration did not take because you did not properly set the switch combination to exit the calibration mode or because of FA-10 circuit problems: then the left GREEN Hearing Aid Simulator LED will remain flashing. Recheck the switch combination items 1 through 7 above. If the switch combination is correct, then: sorry! You must repeat the calibration. First replacing U9, the 93C66 EEROM located on the FA-10 CPU/KEYBOARD.

3.6 EEROM Failures

Duplicate calibration information is stored in the EEROM to insure that the EEROM data is valid. In fact, there are actually five sets of calibration tables in the audiometer. Two are duplicate factory calibration tables, done by computer through the RS232 port. Another two are duplicate field calibration tables created using the procedures described in this booklet. The fifth set of calibration tables is in the EPROM. It is based on average data of the transducers used, and cannot be considered more than approximately correct.

The EEROM, where the calibration information is stored, uses a CRC (cyclical redundancy check) that will detect a failure of the data stored in the EEROM. Three levels of calibration failure are identified by the pattern of the flashing of the Hearing Simulator LEDs.

Should an EEROM failure occur when you turn the audiometer on, turn FA-10 power off, then on again to see if the error will correct itself. If an EEROM error occurs while trying to save the new calibration values just entered, try to exit calibration again. If the error does not go away or is intermittant, replace the EEROM.

Note: See Section 3.5.4 if you repalce the EEROM.

3.6.1 Field Calibration Table Bit Error Warning

*, ** OR ***

The Hearing Aid Simulator LEDs flash in a pattern of one, two, or three times in succession, with pauses between the grouping of flashes.

One of the two field calibration tables contains an error. The other Table is good. The FA-10 is still calibrated but should be serviced. The EEROM is less than perfect.

This type of error can often be corrected by recalibrating the audiometer as described above, BUT DO NOT. Order a new EEROM from Frye Electronics, because the cost of this part is small compared to the usual cost of calibration.

3.6.2 Both Field Calibration Table Bit Error Warning

****** OR *******

The Hearing Aid Simulator LEDS flash in groups of 4 or 5 flashes. In addition, Hearing Level and Frequency LEDS will flash every three seconds.

Both field calibration tables have failed. The FA-10 is now using one of the two factory calibration tables. If the factory calibration were still valid, then the FA-10 is still calibrated, but servicing is recommended. If the factory calibration is not valid because of a transducer change, or because sound field was calibrated in the field, then the FA-10 should be considered out of calibration.

A serious multiple failure has occurred inside the EEROM. You might succeed in doing a field calibration, BUT DO NOT. Replace the EEROM.

3.6.3 Total EEROM Failure Warning

******** OR *********

The third level of failure is complete EEROM failure signaled by a flashing pattern of six or seven on the Hearing Simulator LEDs. Hearing Level and Frequency LEDs will flash faster (once per second) than for an EEROM error. In this case, the audiometer will default to the backup calibration burned into the EPROM. This calibration is based on average values and is not precise.

If the user insists on taking data with this warning present, data can be salvaged by providing a table of calibration data from before calibration and from after calibration.

3.6.4 Calibration Failure / Fail-Safe Shutdown

********* + *******

Should all five sets of calibration tables fail, the audiometer will go into fail-safe mode and shut down all operation. If you see the Hearing Simulator LEDs flash a count of seven followed by a flash count of five, you know that the back-up calibration in the EPROM has failed.

3.6.5 Recovery from a Fail-Safe Error

A shutdown is a very rare occurance. It is possible that a shutdown will be due to a transient failure such as a static discharge or power surge. In such cases, the problem can normally be cured by turning the instrument off and then back on again. A problem caused by hardware failure will require the instrument to be repaired.

An inadvertent loss of calibration due to technician error can normally be cured by recalibrating the instrument. The EEROM can be calibrated over 10,000 times so that should not be a cause of concern.

APPENDIX A

Procedure to Establish Artificial Mastoid Calibration Table

This procedure is to be done each time the artificial mastoid is sent to a certification laboratory. It is NOT done for each audiometer. Keep completed TABLE 6 in a safe place for reference.

Information Required

1. Artificial mastoid sensitivity at 1000 Hz measured in nanovolts per micronewton (nV/μN). If you have sensitivity in nanovolts per dyne, divide by 10 to get nanovolts per micronewton. 1 microvolt = 1000 nanovolts.

2. A graph or table showing the artificial mastoid output at frequencies from 250 Hz to 6000 Hz; in dB relative to 1000 Hz.

Start:

1. Make a copy of TABLE 2. Do not mark up the original in this manual.

2. Make a copy of TABLE 6. Do not mark up the original in this manual.

3. Fill out the top portion of TABLE 6 from documentation provided with your artificial mastoid.

4. From the table or graph provided with your artificial mastoid, enter the relative sensitivity of your artificial mastoid at 8 frequencies. 1 KHz must be 0 dB. The numbers must be in dB. If the frequency has less output than 1 KHz, then the relative output has a minus (-) sign.

5. Add the numbers in COLUMN B plus the numbers in COLUMN C and write the totals in COLUMN D

6. Using a scientific calculator, for each number in COLUMN D:

   - Divide number by 20
   - Press 10^x key (raise 10 to the above result)
   - Multiply by S the sensitivity of your artificial mastoid at 1000 Hz)
   - Write the result in COLUMN E including voltage label (nV, μV, mV, V).

   Note: The result must have at least 3 significant digits. Change to microvolts or millivolts when required.

7. Multiply each number in COLUMN E by 10 and write the result in COLUMN F including voltage label (nV, µV, mV, V).

8. Multiply each number in COLUMN E by 100 and write the result in COLUMN G including voltage label (nV, µV, mV, V).

9. Enter the appropriate values in TABLE 2.

End of procedure

Note: If you wish to calculate voltages 10 dB higher, multiply by the square root of 10.
$\sqrt[2]{10} = 3.1623$.

TABLE 6

FRYE ELECTRONICS INC. ARTIFICIAL MASTOID CALIBRATION TABLE (ANSI S3.43-1992)

DATE: ___________________________

ARTIFICIAL MASTOID MANUFACTURER:_____________________MODEL NUMBER:_____________

SERIAL NUMBER:______________________

SENSITIVITY AT 1000 Hz:________________ nanovolts per microNewton = S

COLUMN A	COLUMN B	COLUMN C	COLUMN D	COLUMN E	COLUMN F	COLUMN G
SOURCE	MASTOID RELATIVE SENSITIVITY	ANSI THRESHOLD	RELATIVE OUTPUT AT 0 dB HL	OUTPUT VOLTAGE AT 0 dB HL	OUTPUT VOLTAGE AT 20 dB HL	OUTPUT VOLTAGE AT 40 dB HL
250 Hz TONE	dB	67.0 dB	dB			
500 Hz TONE	dB	58.0 dB	dB			
750 Hz TONE	dB	48.5 dB	dB			
1 KHz TONE	0.0 dB	42.5 dB	42.5 dB			
1.5 KHz TONE	dB	36.5 dB	dB			
2 KHz TONE	dB	31.0 dB	dB			
3 KHz TONE	dB	30.0 dB	dB			
4 KHz TONE	dB	35.5 dB	dB			
6 KHz TONE	dB	40.0 dB	dB			
8 KHz TONE	dB	40.0 dB	dB			
1 KHz NBN	0.0 dB	48.5 dB	48.5 dB			
SPEECH NOISE	0.0 dB	55.0 dB	55.0 dB			
EXT SOURCE	0.0 dB	55.0 dB	55.0 dB			
WHITE NOISE	0.0 dB	36.5 dB	36.5 dB			
			D=B+C	$E=Sx10^{(D/20)}$	F=10 x E	G=100 x E

APPENDIX B

Conforms to ANSI S3.6-1996 and IEC 645-1 1992

Basis of Calibration Numbers

Narrow Band Noise is calibrated for effective masking. White noise is calibrated in SPL.

TABLE 7

TELEPHONICS TDH-39, TDH-39P 100 Ω EARPHONES CALIBRATION FACTORS, WITH TYPE 9A COUPLER (Add these levels to Hearing Level setting to get the required sound level meter readings.)		
Frequency	TDH-39 TDH-39P	Supporting Document
125	45.0 dB	ANSI S3.6-1996 TABLE 6
250	25.5 dB	ANSI S3.6-1996 TABLE 6
500	11.5 dB	ANSI S3.6-1996 TABLE 6
750	7.5 dB	ANSI S3.6-1996 TABLE 6
1000	7.0 dB	ANSI S3.6-1996 TABLE 6
1500	6.5 dB	ANSI S3.6-1996 TABLE 6
2000	9.0 dB	ANSI S3.6-1996 TABLE 6
3000	10.0 dB	ANSI S3.6-1996 TABLE 6
4000	9.5 dB	ANSI S3.6-1996 TABLE 6
6000	15.5 dB	ANSI S3.6-1996 TABLE 6
8000	13.0 dB	ANSI S3.6-1996 TABLE 6
1 kHz Narrow Band Noise	13.0 dB	ANSI S3.6-1996 sect. 6.3.1
Speech Noise	19.5 dB	Same as External Source
White Noise	0.0 dB	(Calibrated in SPL)
External Source	19.5 dB	ANSI S3.6-1996 sect. 6.2.12

The NBN calibration is based on the pure tone calibration for the selected frequency plus the correction recommended by ANSI S3.6-1996 Sect. 6.3.1 for effective masking with NBN. The 1 KHz calibration sets the base correction level for all frequencies. Only 1 kHz needs to be calibrated. 1 kHz pure tone must be calibrated before 1 kHz NBN is calibrated.

The 19.5 dB used in Speech Noise and External Source is derived by adding 12.5 dB, the “crest factor” for voice from ANSI S3.6-1996 plus 7.0 dB, the correction factor for 1000 Hz tone.

TABLE 8

EARTONE 3A and 5A 50 Ω EARPHONES CALIBRATION FACTORS Using HA-2 coupler with rigid tube (ANSI S3.6–1996 sec. 9.3.2) (Add these levels to Hearing Level setting to get the required sound level meter readings.)		
Frequency	3A	Supporting Document
125	26.0 dB	ANSI S3.6-1996 TABLE 7
250	14.0 dB	ANSI S3.6-1996 TABLE 7
500	5.5 dB	ANSI S3.6-1996 TABLE 7
750	2.0 dB	ANSI S3.6-1996 TABLE 7
1000	0.0 dB	ANSI S3.6-1996 TABLE 7
1500	2.0 dB	ANSI S3.6-1996 TABLE 7
2000	3.0 dB	ANSI S3.6-1996 TABLE 7
3000	3.5 dB	ANSI S3.6-1996 TABLE 7
4000	5.5 dB	ANSI S3.6-1996 TABLE 7
6000	2.0 dB	ANSI S3.6-1996 TABLE 7
8000	0.0 dB	ANSI S3.6-1996 TABLE 7
1 kHz Narrow Band Noise	6.0 dB	ANSI S3.6-1996 sect. 6.3.1
Speech Noise	12.5 dB	Same as External Source
White Noise	0.0 dB	(Calibrated in SPL)
External Source	12.5 dB	ANSI S3.6-1996 sect. 6.2.12

The NBN calibration is based on the pure tone calibration for the selected frequency plus the correction recommended by ANSI S3.6-1996 Sect. 6.3.1 for effective masking with NBN. The 1 KHz calibration sets the base correction level for all frequencies. Only 1 kHz needs to be calibrated. 1 kHz pure tone must be calibrated before 1 kHz NBN is calibrated.

The 12.5 dB used in Speech Noise and External Source is derived by adding 12.5 dB, the “crest factor” for voice from ANSI S3.6-1996 plus the correction factor for 1000 Hz tone.

TABLE 9

Radioear B-71 100Ω BONE VIBRATOR 0 HL CALIBRATION (MASTOID 0 dB =1 μNEWTON) ASSUMING MASTIOD WITH FLAT FREQUENCY RESPONSE		
Frequency	Mastoid output	Supporting Document
125	OFF	
250	67.0 dB	ANSI S3.43-1996 TABLE 8
500	58.0 dB	ANSI S3.43-1996 TABLE 8
750	48.5 dB	ANSI S3.43-1996 TABLE 8
1000	42.5 dB	ANSI S3.43-1996 TABLE 8
1500	36.5 dB	ANSI S3.43-1996 TABLE 8
2000	31.0 dB	ANSI S3.43-1996 TABLE 8
3000	30.0 dB	ANSI S3.43-1996 TABLE 8
4000	35.5 dB	ANSI S3.43-1996 TABLE 8
6000	40.0 dB	ANSI S3.43-1996 TABLE 8
8000	40.0 dB	ANSI S3.43-1996 TABLE 8
1 kHz NBN	48.5 dB	ANSI S3.6-1996 section 6.3.1 (1000 Hz reference level + 6 dB)
Speech Noise	55.0 dB	SAME AS EXTERNAL SOURCE
External Source	55.0 dB	ANSI S3.6-1996 sect. 6.2.12 (1000 Hz reference level +12 .5dB)
White Noise	36.5 dB	1000 Hz Value - 6dB (Empirical)

Notes:

- Add correction factor for your artificial mastoid.
- To obtain levels re 1 Dyne, subtract 20 dB from values given.
- At 250 Hz the Bone Vibrator should be calibrated at 20 dB HL.
- White noise from a bone vibrator will have poor frequency response characteristics due to limitations of the bone vibrator. White Noise is calibrated to an Empirical SPL level.

The 55 dB used in Speech Noise and External Source is derived by adding 12.5 dB, the “crest factor” for voice from ANSI S3.6-1996 plus the correction factor for 1000 Hz tone.

TABLE 10

SPEAKER CALIBRATION (WARBLE ON) ADD THESE NUMBERS TO HEARING LEVEL TO GET SPL		
Frequency	SPL at 0 dB HL	Supporting Document
125	23.5 dB	ANSI S3.6–1996 TABLE 9
250	12.0 dB	ANSI S3.6–1996 TABLE 9
500	3.0 dB	ANSI S3.6–1996 TABLE 9
750	0.5 dB	ANSI S3.6–1996 TABLE 9
1000	0.0 dB	ANSI S3.6–1996 TABLE 9
1500	–1.0 dB	ANSI S3.6–1996 TABLE 9
2000	–2.5 dB	ANSI S3.6–1996 TABLE 9
3000	–9.0 dB	ANSI S3.6–1996 TABLE 9
4000	–8.5 dB	ANSI S3.6–1996 TABLE 9
6000	–3.0 dB	ANSI S3.6–1996 TABLE 9
8000	+8.0 dB	ANSI S3.6–1996 TABLE 9
1 kHz NBN	6.0 dB	ANSI S3.6-1996 section 6.3.1
Speech Noise	12.5 dB	Same as External Source
White Noise	0.0 dB	White Noise is presented in SPL
External Noise	12.5 dB	ANSI S3.6–1996 section 6.2.12

The two speakers are located 3 feet from the patient's head, at ear level, one 45° to the left and one 45° to the right of the patient's nose.

The NBN calibration is based on the pure tone calibration for the selected frequency plus the correction recommended by ANSI S3.6-1996 Sect. 6.3.1 for effective masking with NBN. The 1 KHz calibration sets the base correction level for all frequencies. Only 1 kHz needs to be calibrated. 1 kHz pure tone must be calibrated before 1 kHz NBN is calibrated.

The 12.5 dB used in Speech Noise and External Source is derived by adding 12.5 dB, the "crest factor" for voice from ANSI S3.6-1996 plus the correction factor for 1000 Hz tone.

APPENDIX C

LED Error Codes Which May Occur During FA-10 Operation

Red LEDs

The red LEDs on the front panel are used to indicate error conditions. There are three error LEDs. They have the following meanings:

Operational Errors

Problem: Left Level LED flashing at a 1/10 second rate:
The left level is out of calibration.

Right Level LED flashing at a 1/10 second rate:
The right level is out of calibration.

Cause: The current level setting is beyond the ability of the audiometer to output a calibrated signal. (The current signal output is at the maximum level possible for the selected transducer.)

Cure: Reduce the Hearing Level.

Problem: Frequency and Left Level LED flashing 1/10th sec rate: The left channel selection is not a valid selection.

Frequency and Right Level LED flashing 1/10th sec rate: The right channel selection is not a valid selection.

Cause: The current mode setting is not a valid selection. (The current signal output is at the minimum level possible for the selected transducer.)

Cure: Change the selected mode. Change frequency, Input, or Output selector to appropriate setting.

Problem: Frequency plus Left Level LED on continuously: The left channel is under RS232 control.

Frequency plus Right Level LED on continuously: The right channel is under RS232 control.

Frequency plus Left Level plus Right Level LED on continuously: Both channels are under RS232 control.

Cause: This is not a true error condition, rather it is a warning. It indicates that the front panel controls are no longer controlling the instrument, so the settings can not be relied on as being valid. Control is being managed by the attached computer through the RS232 computer interface.

Cure: The computer can return control to the audiometer front panel controls at anytime, or the instrument can be turned off then back on to force a return to normal front panel operation.

Equipment Errors

Problem: Left Level LED continuously flashing at 1/4 sec rate: The left level switch is generating an invalid code.

Right Level LED continuously flashing at 1/4 sec rate: The right level switch is generating an invalid code.

Frequency LED continuously flashing at 1/4 sec rate: The frequency switch is generating an invalid code.

Cause: The associated switch is generating an invalid (non-existing) selection. The switch may be defective.

Cure: Change the switch position. If the problem does not go away, the switch may be defective and should be replaced by a qualified service technician.

Problem: Left level, Right level, and Frequency LEDs all flashing at a 1/4 second rate with or without a periodic one second pause or All LEDs (except power and response) flashing at a 1/10 second rate:

Cause: System failure has occurred, LEDs are indicating the error number by the flash count.

Cure: Turn the audiometer off then back on. If the problem does not go away, the audiometer is not operational and must be repaired by a qualified service technician.

Problem: All LEDs (except response) are on continuously:

Cause: While the power-on test sequence is being performed, all the front panel LEDs (except the response LED) will be turned on and left on until the test has been completed. When the audiometer self-test is complete and the instrument is ready to use when all the LEDs except the power LED will turn off. (Depending on the switch positions, some LEDs may remain on.)

Cure: If all the LEDs stay on, or the audiometer repeatedly turns all the LEDs on then off, the audiometer is not operational and must be repaired by a qualified service technician. The audiometer will not be operational until the problem has been corrected.

Equipment Error Definitions

Both level LEDs and freq LED will flash for system type errors.

Primary error conditions — single count flashing

If the LEDs flash a number of times, wait 1/2 second, and repeat the flash count, it is an indication of one of the following errors:

Flashes	**Error Description**
2	NMI failure
3	ROM Memory failure error
4	RAM Memory failure error
5	Calibration failure
6	RS232 mode failure

Extended error conditions — double count flashing

If the red LEDs flash seven times, wait 1/2 second, then flash a smaller number of times, it is an indication of one of the following errors:

Flashes	Error Description
7 – 1	Cold start error (program restarted)
7 – 2	Stack overflow error encountered
7 – 3	Unexpected restart encountered
7 – 4	Tick Timer delay failure
7 – 5	Calibration mode failure
7 – 6	Serial bus failure

If the red LEDs flash continuously at a 1/4 second rate with no pauses, it is an indication of the following error:

Flashes	Error Description
255	Watch dog timeout error

If the red LEDs flash continuously at a 1/10 second rate with no pauses, it is an indication of the following error:

Flashes	Error Description
0	Uncorrectable system failure —cause unknown

APPENDIX D

Special Power-on Modes for the FA-10 Audiometer

FA-10 Calibration:

Normal Entry:
- Outputs to Other channel
- Inputs to Tone
- Hearing Aid Simulators to Off
- Press and hold Warble and Pulse while turning on the audiometer

Enter with Restored Factory Calibration:
- Outputs to Other channel
- Inputs to Tone
- Hearing Aid Simulators to Off
- Press and hold Talk Forward and Output Reverse while turning on the audiometer.

Enter with Default Average Calibration:
- Outputs to Other Channel
- Inputs to Tone
- Hearing Aid Simulators to Off
- Press and hold Talk Forward, Warble, Pulse, and Output Reverse, while turning on the audiometer.

Save Current Calibration and Exit Calibration mode:
- Outputs to Other channel
- Inputs to Tone
- Hearing Aid Simulators to HFE
- Press and hold Pulse and Warble until LEDs go off.

Save Current Calibration as Factory Calibration:
- Outputs to Other channel
- inputs to Tone
- Hearing Aid Simulators to HFE
- Press and Hold Pulse, Warble, and both Stimulus buttons while turning on the audiometer.
- (Note: do this only if you have changed the EEROM or replaced a transducer.)

Discard Calibration changes and Exit Calibration mode:
- Turn the audiometer off and back on.

Version number of software:

The software information will be transmitted in ASCII at 9600 baud out of the RS232 port at power on time. You can also get the version number via an RS232 command request (see RS232 documents).

If RS232 is not available, you can ask for the software version number by pressing and holding the Talk Forward push button while turning the FA-10 on. The LEDs will flash the version number. The flashing will be repeated about once every five seconds. This can be terminated by either pressing a stimulus switch, or turning the audiometer off.

Left HAS = model high digit
Right HAS = model low digit
Left Level LED = version high digit
Freq LED = version middle digit
Right Level LED = version low digit

one flash = 1; 9 flashes = 9; no flashes = 0

FA-10 Easter Egg:

Set Inputs to Tone
Set Hearing Aid Simulators to Off
(Output selection is not important)
Press and hold both –2.5 dB and both Stimulus buttons while turning the FA-10 power on.

APPENDIX E

Rear Panel Safety Markings

CAUTION: FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE ONLY WITH 1/2 AMP SLOW 250 V FUSE

Never replace a fuse with a fuse which has a rating higher than specified.

The fuses are 0.5A 250V 3AG Slow

Fuses must have at least one safety approval mark.

Symbol	**Meaning**
	"Read the accompanying documents"
	For purpose of safety classification under IEC60601-1, the FA-10 is class 1, type B, ordinary equipment suitable for continuous operation.

For the FA-10 to comply with IEC60601-1, all mains connected electrical equipment attached to the FA-10 must also comply with IEC60601-1. All computer and audio equipment attached to the FA-10 must be medical grade or else used with a medical grade isolation transformer.