Instruction Manual

Model 106C/130/155
Optical Module

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WARRANTY

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1064nm, 1560nm AND 1310nm OPTICAL MODULES

MODEL 106C, MODEL 155 AND MODEL 130

Graphic (Model 155 & 130)

The Model 106C, Model 155 and Model 130 are three in a series of plug-in modules that provide electrical and optical output pulses when installed in the Model 6040 mainframe.

These particular modules provide optical pulses of 1064, 1560 and 1310 nm wavelengths at peak levels to 1 mV at rates to 100 MHz.

SECTION 1

SPECIFICATIONS

MODEL 106C/155/130 CHARACTERISTICS

Timing Characteristics

Rep Rate:	0 Hz-100 MHz
Width:	3 ns - 640 s (Pulse Mode); 3 ns (min.) at reduced amplitude. Impulses, fixed 400 ps fwhm (typical).

Input Characteristics

EXTERNAL DRIVE

Range:	dc - 300 MHz (200 MHz for zero Baseline level): specifications apply dc - 100 MHz.
Input Impedance:	50 ohms.
Minimum Signal Amplitude:	300 mV.
Maximum Signal Amplitude:	±7 V dc or 10 V ac p-p.
Minimum Width:	5 ns; 3 ns (min.) at reduced amplitude.
Threshold Range:	±2.5 V.
Threshold Resolution:	10 mV.
Insertion Delay:	5 ns, typical (between EXT DR and LIGHT OUT).
Jitter:	30 ps rms (between EXT DR and LIGHT OUT).
Connector:	Threaded SMA (3 mm).

EXTERNAL MODE

Range:	100 Hz to 700 MHz (-3 dB).
Input Impedance:	50 ohms.
Sensitivity:	200 mV rms/mW, typical.
Maximum Signal Amplitude:	±2 V dc or 3 V ac p-p.
Total Harmonic Distortion:	< 20 dB below fundamental (0.5 mW avg, level with 0.5 mW rms modulation).
Insertion Delay:	5 ns, typical (between EXT MOD and LIGHT OUT).
Connector:	Threaded SMA (3 mm).

SPECIFICATIONS cont'd.

Output Characteristics

LIGHT OUT

Wavelength:	Model 106C: 1064nm ±30 nm Model 155:1550 nm ±30 nm. Model 130:1310 nm ±50 nm.
Spectral Width:	2 nm rms (from 50 uW to 1 mW).
Power Level:	1 mW max. (Peak or Baseline). 0 mW min. Impulse is fixed at 50 μW Baseline and 0.5 mW Peak (typical).
Power Level Resolution:	5 μW (from 50 μW to 1 mW),
Extinction Ratio:	CW Mode and External Modulation Mode, has 5 μW resolution from 0 to 1 mW
Mesial Level:	∞ (zero Baseline), or 20.0 to 1.01.
Pulse Adjustment Range:	25 μW (zero Baseline), or 55 μW to 0.995 mW. (Max. pulse size: min. pulse size.) 20 dB (non-zero Baseline), 13 dB (zero Baseline), 20 dB (CW. External Modulation).
Accuracy, Absolute:	±1 dB (from 50 μW to 1 mW).
Accuracy, Relative:	±0.5 dB (±10 %) from 100 μW to 1 mW (Pulse Mode). ±0.05 dB (±0.5 %) from 50 μW to 1 mW (CW. External Modulation).
Temperature Coefficient:	0.05 dB/°C.
Transition Times (10 to 90%):	0.5 ns rise time, 1 ns fall time (zero Baseline), 1 ns rise time, 1 ns fall time (nonzero Baseline).
Insertion Delay:	35 ns, typical (between mainframe TRIG OUT and LIGHT OUT; see Figure 1-1).
Jitter:	100 ps rms (between mainframe TRIG OUT and LIGHTOUT).
Connector:	ST, 8/125 um single-mode fiber, 0.12 NA (contact factory for other connectors).

SPECIFICATIONS cont'd.

Modes

PULSE — Conventional pulse generator with rate, delay, width and single/double pulse selections controlled by the 6040 mainframe. External Drive operation produces pulses corresponding in rate and duty cycle to an external pulse train.

EXTERNAL MODULATION — Converts digital and analog electrical signals are into their optical equivalent.

IMPULSE — Provides a narrow pulse of fixed width and amplitude, with rate and delay controlled by the 6040 mainframe.

Module Status Byte Summary

Table 1-1. Module Status Byte

Bit	Description
7	Always zero
6	Always zero
3	Always zero
4	Always zero
3	Always zero
2	Always zero
1	Laser Active
0	Laser Guard

SECTION 2

OPERATING INFORMATION

FEATURES

The Model 106C, 155 and 130 plug-in modules provide 1064nm, 1550 nm and 1310 nm optical output sources for the Model 6040 Universal Pulse Generator. Accurate and adjustable outputs are available for all of the four modes in which the 6040 mainframe can operate.

In Pulse Mode operation, the 106C/155/130 supplies flat-topped pulses with fast rise and fall times and independently adjustable Peak and Baseline levels. The timing for these pulses may be supplied in a number of ways.

A delayed pulse of adjustable width may be generated by the mainframe. This delay can be specified with respect to an internal trigger occurring at a selected repetition rate or with respect to an externally supplied trigger signal (TRIG IN). In addition, Single Cycle operation allows the user to trigger the instrument manually, using a pushbutton (or using remote programming). In each case a trigger out signal (TRIG OUT) is provided by the 6040 for reference (see Figure 1-1). Double Pulse operation, producing both an initial and delayed pulse put of the same jack may be selected for any trigger choice. For all of these timing options, the mainframe supplies electrical output pulses (PULSE OUT) coincident with the module's optical output (LIGHT OUT).

External Drive operation is also available in the Pulse Mode. This allows a drive signal, supplied by the user to the module's front panel (EXT DR), to generate the optical pulses directly. The occurrence and duration of each light pulse will correspond to that of each pulse in the external drive signal: when the EXT DR pulse goes high, the light pulse goes to the Peak value. Peak and Baseline output levels remain specified by the mainframe (as well as the threshold level for the external drive signal). With External Drive, the mainframe's pulse and trigger outputs are disabled.

In External Modulation Mode, an electrical signal supplied to the module's front panel (EXT MOD) by the user will be converted into its optical analog. The quiescent optical level, corresponding to the zero point that the input signal modulates about, is selected by the mainframe (External Modulation Level), but no other parameters can be altered.

In the Impulse Mode, a narrow optical pulse of fixed width and amplitude is produced at the module output (LIGHT OUT) with a corresponding pulse (of 5 ns duration) appearing at the mainframe (PULSE OUT). As with the Pulse Mode, the trigger source may be internal, external or from manual (or remote programming) control. Either a single delayed impulse or a pair of impulses separated by a delay may be obtained. In Impulse Mode, External Drive operation is disabled; and Peak and Baseline Level settings also have no effect.

CW Mode results in a steady-state optical output. The output power level in this Mode may be adjusted by the mainframe (CW Level).

For more detailed information on the characteristics of each Mode and hour to control the module from the mainframe, see the Specifications section and the 6040 manual.

OPERATING INFORMATION

General

POWER UP

When power is applied to the 6040 mainframe with a 106C, 155 or 130 module installed, the instrument settings from the module's memory 0 are activated. The mainframe automatically checks what type of plug-in module is in place and loads the appropriate parameters. The LCD, after showing the mainframe's software version number and performing a memory check, will display "106C Ver. x.x" (or “155 Ver. X.x” or "130 Ver. x.x") where "x.x" is the version number of the module.

Module Installation

The module must be installed with mainframe power off. A module can be damaged or have its memory corrupted if inserted or removed from the mainframe with the power on. To install the module, simply slide it in and tighten the mount screw knob.

Safety Precautions

Laser light emitted from the end of the connected light fiber is invisible. Fibers should be terminated in a system which will not allow human exposure to this radiation. Do not stare into the beam or into a beam from a reflecting surface. Use of controls or adjustments or performance procedures other than those specified herein may result in hazardous exposure. Safety labels attached to the module are shown in Figure 2-1.

Always keep the LIGHT OUT connector covered with the dust cap when a fiber is not attached in order to avoid hazardous exposure and to keep the connector as clean as possible.

Warm Up Requirements

No warm up period, other than that necessary for the mainframe itself, is required.

TROUBLESHOOTING

Follow the procedure in the Troubleshooting section of the 6040 manual. Make sure that the module is seated correctly in the mainframe. If the module's memory has been corrupted, a cold boot will put the module's default settings (given below) into effect (as described in the Cold Boot paragraph in the 6040 manual).

OPERATING INFORMATION cont'd

The Quick Test procedure for the mainframe may be applied to the 106C/155/130 by selecting the Pulse Mode and following the test sequence using the module's LIGHT OUT connector and an optical detector in place of the mainframe's PULSE OUT. After Pulse Mode operation has been verified, the Impulse Mode can be tested. This will require a sampling oscilloscope with a 1 GHz bandwidth. The impulse should appear as a narrow pulse (approximately 400 ps). Its amplitude is roughly equal to that of a 0.3 mW, 5 ns pulse generated in the Pulse Mode. The CW and External Modulation Modes are similar. These should produce continuous outputs. The output under External Modulation should follow any waveform presented to the module's EXT MOD connector.

Default Settings

The following default settings for the 106C/153/130 module go into effect whenever a cold boot is performed.

MODE: Pulse

TRIG: Single Cycle
(with other values set as follows)
Internal Trigger Rate = 1 kHz.
External Trigger Threshold = 0.00 V
Trigger Slope +
External Drive Threshold = 0.00 V

TIMING: Delay = 1 µs
Width = 1 µs
Single Pulse

LEVEL: Peak= l.000 mW
Baseline = 0.000 mW
External Modulation
CW=0.00 mW

GPIB/RS232: GPIB Address = 6
Baud Rate = 1200
Full Duplex
Remote Enabled

Front Panel Descriptions

LED INDICATORS

The 106C/155/130 module has two LED indicators on the front panel.

LASER ACTIVE will light when the instrument is in a state that can produce a light output.

LASER GUARD will light if the laser is being protected from an unsafe power output level, whenever the Mode is changed and when the unit is first turned on. LASER GUARD will remain on if any unsafe circuit conditions exist (e.g., excessive current driving the laser).

CONNECTORS

Three connectors appear on the 106C/155/130 module front panel.

LIGHT OUT provides the optical output from the module. A single-mode 8/123 Mm fiber with an ST connector is required (the unit can be configured for other connectors; consult the factory for details). To keep dust out of the connector when a fiber is not attached, a dust cap is provided.

EXT DR (External Drive) is a threaded SMA (3 mm) connector for accepting drive signal inputs to the module.

EXT MOD (External Modulation) is a threaded SMA (3 mm) connector that accepts external signals to modulate the instantaneous light output power level.

Rear Panel Description

The rear panel of the 106C/155/130 module has a mounting screw (for installation into the mainframe), one 40-pin edge connector, and one SMA connector.

The 40-pin connector allows the 6040 mainframe to control and communicate with the module and also supplies the power to the module.

The SMA (snap-on type) connector receives the high speed pulse generator DRIVE signal from the mainframe. This signal is an ECL version of the mainframe's front panel PULSE OUT.

Mainframe Operation

This section presents information on how to operate the Model 6040 Universal Pulse Generator with the Model 106C, 155 or Model 130 optical module installed. Only the details that are specific to the module are described. For an overall description of how to use the mainframe with plug-in modules, please refer to the 6040 manual.

Front Panel Programming

When operating the instrument from the front panel, certain control keys have module dependent action, as indicated in the 6040 manual. The aspects of these keys, and the menus they control, that are not general to the mainframe will be listed here.

An overall chart of the menu keys, showing which menu selections have control in each Mode, is given in Table 2-1. An "x" in the column for a given Mode indicates that the menu selection operates in that Mode.

OPERATING INFORMATION cont'd

Table 2-1. Menu Keys for the 133/130 Module.

	MODE Menu			
	Pulse	**Impulse**	**CW**	**External Modulation**
TRIG Menu				
Single Cycle		X		
Internal Trigger (and Rate)		X		
External Trigger (and Threshold)		X		
External Trigger Slope				
External Drive (and Threshold)		X		
TIMING Menu				
Delay	X	X		
Width	X			
Single/Double Pulse	X	X		
LEVEL Menu				
Peak	X			
Baseline	X			
CW			X	
External Modulation				X

OPERATING INFORMATION cont'd

{MODE} The Mode menu for the 106C/155/130 has all four selections available: Pulse, Impulse, CW and External Modulation.

Pulse Mode can operate over the entire timing range of the 6040, producing flat-topped delayed pulses. The Delay interval, Peak level. Baseline level and pulse Width are all adjustable.

External Drive operation is available in this Mode, allowing the module to be digitally modulated at rates from zero to 300 MHz (for nonzero Baseline levels) or 200 MHz (for zero Baseline level).

Impulse Mode produces pulses of fixed 400 ps width with fixed 30 u¥ baseline and 1 mW peak levels (typical).

CW Mode provides continuous wave optical output.

External Modulation Mode allows a user-provided analog or digital signal to be linearly converted to its optical equivalent. Inputs ranging from 100 Hz to 700 MHz are converted with 200 mV rms/mW sensitivity (typical).

{TRIG} The Trigger source and parameter menu, which operates in the Pulse and Impulse Modes, has all five menu items: Single/Double Cycle, Internal Trigger (and Rate), External Trigger (and Threshold), External Trigger Slope, and External Drive (and Threshold).

Internal Trigger Rate and External Trigger Threshold are adjustable over the 6040's entire range.

External Drive is valid only in Pulse Mode (and has no effect in Impulse Mode). The External Drive Threshold for the discriminator on the EXT DR input to the module is adjustable from -2.3 V to +2.3 V with 10 mV resolution.

{TIMING} This module places no constraints on timing settings selected with the Timing parameter menu.

{LEVEL} All four Level parameter menu selections are available for this module: Peak Level, Baseline Level, External Modulation Level and CW Level.

Peak and Baseline Levels select the high and low power levels in Pulse Mode operation. These levels may be set to zero or they may be adjusted between 30 μW and 1 mW in 3 MW steps (levels between zero and 50 μW may be selected but output characteristics are not guaranteed). Peak Level and Baseline Level may be set independently, but if Peak is set below Baseline the output will be a constant CW at the Baseline Level.

External Modulation Level sets the quiescent optical power level. This may be selected over the entire range of zero to 1 mW in 3 MW steps.

CW Level may also be adjusted to any power level between zero and 1 mW with 5 μW resolution.

{UNITS} This key is not used with the 106C/155/130 module (and has no effect).

FUNCTION KEYS {A}, {B}, {C} These keys are not used with the 106C/155/130 module (and have no effect).

Remote Programming

The remote programming commands that are specific to this module correspond to the module dependent front panel commands, as described in the previous section. Consult the 6040 manual and the above section for details on controlling the instrument with remote programming. The Module Status command, the only command that is specific to the 155/130 module, will be described here.

PS Module Status: This command returns the Module Status byte for the 155/130.

Module Status Byte:

Bit	Description
7	Always zero
6	Always zero
5	Always zero
4	Always zero
3	Always zero
2	Always zero
1	Laser Active
0	Laser Guard

Bits 2-7: These bits are always zero and are reserved for future use.

Bit 1: This bit is set if the LASER ACTIVE LED is lit.

Bit 0: This bit is set if the LASER GUARD LED is lit.

SECTION 3

THEORY OF OPERATION

GENERAL

Module Interface

Figure 3-1 shows a simplified block diagram of the Module Interface board. The path for communication between mainframe and module is via PS. The eight QAD lines and five QA lines are the bus interface lines, and a MOD DIS line is used for disabling the Output board. Power is also delivered by P8.

The address demultiplexer and select logic circuitry decodes the bus signals and selects one of the other blocks.

The I.D. ROM contains information necessary for operation specific to the Output board. This includes boundaries for parameters, values used to initialize the nonvolatile RAM (NVRAM), and the version number of the I.D. ROM.
The nonvolatile RAM is used for saving and retrieving ten panel settings. It also holds the GPIB/RS232 bus settings.

The digital control circuits are used to monitor and set the operating state of the Output board. The DACs and amplifiers allow setting of up to four analog values used for level control. All of the control, status, and analog signals are delivered to the Output board by two 20-pin connectors, J1 and J2.

Laser Driver Output

Figure 3-2 shows a simplified block diagram of the Laser Output board. The connection to the Module Interface board is shown in the lower left hand corner. There are three analog lines used to set the output levels and the threshold of the External Drive discriminator. The control lines select which Mode the Laser Output will operate in.

The selection of the digital drive source is controlled by three digital control lines, EXT DRIVE ENABLE, IMPULSE, and EXT MOD. These determine which of the two drive sources will be controlling the state of S1, (a high speed transistor switch). A discriminator, whose threshold is set by the analog voltage EXT DRIVE LEVEL, is connected to the drive source from the front panel EXT DR connector. The other signal source is the rear panel DRIVE connector which delivers the mainframe's pulse generator output.

The level control circuitry sets one or both of the current sources as determined by the analog inputs PEAK LEVEL, and BASELINE LEVEL and the Mode control lines. During the Impulse, CY and External Modulation Modes, it uses the PIN detector in the laser module to monitor and stabilize the laser's output. When LASER GUARD is active, the current sources are set for zero output.

THEORY OF OPERATION

The two current sources are used for different Modes. The current source on the left is used during Pulse and Impulse Modes (to supply the Peak level), and during the External Modulation Mode. This current source can be modulated from a wideband preamp which is driven by the front panel SMA connector EXT MOD. The current is switched to the laser by SI, as determined by the DIGITAL DRIVE SELECT and the drive signals. The current source on the right is used during PULSE MODE when a nonzero Baseline level is selected and in the CW Mode.

The Laser Protection circuitry monitors the laser output and circuit conditions. If the laser output exceeds a preset level, S2 will be closed and all laser drive current will be shunted to ground. The current is then monitored until it is reduced below another preset value before S2 is allowed to reopen. This block drives the front panel LEDs, LASER ACTIVE and LASER GUARD, which allow the user to monitor the state of these circuits. The DAC EN signal is used to notify the Module Interface board of a potential problem and disable its DACs, thus setting all level control voltages to zero. The MOD DIS signal is used to disable the module's output.
The Laser Module is a single package that contains the laser diode, a PIN monitor diode, a thermoelectric cooler (TEC), and a temperature sensing device. An 8/123 Um single-mode fiber is connected to the front panel (LIGHT OUT). The TEC and thermistor are used in conjunction with an op amp and transistor to regulate the temperature of the laser diode, thus improving power and wavelength stability.

CIRCUIT DESCRIPTION

Module Interface Board (Schematic 6040-35)

The Module Interface board contains all the necessary circuits to allow the 6040 mainframe to control the module. Interfacing between the module and the mainframe is realized via the 40-pin edge connector, PS, This delivers eight data bits (QADO-QAD7) and 13 address bits (QADO-QAD7, multiplexed, and QA8-QA12, nonmultiplexed). P8 also delivers power to the Interface board and the Output board.

Z2 is an eight bit latch that demultiplexes QADO-QAD7 to produce the lower eight address bits QAO-QA7. This allows up to 8K bytes to be addressed within the Interface board, though not all of this is utilized at the present time. Table 3-1 gives the memory map for the module.

Z1 is a dual quad selector. Z1 A is used to select between one of four 2K byte segments. These four segments are used for: 1) Z3, the I.D. ROM; 2) Z4, the nonvolatile RAM; 3) reserved for expansion; 4) Z5, Z6 and Z7, the digital and analog control of the output board. Z1B selects which IC in the fourth segment is accessed.

Z3 is the I.D. ROM. It is an 8K byte ROM (only the lower 2K is used) that contains the module dependent information necessary for the 60-40 to operate correctly.

Table 3-1. Plug-In Module Memory Map

Memory Range	
C000-C777	Z3, I.D.ROM
C800-CFFF	Unused
D000-D7FF	Z4, Nonvolatile RAM (NVRAM)
D800-DFFF	I/O
D800-DFFF	
D800-D9FF	Z5, 82C55 PPI
D800	Port A
D801	Port B
D802	Port C
D803	Control
DA00-DBFF	Unused
DC00-DDFF	Z6, 7528; Dual DAC
DC00-DC03	PEAK LEVEL
DC04-DC07	BASELINE LEVEL
DE00-DFFF	B27, 7528; Dual DAC
DEOO-DE03	SPARE
DE04-DE07	EXT DRIVE LEVEL

This includes the Modes that are valid, parameter boundaries, and the type of output that the module has (optical or electrical). It also contains the values for initializing the nonvolatile RAM.

Z4 is a 2K byte nonvolatile RAM (NVRAM). It is used to save instrument settings and power-on conditions.

Z5 is a configurable Parallel Peripheral Interface 1C set up to allow 16 bits of output and eight bits of input. The outputs are used to select the operating state of the Output board while the inputs monitor the board's status.
DACs Z6 and Z*7.* in conjunction with op amps Z8 and Z9, generate analog signals that set the value of the Peak, Baseline, and quiescent level of the output. They are also used to set the threshold level for the External Drive discriminator. The variable resistors, R3-R6, are used to compensate for slight differences in the DACs.

The voltage reference for the analog signals is CR1, a 6.2 V temperature compensated zener diode. Q1 is used to disable CR1 if the signal DAC EN is allowed to go up to +12 V. The Output board asserts this in the event of a Mode change or if any unusual condition is detected.

The MOD DISABLE line allows the Output board to be disabled via the 6040 rear panel MODULE DISABLE connector.

The Module Interface board has two grounds, digital and analog. The analog ground is used exclusively by the DAC and op amp circuitry (Z6, Z7, Z8, Z9, etc.), while all other circuitry is connected to digital ground. These are separated to prevent any noise or dc offsets by power supply return currents from affecting the analog control voltages.

The 20-pin connectors J1 and J2 deliver the digital and analog control signals to the Output board, while the 16-pin connector J11 delivers the power supply voltages. J3 is an expansion connector to be used in conjunction with future modules.

LASER OUTPUT BOARD (Schematic 155-31)

Inputs and Control Signals (Schematic Sheets 1 and 2)

The Laser Output board receives three types of inputs: digital control signals from the Interface board via P1, analog control signals from the Interface board via P2, and drive and external modulation inputs via front or rear panel coax connectors. Four of the digital control signals, IMPULSE, EXT MOD, CW, and BIAS, are used to control analog switches, Z14 and Z11 (sheet 1). These switches are in their low impedance (closed) state when the control input, the terminal with inversion circle, is low (near ground).

Table 3-2 shows how these digital control signals affect the condition of the analog switches in each Mode. The switches are identified by their control terminals (e.g., Z14-9); "L" and "H" indicate low and high logic/voltage levels. By turning on and off these switches, these digital signals provide proper routing for BASELINE LEVEL and PEAK LEVEL, the analog signals that control the amplitude at the laser output. As an example, in the Pulse Mode with a nonzero Baseline (and not using External Drive), the only high input to Z9 is BIAS (Z9-5). Thus Z9-10 and Z9-12 are both high and Z9-6 is low. Z14-1 is low and this connects the BASELINE LEVEL amplitude control to Z8-3 via Z13-7 and Z14-3 Other Modes may be similarly analyzed using this table.

Three digital control signals, EXT MOD, CW (sheet 1) and EXT DRIVE EN (sheet 2). select which drive source is presented at the output of the ECL multiplexer, Z4 In Pulse Mode either the DRIVE signal from the mainframe or the EXT DR signal from the module front panel can be selected. This signal, after passing through Z3 and R162, becomes PREDRIVE, which determines when the laser is switched between Peak and Baseline levels. In External Modulation Mode, EXT MOD selects X4 (Z4-11), which is tied high, for the multiplexer output, causing PREDRIVE to be held high. In CW Mode, X2 is selected, causing PREDRIVE to be held low.

Laser Module

The Laser Module is shown enclosed by dashed lines within which are six components. The laser itself is the left hand diode whose anode is grounded and connected to the case at pins 13 and 13. The case is connected to ground via pins 1 and 2. A 170 µH choke is provided internally for applying dc bias to the laser. This is used in all the Pulse Modes with nonzero Baseline and in the CW Mode. The diode shown between pins 7 and 8 is a built in monitor (detector) that is used for controlling the laser's output in the CW, External Modulation, and Impulse Modes and is also used to detect excessive optical power. An internal 22 ohm resistor provides wideband termination for the high speed signals from 06. A thermoelectric cooler (TEC) is incorporated in the module and is shown connected between pins 3/4 and 3/6. Its associated temperature sensor is connected between pins 11 and 12. The temperature is maintained at approximately 20° C by means of a feedback loop consisting of Z1 and 010. This loop supplies enough cooling current to bring the sensor voltage to 2.9 V (Z1-3). R104 limits the maximum current during start-up to a safe level (approximately 2 A).

CW Mode (Schematic Sheets 1 and 3)

CW operation utilizes the dc current source, Q1 and Z7. The voltage from Z8-1 (labeled CW OR BASELINE LEVEL) is applied to one arm of the resistor bridge, R36, R37, R63 and R66. This same voltage is forced to appear across R82 and R83 A typical calibration is for R82 and R83 to be 30 ohms so that 20 mA/V is produced by Q1. This current flows (via R81, L1, and the internal 170 µH inductor) through the laser to ground. Since PREDRIVE is held low the path for current through Q6 will be cut off. Once the threshold current of the laser is exceeded, the relationship between the current in the laser and its optical output is linear.

The path of the CW OR BASELINE LEVEL signal may be followed on schematic sheet 1. First, we note that the PEAK LEVEL control voltage is inverted by Z13-1 and delivered to Z16-3 via R20. Second, we determine the status of the switches that affect the CW OR BASELINE LEVEL signal. Z11-3, for example, is connected to three such switches. From Table 3-1 it is seen that its control signal is IMPULSE from Z9-2, and that it is high in the CW Mode. Thus, Z9-3 is not conducting. Z14-16 is similarly found to be low so this switch is conducting. Also, Z14-1 is high which renders this switch open. Since Z14-9 is low, the EXT MOD OR CW FEEDBACK signal from Z16-7 is applied to Z16-2. The output from Z13-1 is also applied to Z16-3. The output from Z13-1 is not influenced by R22 because Z14-6 is open and no voltage is applied to R22.

Table 3-2. Control Signals

IC	Mode					Destination	Signal Label
	Pulse		CW	EXT MOD	Impulse		
	Zero BsIn	Nonzero BSIn					
Z9-1	L	L	L	L	H		IMPULSE
Z9-2	H	H	H	H	L	Z3 (Sheet 2)	$\overline{\text{IMPULSE}}$
Z9-11	L	L	H	L	H	Z4 (Sheet 2)	EXT MOD
Z9-10	H	H	H	L	H	Z10-5	$\overline{\text{EM}}$
Z9-13	L	L	H	L	L	Z4 (Sheet 2)	CW
Z9-12	H	H	L	H	H	Z10-4	$\overline{\text{CW}}$
Z9-5	L	H	L	L	L		BIAS
Z9-6	H	L	H	H	H	Z14-1	$\overline{\text{BIAS}}$
Z10-6	L	L	H	H	L	Z14-8	CW + EM
Z10-3	H	H	L	L	H	Z14-9	$\overline{\text{CW + EM}}$

Analog Switches

Z14-1	H	L	H	H	H	$\overline{\text{BIAS}}$
Z14-8	L	L	H	H	L	CW + EM
Z14-9	H	H	L	L	H	$\overline{\text{CW + EM}}$
Z14-16	H	H	L	H	H	$\overline{\text{CW}}$
Z11-1	H	H	H	H	L	$\overline{\text{IMPULSE}}$
Z11-8	H	H	H	H	L	$\overline{\text{IMPULSE}}$

In summary, the PEAK LEVEL control voltage is inverted about ground by Z13-1 and also undergoes a gain reduction of six (-6 V from PEAK LEVEL becomes +1 V at Z13-1). The current from the monitor diode is converted at Z16-7 to approximately 1 V for a 1 mW optical output and is applied to Z16-2 where it will almost cancel the signal from Z13-1. If this does not happen, a large error signal appears at Z16-1 where it passes via Z14-4 and Z8-1 to the current generator, Z7 and Q1 (sheet 3)

External Modulation Mode (Schematic Sheets 1 and 3)

We have traced in detail, for CW Mode, the manner in which the PEAK LEVEL control voltage causes a predictable current to be applied to the laser. Similar considerations show how the quiescent light level for the External Modulation Mode is derived. The PEAK LEVEL control voltage is still used to set the desired optical level (around which the modulation will occur). Feedback via Z16-7 is used as with CW. Z1 1-1 is high (as for CW) but now Z14-16 is also high. This has the effect of routing the error signal (Z16-1) through Z8-7 (a precision rectifier).

It is then applied (sheet 3) as the ETT MOD OR PULSE AMPLITUDE signal to Z1-5 (a x2 attenuator followed by an adjustable x3 gain stage). Since PREDRIVE is held high, the laser's dc bias is now provided by Q9 (via 06) R108 samples the current which is compared to the voltage from Z1-7 by a bridge arrangement (R72, R73, R74, R95). Z2-7 generates the error signal applied to Q8 and then to Q9.

The actual modulation is applied from J801, via FET current amplifier Q11, to Q8 where it generates a base voltage for Q9 which (via R112) generates a predictable signal current through R108 and Q6 that finally drives the laser. Although this circuit appears to be direct coupled from J801, it acts as if it were ac coupled due to the action of Z2, which monitors the total laser current (flowing through R108). The low frequency cut off is approximately 100 Hz.

THEORY OF OPERATION

Pulse Mode

In Pulse Mode, two conditions exist: the circuitry involved when the Baseline level is set to zero is different from the circuits used with a nonzero Baseline. In Pulse Mode with zero Baseline, there is no optical output between pulses (during a logical "zero" there is zero light output). The upper level is set by the PEAK LEVEL control voltage which, in turn, determines the amount of current switched into the laser. In Pulse Mode with a nonzero Baseline, both the upper ("one") and lover ("zero") logic levels must be adjustable according to the Peak and Baseline settings.

Pulse Mode (Nonzero Baseline)

Pulse Mode with nonzero Baseline requires 1) producing a current that determines the optical power radiated between pulses (the Baseline), and 2) calculating the difference between the desired Peak power and the Baseline power, and then generating a pulse of corresponding amplitude. This pulse is added to the already present Baseline level to produce the desired Peak level. The Baseline current is generated and applied to the laser in the same manner as for CW operation, except that optical feedback is not used.

The path from the BASELINE LEVEL control voltage is through Z13-7, Z14-3 (conducting), past Z14-14 and Z1 1-3 (both open), to Z8-1 (unity gain) and finally to Z7 (sheet 3). As stated above, Z7 and Q1 form a current source, and this is what supplies the Baseline current to the laser.

The path from the PEAK LEVEL control voltage is through Z13-1 (sheet 1), Z16-1, past Z14-15 (open), to ZS-7, through CR7, Z1-7 (sheet 3), and finally to Z2-7. As stated above, Z2-7, Q8 and Q9 form a current source which also drives the laser. Pulse Mode differs from External Modulation in that the current is switched by Q6 and Q7 (as defined by the level of the PREDRIVE signal) and there is no optical feedback.

The pulse current (through Q6 and Q7) is determined for PEAK LEVEL by the precision rectifier formed by ZS and CR7 and the two resistor dividers R31/R40 and R32/R39 (sheet 1). This circuit produces a voltage which is the difference between the voltages at Z16-1 (the scaled version of the PEAK LEVEL control voltage) and Z8-1 (the scaled version of the BASELINE LEVEL control voltage), yet not less than zero. The output, at the cathode of CR7, is applied to Z1-5 (sheet 3) which provides an adjustable gain of from xO.5 to x2. At this point, a 3 V difference between the control voltages has become 500 mV at Z1-7. Z2-7 and R108 (47 ohm) convert this to approximately 10 mA, which is the value needed for a 0.30 mW optical power change. Thus a 3 V difference between the PEAK LEVEL and BASELINE LEVEL control voltages is converted to a 0.30 mW optical step. Since this step is added to the Baseline level already present (via Z7, Q1) the Peak and Baseline levels are determined by their respective control voltages, provided that the "gains" (voltage to current conversion factors) of the two channels are set to be equal.

THEORY OF OPERATION

PREDRIVE, the timing signal from the multiplexer (Z4), is applied (from Z3-2) to the base of predriver Q4. Q4 and Q3 are a switching pair whose current is controlled by Z2-1 and Q3. The predrive current through Q4 and 03 increases with increasing optical output and, as the current increases, the main drivers Q6 and Q7 receive larger switching voltages. This is achieved by utilizing a current source. comprised of Z2-1 and 03, which tracks the EXT MOD OR PULSE AMPLITUDE control voltage at Z1-7. A small offset is introduced into this current source so that at very small pulse levels there is sufficient predrive current to switch Q6 and Q7.

Pulse Mode (Zero Baseline)

With Zero Baseline, only the switching transistors Q6 and Q7 (sheet 3) supply current to the laser. The PEAK LEVEL control voltage is processed directly through Z13-1. Z16-1 and Z8-7. Switches Z11-8, Z14-1, Z14-9 and Z14-6 are open and Z14-8 is closed. Thus Z13-1 is a x6 attenuator while Z16-1 is a x1 voltage follower. Since the switch Z14-1 is open, the BASELINE LEVEL control voltage is not presented to Z8-3, which will now be held at ground by R24. This allows Z8-7 (through CR7) to be a xl follower of the voltage at Z16-1

This has two implications. 1) the CW OR BASELINE LEVEL current source is turned off, which prevents any quiescent light and 2) the PEAK LEVEL control voltage adjusts the pulsed current to values that produce a power level between zero and 1.0 mW (the same range that the CW OR BASELINE LEVEL current source uses with a nonzero Baseline Pulse Mode, as determined by the BASELINE LEVEL control voltage.

External Drive (Schematic Sheet 2)

External Drive is used in the Pulse Mode to shift the source of the drive signal from the mainframe to the front panel EXT DR connector. The circuits behave the same as under ordinary Pulse Mode operation except that the PREDRIVE signal is now obtained (via the multiplexer Z4-5) from the External Drive circuit. Two control signals from P2, EXT DRIVE LEVEL and EXT DRIVE POL, select the trigger threshold and polarity for the signal presented to the EXT DR jack.

Impulse Mode

Impulse Mode is used to generate a narrow, fixed width and fixed amplitude pulse. The digital timing is obtained from PREDRIVE (sheet 2). The leading edge of the impulse signal Z3-2 is caused by DRIVE itself. R157 and Z3-15 provide a short time delay (less than 2 ns) that produces the trailing edge. The result is a short, positive pulse delivered to the base of Q4 (sheet 3).

The predrivers (Q4 and Q3) and the main drivers (Q6 and Q7) have both been programmed by PEAK LEVEL for a high (120% of full scale) current that represents the amplitude of the impulse waveform. In order to assure fast response, the laser is biased to just above its threshold current by an auxiliary feedback loop that holds the laser at this point regardless of duty factory variations. The optical output is monitored by internal detector diode DSI-7, and in Impulse Mode represents the average optical power. Both the Baseline level and the average power of the impulses themselves contribute to this signal. The latter contribution varies with rep rate (duty factor).

Since it is desired to stabilize the Baseline level only, a signal proportional to the duty factor is required. This signal is obtained from Z3-2 (via R163). Both signals are sent to the auxiliary feedback loop. The IMPULSE COMPENSATION and IMPULSE FEEDBACK signals (sheet 1) are combined in Z6 along with a dc level from R37 and are sent back (via Z11-3 and Z8-1) to the Baseline current source (Q1, sheet 2). R37 adjusts for the small (approximately 10 µW) amount of residual light that is emitted between impulses. R42 adjusts the balance between the optical sample (from D51-7) and the digital sample (Z3-2) so that there is no change with varying rep rates.

Laser Protection (Schematic Sheets 1 and 3)

The laser is protected from excessive drive currents by a group of circuits referred to as LASER GUARD. These circuits ensure that whenever an unusual situation occurs the laser is promptly shunted by a low impedance. This action is called "crowbar." The path around the laser is from DS1-10 through LI, Q2, and R79 to ground. Even if both sets of driver transistors (Q6, Q9 and Q1) were to short circuit, the resulting current would be shunted around the laser by Q2.

If there is excessive current (20 mA or more) flowing in the crowbar transistor, Q2, it is sensed by Z7. This causes a positive voltage (via CR14) to reinforce the triggering of Z12. The circuit remains in the crowbar state until the over current condition is removed. Although the control circuits generally turn on "gracefully" without excessive current transients, a time constant is provided (C59, R101) that turns Q2 on when the power is initially applied.
Another input to Z12-4 is from the internal monitor diode DSI-7. This produces a voltage across R102 and R103 that is set to trigger Z12 when the optical output becomes too high.

When a change of Mode is made, the ENABLE signal (Z9-9, sheet 1) triggers the crowbar action. This is applied to a timer circuit, Z12, that acts to turn on the crowbar transistor Q2 (via 012) It also is triggered at initial power-on by CR-23 and R130 A CROWBAR signal is sent to Z17-2 (sheet 1). This is another timer that acts to further hold off the control circuitry and permit a smooth return to normal operation.

While Z17 is in its timing cycle, the LASER ACTIVE LED is turned off and a positive level from Z17-3 via Z15-1 turns on the LASER GUARD indicator. After several seconds the Z17 timer will recover (if no over current condition is present) and allow the control circuits to recover.

SECTION 4

MAINTENANCE AND CALIBRATION

MAINTAINENCE

Light Output Connector

For satisfactory performance, proper care in the use of the optical components is necessary. There must be no contamination to interfere with the passage of light through the fiber end connections and the bulkhead connector. The following procedures should be observed.

1. Minimize the number of times connecting and disconnecting the optical cable.

2. Keep the connectors absolutely clean.

3. Keep the output bulkhead connector and the user's connector capped when not in use.

CALIBRATION

General

The calibration of the 106C/155/130 module is in two parts: the first is for setting control voltages on the Module Interface board (PCB 6040-4); the second is for setting the Laser Output board (PCB 155-1) for the correct power output and impulse characteristics and to verify the External Modulation bandwidth.
It is recommended that the calibration of the 155/130 module be verified every 12 months. The instrument requires no warm up period exceeding that of the 6040, for which ten minutes is suggested.

Equipment Required

- 3-1/2 digit (or better) DVM.

- BNC 6100 Optical Power Meter (or equivalent) calibrated for the appropriate wavelength.

- 1 GHz bandwidth oscilloscope (sampling or real time). A Tektronix 7000 Series with appropriate sampling plug-ins is satisfactory.

- 1 GHz bandwidth 1330 nm detector (InGaAsP). A Tektronix S-42 Optical Sampling Head can be used with the 7000 Series Oscilloscope.

- 1 GHz variable sine wave generator. An HP 8657A Signal Generator with a Type N to SMA adapter can be used.

- Threaded SMA (3 mm) terminated 30 ohm coaxial cables, 1 meter length.

- BNC terminated 30 ohm coaxial cables, 1 meter length.
- Variable dc voltage source (capable of ±3 V into 30 ohms).
- Single-mode optical fiber patch cord terminated with appropriate connectors..

PROCEDURE

Note: This calibration should be carried out in the order presented.

Before starting, verify that the power supply voltages are at their nominal levels (+12 V ±0.1 V, -12 V ±0.1 V, +5 V ±0.05 V, and -5-2 V ±0.05 V) with the Module plugged in. Operate the Module on extension cables.

Module Interface DAC Calibration

Refer to Schematic 6040-35 (PCB 6040-4). Set the Mode to Pulse; set the Peak and Baseline levels both to 1.000 mW; set the Trigger to External Drive with a threshold of +2.50 V.

Connect the DVM between TPG (A GND) and Z9-1. Adjust R3 for a voltage of -5-000 V ±2 mV.

Connect the DVM between TPG (A GND) and Z8-7. Adjust R4 for a voltage of -4.000 V ±2 mV.

Connect the DVM between TPG (A GND) and Z8-7, Adjust R5 for a voltage of -4.000 V ±2 mV.

External Drive Discriminator

All further measurements and adjustments refer to the Laser Output board. Schematic 155-31 (PCB 155-1).

Set the Mode to Pulse. Set Trigger to External Drive with a threshold of +0,99 V. Connect the DVM to Z18-1 (Schematic 155-31, sheet 2) and record the voltage. Now set the threshold for -0.99 V. Adjust R141 so that the DVM reading exactly complements the recorded value.

Connect a +1.00 V dc supply to the module EXT DR connector. Connect the DVM to Z5-8. Scan the TRIG External Drive threshold parameter from 0.90 V to +1.10 V and verify that Z5-8 changes from low to high (-1.7 V to -0.8 V) when the threshold voltage is set for 1.00 V ±30mV.

MAINTENANCE AND CALIBRATION

CW and External Modulation Calibration

Using the patch cord, connect LIGHT OUT to the 6100 Optical Power Meter. Set the 6100 for Average power measurement and the 0 dBm range.

Set the 6040 Mode to CW and the CW level to 1.000 mW If necessary, adjust R11 (Schematic 133-31, sheet 1) to obtain a reading of 1.000 mW ±10 µW on the 6100. Set the CW level for 100 µW and verify the output to be within 10 µW.

Set the 6040 Mode to External Modulation (with no input connected to EXT MOD) and set the External Modulation level for 1.000 mW. Verify an output of 1.000 mW ±10 µW. Set the External Modulation level for 100 µW and verify the output to be within 10 µW.

Pulse Baseline Calibration

Set the 6040 Mode to Pulse, and the Trigger to Single Cycle.

A) Set the 6040 Baseline level to 1.000 mW. Adjust R83 (Schematic 133-31. sheet 3) to obtain a reading of 1 .000 mW ±20 µW on the 6100.

B) Set the Baseline level to 100 µW. Adjust R22 as necessary to obtain 0.100 mW ±20 µW.

Repeat steps A) and B) until both readings are within 20 µW of their stated values.

Pulse Peak Calibration

A) Set the Baseline level to 0.000 mW, Set the Trigger to External Drive with a threshold of -50 mV. Adjust R58 (Schematic 155-31, sheet 3) for an output of 1.000 mW ±20µW.

B) Set the Baseline level to 100 µW. Adjust R19 to obtain an output of 1 .000 mW ±20 µW.

Repeat steps A) and B) until both readings are within 20 µW of their stated values.

Note: The following sections require high bandwidth paths; any improperly cabled terminated paths will yield incorrect results.

MAINTENANCE AND CALIBRATION

Pulse Dynamic Characteristics

Connect the 6040 TRIG OUT to the External Trigger input of the oscilloscope (bandwidth must be at least 1 GHz). Connect the 6040 LIGHT OUT to the detector (also 1 GHz). Connect the detector's output to channel A of the oscilloscope.

With the 6040 still in Pulse Mode, set the Peak level to 1.000 mW and the Baseline level to 100 μW. Set TRIG for Internal Trigger, 100 kHz. Set Timing for a Width of 40 ns. and a Delay appropriate to view the detector output on the scope. Verify that leading and trailing edges have transition times (10-90%) ≤ 1 ns.

SECTION 5

PARTS LIST AND SCHEMATICS

Abbreviations

CER	Ceramic	**PF**	Pico farad
COMP	Composition	**SIP**	Single Inline Package
DIP	Dual Inline Package	**TAN**	Tanalum
ELEC	Electrolytic	**UH**	Microhenry
FAC SEL	Value Set at Factory	**UF**	Microfarad
K	Kilohm	**V**	Working Volts
M	Megohm	**VAR**	Variable
MF	Metal Film	**W**	Watts
MIC	Mica	**WW**	Wire wound
MONO	Monolithic Ceramic		

-------------------------- NOTE ----------------------------

The number in the ***second column*** *is the*
BERKELEY NUCLEONICS re-order number

LASER OUTPUT BD. 155-1, MODEL 155 649-144
LASER OUTPUT BD. 155-1, MODEL 130 649-145

C1	122-002 1μF 10% 35 V TAN
C2	110-019 0.5 μF 20% 25 VCER
C3	122-009 0.68 μF 10% 35 VTAN
C4	110-021 0.01 μF 20% 18 V CER
C5	122-001 047 μF 10% 35 V TAN
C6	110-021 0.01 μF 20% 18 V CER
C7	NOT USED
C8	NOT USED
C9	NOT USED
C10	NOT USED
C11	120-015 33μF 10% 35 VTAN
C12	110-033 0.1 μF± 20% 50 V CER MONO
C13	110-033 0.1 μF± 20% 50 V CER MONO
C14	110-033 0.1 μF± 20% 50 V CER MONO
C37	110-033 0.1 μF±20% 50 V CER MONO
C15	110-033 0.1 μF± 20% 50 V CER MONO
C16	110-033 0.1 μF± 20% 50 V CER MONO
C17	110-033 0.1 μF± 20% 50 V CER MONO
C18	1100330.1 μF± 20% 50 V CER MONO
C19	110-033 0.1 μF± 20% 50 V CER MONO
C20	110-033 0.1 μF± 20% 50 V CER MONO
C21	110-033 0.1 μF± 20% 50 V CER MONO
C22	110-033 0.1 μF± 20% 50 V CER MONO
C23	**110-033 0.1μF ± 20% 50V CER MONO**
C24	**122-015 33 μF 10% 35 V TAN**
C25	**110-033 0.1 μF ± 20% 50V CER MONO**
C26	**110-033 0.1 μF ± 20% 50V CER MONO**
C27	**110-033 0.1 μF ± 20% 50V CER MONO**
C28	**110-033 0.1 μF ± 20% 50V CER MONO**
C29	**110-033 0.1 μF± 20% 50 V CER MONO**
C30	**110-033 0.1 μF± 20% 50 V CER MONO**
C31	**110-033 0.1 μF± 20% 50 V CER MONO**
C32	**110-033 0.1 μF± 20% 50 V CER MONO**
C33	**110-033 0.1 μF± 20% 50 V CER MONO**
C34	**110-033 0.1 μF±20% 50V CER MONO**
C35	**110-033 0.1 μF±20% 50 V CER MONO**
C36	**122-015 33 μF 10% 35 V TAN**
C38	**110-033 0.1 μF±20% 50 V CER MONO**
C39	**110-033 0.1 μF±20% 50 V CER MONO**
C40	**122-015 33μF 10% 35 VTAN**
C41	**110-033 0.1 μF± 20% 50 V CERMONO**
C42	**110-033 0.1 μF± 20% 50 V CER MONO**
C43	**110-033 0.1 μF± 20% 50 V CER MONO**
C44	**110-0330.1 μF± 20% 50 V CER MONO**
C45	**110-019 0.05 μF 20% 25 VCER**

C46	NOT USED
C47	NOT USED
C48	NOT USED
C49	NOT USED
C50	NOT USED
C51	NOT USED
C52	110-019 0.05 µF 20% 25 VCER
C53	110-021 0.01 µF 20% 16 VCER
C54	110-033 0.01 µF 20% 50 V CER MONO
C55	110-033 0.01 µF 20% 50 V CER MONO
C56	110-011 0.001 µF 10% 1KV CER
C57	110-034 100PF ±10% 25 V CER
C58	110-019 0.05 µF 20% 25 V CER
C59	122-015 33 µF 10% 35 V TAN
C60	110-034 100 PF ±10% 25 V CER
C61	110-011 0.001 µF 10% 1 KV CER
C62	110-021 0.01 µF 20% 16 V CER
C63	110-019 0.05 µF 20% 25 V CER
C64	110-011 0.001 µF 10% 1KV CER
C65	110-034 100 PF ±10% 25 V CER
C66	110-011 0.001 µF 10% 1KV CER
C67	110-019 0.05 µF 20% 25 V CER
C68	122-013 3.3 µF 10% 15 V TAN
C69	NOT USED
C70	NOT USED
C71	NOT USED
C72	110-021 0.01 µF 20% 16 V CER
C73	110-034 100 PF ± 10% 25 V CER
C74	110-034 100 PF ± 10% 25 V CER
C75	NOT USED
C76	NOT USED
C77	NOT USED
C78	NOT USED
C79	NOT USED
C80	112-016 10PF 5% 500 V MICA
C81	112-003 47 PF 5% 500 V MICA
C82	112-021 5 PF 5% 500 V MICA
C83	112-019 15 PF 5% 500 V MICA

CR1	NOT USED
CR2	NOT USED
CR3	412-009 IN52318
CR4	411-004 IN4152
CR5	412-012 IN5227
CR6	411-004 IN4152

CR7	**411-004 IN4152**
CR8	**NOT USED**
CR9	**NOT USED**
C10	**412-009 IN52318**
C11	**411-003 IN4005**
C12	**411-004 IN4152**
CR13	**411-004 IN4152**
CR14	**411-004 IN4152**
CR15	**411-004 IN4152**
CR16	**411-004 IN4152**
CR17	**412-009 IN52318**
CR18	**413-002 IN4738**
CR19	**411-002 IN270**
CR20	**411-004 IN4152**
CR21	**411-004 IN4152**
CR22	**NOT USED**
CR23	**411-004 IN4152**
CR24	**411-004 IN4152**
CR25	**411-004 IN4152**

DSI	**665-011 MODEL 106LASER(1064NM)**
DSI	**665-010 MODEL 155LASER(1550NM)**
DSI	**665-009 MODEL 130LASER(1310 NM)**

01	**430-027 MP83848**
02	**430-008 2N2905**
03	**430-026 MP83640**
04	**430-056 MM4409**
05	**430-056 MM4409**
06	**430-059 A500**
07	**430-059 A500**
08	**430-056 MM4049**
09	**430-059 A500**
010	**430-060 2N6041**
011	**431-006 SD210**
012	**430-027 MPS3646**
013	**430-027 MPS3646**
014	**431-006 SD210**
015	**430-026 MPS3640**

R1	**223-010 1KX 5 SIP RES NETWORK**
R2	**NOT USED**
R3	**NOT USED**
R4	**NOT USED**
R5	**NOT USED**
R6	**222-059 29.4 K 1% 1/4 W MF**
R7	**222-059 29.4 K 1% 1/4 W MF**
R8	**NOT USED**

R9 213-301 300 OHMS 5% 1/4 W COMP
R10 213-332 33 K 5% 1/4 W COMP
R11 244-035 2 K MULTITURN
R12 NOT USED
R13 NOT USED

R14 NOT USED
R15 NOT USED
R16 NOT USED
R17 222-022 4.99 K 1% 1/4 W MF
R18 222-045 4.22 K 1% 1/4 W MF

R19 244-035 2 K MULTITURN
R20 213-103 10 K 5% 1/4 COMP
R21 213-473 47 K 5% 1/4 COMP
R22 244-036 10 K MULTITURN
R23 NOT USED

R24 213-104 100 K 5% 1/4 W COMP
R25 213-105 1 M 5% 1/4 W COMP
R26 213-102 1 K 5% 1/4 W COMP
R27 213-102 1 K 5% 1/4 W COMP
R28 213-104 100 K 5% 1/4 W COMP

R29 213-274 270 K 5% 1/4 W COMP
R30 213-131 130 OHM 5% 1/4 W COMP
R31 222-071 1 M 1% 1/4 W MF
R32 222-071 1 M 1% 1/4 W MF
R33 213-102 1 K 5% 1/4 W COMP

R34 213-105 1 M 5% 1/4 W COMP
R35 213-105 1 M 5% 1/4 W COMP
R36 213-104 100 K 5% 1/4 W COMP
R37 244-036 10 K MULITURN
R38 213-820 82 OHM 5% 1/4 W COMP

R39 222-071 1 M 1% 1/4 W MF
R40 222-071 1 M 1% 1/4 W MF
R41 213-513 51 K 5% 1/4 W COMP
R42 244-036 10 K MULTITURN
R43 213-512 5.1 K 5% 1/4 W COMP

R44 213-201 200 OHM 5% 1/4 W COMP
R45 213-391 390 OHM 5% 1/4 W COMP
R46 213-512 501 K 5% 1/4 W COMP
R47 213-102 1 K 5% 1/4 W COMP
R48 213-472 4.7 K 5% 1/4 W COMP

R49 NOT USED
R50 222-014 499 OHM 1% 1/4 W MF
R51 222-014 499 OHM 1% 1/4 W MF
R52 213-471 470 OHM 5% 1/4 W COMP
R53 NOT USED

R54 NOT USED
R55 NOT USED
R56 222-026 110 K 1/% 1/4 W MF
R57 222-026 110 K 1/% 1/4 W MF
R58 244-011 1 K MULTITURN

R59 NOT USED
R60 NOT USED
R61 NOT USED
R62 NOT USED
R63 NOT USED
R64 NOT USED

R65 222-026 110 K 1/% 1/4 W MF
R66 222-026 110 K 1/% 1/4 W MF
R67 213-102 1 K 5% 1/4 W COMP
R68 213-102 1 K 5% 1/4 W COMP
R69 222-026 110 K 1/% 1/4 W MF

R70 222-055 102 K 1% 1/4 W MF
R71 222-070 95.3 K 1% 1/4 W MF
R72 222-026 110 K 1/% 1/4 W MF
R73 222-025 110 K 1/% 1/4 W MF
R74 222-026 110 K 1/% 1/4 W MF

R75 214-080 65 OHM 5% 1/8 W COMP
R76 222-051 10K 1% 1/4 W MF
R77 222-043 237 K 1% 1/4 W MF
R78 222-051 10 K 1% 1/4 W MF
R79 213-150 15 OHM 5% 1/4 W COMP

R80 222-017 215 K 1% 1/4 W MF
R81 213-820 82 OHM 5% 1/4 W COMP
R82 213-330 33 OHM 5% 1/4 W COMP
R83 244-032 50 OHM 20-TURN
R84 213-101 100 OHM 5% 1/4 W COMP

R85 222-026 110 K 1/% 1/4 W MF
R86 213-102 1 K 5% 1/4 W COMP
R87 213-301 300 OHM 5% 1/4 W COMP
R88 213-102 1 K 5% 1/4 W COMP
R89 214-501 500 OHM 5% 1/8 W COMP

R90 214-580 68 OHM 5% 1/8 W COMP
R91 214-510 51 OHM 5% 1/8W COMP
R92 214-131 130 OHM 5% 1/8 W COMP
R93 214-391 390 OHM 5% 1/8 W COMP
R94 214-510 51 OHM 5% 1/8 W COMP

R95 222-026 110 K 1/% 1/4 W MF
R96 213-106 10 M 5% 1/4 W COMP
R97 213-102 1 K 5% 1/4 W COMP
R98 214-510 51 OHM 5% 1/8 W COMP
R99 213-102 1 K 5% 1/4 W COMP
R100 213-103 10 K 5% 1/4 W COMP

R101	213-102 1K 5X 1/4 W COMP
R102	213-102 1 K 5% 1/4 W COMP
R103	244-038 5 K MULTI TURN
R104	231-008 2 OHM 1% 10 WWW
R105	222-050 8.66 K 1% 1 /4 W MF
R106	213-103 10 K 5% 1 /4 W COMP
R107	214-510 51 OHM 5% 1 /8 W COMP
R108	214-470 47 OHM 5% 1 /8 W COMP
R109	214-470 47 OHM 5% 1/8 W COMP
R110	213-103 10 K 5% 1 /4 W COMP
R111	214-820 82 OHM 5% 1/8 W COMP
R112	214-220 22 OHM 5% 1/8 W COMP
R 113	214-100 10 OHM 5% 1/8 W COMP
R114	213-105 1 M 5% 1/4 W COMP
R 115	213-103 10 K 5% 1/4 W COMP
R116	222-013 422 OHM 1% 1 /4 WMF
R117	213-511 510 OHM 5% 1 /4 W COMP
R118	213-105 1 M 5% 1 /4 W COMP
R119	214-101 100 OHM 5% 1 /8 W COMP
R120	214-392 3.9 K 5% 1/8 W COMP
R121	214-390 39 OHM 5% 1 /8 W COMP
R122	213-102 1 K 5% 1 /4 W COMP
R123	213-222 22 K 5% 1 /4 W COMP
R124	213-102 1 K 5% 1/ 4 W COMP
R125	222-042 2 K 1% 1/ 4 W MF
R126	222-019 274 K 1% 1/ 4 W MF
R127	213-510 51 OHM 5% 1 /4 W COMP
R128	213-105 1 M 5% 1/ 4 W COMP
R129	213-223 22 K 5% 1 /4 W COMP
R130	213-223 22 K 5% 1 /4 W COMP
R131	213-102 1 K 5% 1 /4 W COMP
R131	214-510 51 OHM 5% 1 /8 W COMP
R133	NOT USED
R134	NOT USED
R135	NOT USED
R136	NOT USED
R137	NOT USED
R138	222-051 10 K 1% 1 /4 W MF
R139	222-051 10 K 1% 1 /4 W MF
R140	222-018 249 K 1% 1 /4 W MF
R141	244-034 200 OHM MULTI TURN

R142	**222-018 249K 1% 1/4 W MF**
R143	**222-018 249 K 1% 1/4 W MF**
R144	**222-039 1 K 1% 1 / 4 W MF**
R145	**222-091 182 K 1% 1/4 W MF**
R146	**213-103 10 K 5% 1 /4 W COMP**
R147	**214-391 390 OHM 5% 1/8 W COMP**
R148	**214-391 390 OHM 5% 1 /8/ W COMP**
R149	**213-510 51 OHM 5% 1 /4 W COMP**
R150	**213-510 51 OHM 5% 1 /4 W COMP**
R151	**213-101 100 OHM5% 1 /4 W COMP**
R152	**213-510 51 OHM 5% 1 /4 W COMP**
R153	**213-102 1 K 5% 1 /4 W COMP**
R154	**213-102 1 K 5% 1 /4 W COMP**
R155	**213-102 1 K 5% 1 /4 W COMP**
R158	**213-102 1 K 5% 1 /4 W COMP**
R157	**213-101 100 CHM 5% 1 /4 W COMP**
R158	**214-131 130 OHM 5% 1/8 W COMP**
R159	**214-820 82 OHM 5% 1 /8 W COMP**
R160	**214-820 82 OHM 15% 1 /8 W COMP**
R161	**214-131 130 OHM 5% 1 /8 W COMP**
R162	**214-580 56 OHM 5% 1 /8 W COMP**
R163	**214-102 1 K 5% 1 /8 W COMP**
R164	**222-080 332 OHM 1% 1 /4 W MF**
R165	**214-820 82 OHM 5% 1/8 W COMP**
R166	**214-131 130 OHM 5% 1 /8 W COMP**
R167	**214-391 390 OHM 5% 1 /8 W COMP**
R168	**214-391 390 OHM 5% 1/8 W COMP**
21	**440-168 LF412**
22	**440-168 LF412**
23	**440-134 1OHD102**
24	**440-200 MC1OH 154P**
25	**440-148 SPO685**
26	**440-168 LF412**
27	**440-168 LF412**
28	**440-168 LF412**
29	**440-161S74HCO4**
210	**440-150SHC00**
211	**440-170 DG201**
212	**440-143 NE528**
213	**440-168 LF412**
214	**440-170 DG201**
215	**440-168 LF412**
216	**440-168 LF412**
217	**440-144 555**
218	**440-165 LF412**

MODULE INTERACE BD 6040-4 649-143

C1	122-016 10UF±10% 15 V TAN	**R1**	**223-010 4.7 KX9 SP RES NETWORK**
C2	122-016 10UF±10% 15 V TAN	**R2**	**223-016 4.7 KX9 SP RES NETWORK**
C3	122-014 33UF±10% 6 V TAN	**R3**	**244-011 1 K PC MT MULTITURN**
C4	122-014 33UF±10% 6 V TAN	**R4**	**244-011 1 KPC MT MULTITURN**
C5	110-033 0.1UF±20% 50 V CER MGNO	**R5**	**244-011 1 KPC MT MULTITURN**
C6	110-033 0.1 UF±20%50V CER MONO	**R6**	**244-011 1 KPC MT MULTITURN**
C7	110-033 0.1 UF±20%50V CER MONO	**R7**	**222-018 240 K 1% 1 /4 W MF**
C8	110-033 0.1 UF±20%50V CER MONO	**R8**	**222-018 249 K 1% 1 /4 W MF**
C9	110-033 0.1 UF±20%50 V CER MONO	**R9**	**222-018 249 K 1% 1 /4 W MF**
C10	110-033 0.1 UF±20%50V CER MONO	**R10**	**222-018 249 K 1% 1 /4 W MF**
C11	110-033 0.1 UF±20%50V CER MONO		
C12	110-033 0.1 UF±20%50V CER MONO	**R11**	**NOT USED**
C13	110-033 0.1 UF±20%50V CER MONO	**R12**	**NOT USED**
		R13	**NOT USED**
C14	110-033 0.1 UF± 20% 50 V CER MONO	**R14**	**NOT USED**
C15	110-033 0.1 UF± 20% 50 V CER MONO	**R15**	**213-431 430 OHM 5% 1 /4 W COMP**
C16	122-014 33 UF ± 10% 6 V TAN	**R16**	**213-103 10 K 5% 1/4 W COMP**
C17	122-014 33 UF ± 10% 6 V TAN		**---------------------------------------**
C18	110-011 0.001 UF±10% 1 KV CER	**21**	**440-212 74HC139**
		22	**440-175 74HC373**
C19	110-011 0.001 UF± 10% 1 KV CER	**23**	**440-210 2764**
C20	110-011 0.001 UF± 10% 1 KV CER	**24**	**440-190 MK48202-20**
C21	110-011 0.1 UF± 20% 50 V CER	**25**	**440-195 P82C55-2**

CR1	412-001 1N821	**26**	**440-213 AD7528**
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Q1	430-026 MPS3540	**28**	**440-168 LF412**
	---------------------------------	**29**	**440-168 LF412**