MEMORY AMMETER CONTROLLER
MAC-20

INSTRUCTION MANUAL

Firmware Version 1.85 and above

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MAC-20 Specifications

INPUT POWER:

120 VAC, SINGLE PHASE
50/60 HZ, 20 VA Max

CURRENT RANGES:

0-1,000 / 5,000 / 25,000 / 100,000 Amperes

CURRENT ACCURACY:

+/- 0.5% Reading + 0.5% Range + 1 Digit (Continuous)
+/- 1.0% Reading + 1.0% Range + 1 Digit (Pulse > 0.01 sec)

TIMER RANGES:

0-9.999 / 0-99.99 / 0-999.9 / 0-9999 Seconds
0-999.9 / 0-9999 Cycles

TIMER ACCURACY:

+/- 0.005 sec +/- 0.005% of reading +/- 1 count

DIMENSIONS AND NET WEIGHT

Height:	7.0 in. (178 mm)
Width:	19.0 in. (483 mm)
Depth:	6.0 in. (152 mm)
Weight:	10 lb. (4.55 kg)

STANDARD ACCESSORIES

Remote Initiate cable	1	S-B143
Contact Leads	1 pair	S-A108

MAC-20 Unit Circuitry

The current measurement function of most breaker test sets is based on the principle of an air core inductor, which may be used to sense a magnetic field, which is proportional to the rate of change of current flowing in an adjacent conductor. The output voltage of the inductor is therefore proportional to the rate of change of current in the conductor. For practical purposes, the sensing inductor is usually made in the form of a split core, or "fork", which fits closely around the current-carrying buswork.

In the measurement system, in this case the MAC-20, the signal from the current sensor (typically about 240 mV for 1000 Amperes), is connected to an integrator, consisting of precision resistors and a capacitor. This signal is processed by a variable-gain instrumentation amplifier, and a digitally programmable gain circuit. An analog to digital converter (ADC), under microprocessor control, reads this signal to a precision of 12 bits (+/- 0.025%). This circuitry is contained on a single PC board, originally developed for the Electrical Test Instruments ORTMASTER system.

The heart of the MAC-20 consists of a microprocessor core unit, based on the Zilog Z180, with associated ROM, RAM, and other circuitry, and manufactured by ZWorld Engineering under the trade name SmartCore. It is connected to a motherboard, which contains a regulated power supply, some support circuitry, and two programmable peripheral interface (PPI) IC's. One PPI is configured as a Centronics parallel interface, and controls the A/D subsystem described above. The other PPI interfaces to the keyboard / display PC board, described below. Software contained in the ROM, (also known as "firmware"), performs the required real-time data collection, measurement, user interface, and output control functions.

The keyboard / display PC board contains virtually all of the hardware for the user interface (LED displays and keyboard), as well as contact sensing and output initiation circuitry. The eight LED digits are multiplexed, and have limited alphanumeric capability for more flexible indication of such conditions as overrange. The keys are scanned at roughly 30 times per second, and incorporate LED's to indicate status. An audible indicator (beeper) sounds when a key is pressed. The contact sensing circuitry uses the key scanning system, with a transformer for isolation. The sensing signal is a repetitive pulse of low voltage and low current, and contact sensing leads may be handled without fear of shock. Two separate optically isolated signals are provided for output initiation with an electromechanical contactor or SCR. All functions of the keyboard / display PC board are handled by a single PPI.

MAC-20 Software

A complete description of the software is beyond the scope of this manual; however, the following brief overview may enhance your understanding of the MAC-20. The SmartCore is based on a Zilog Z180 processor running at 9.216 MHz. Its instructions, written in C and assembly language, are contained in a socketed EPROM, and data is stored in self-contained static RAM. The Z180 contains a programmable reload timer (PRT), which is set to provide an interrupt at a rate of 1200 per second. A watchdog timer provides reset control and protection from software hangup conditions.

Much of the processing takes place in the interrupt service routine (ISR), which is executed 1200 times per second. This ISR reads the A/D converter, processes the data, and determines the presence or absence of current. It also functions as the main timer for pulse time measurement, and determines the repetition rate of other processes. The multiplexing of the LED display, and the scanning of the keyboard, are also handled by the ISR, but at slower rates of 300 times per second or less.

While not servicing the ISR, the software executes an idle loop, which updates information to the display, and performs functions requested by new keystrokes.

MAJOR PARTS IDENTIFICATION AND OPERATION

MAC-20 Control Panel

TIME DISPLAY: This 4 digit LED display normally indicates the elapsed time of a current pulse. In SECONDS mode, it displays time up to 9.999 seconds, then autoranges to 99.99 seconds, 999.9 seconds, and 9999 seconds. In CYCLES mode, it reads time (based on 60 Hz), up to 999.9 cycles, then autoranges to 9999 cycles. If time exceeds maximum display capacity (10,000 seconds or 10,000 cycles), the display will read "OVER". In PRESET mode, the display indicates the maximum time of initiation (ON time), in either cycles or seconds. A reading of zero disables the PRESET function, and allows any time.

CURRENT DISPLAY: This 4 digit LED display indicates the output current. In CONTINUOUS mode, as well as in MEMORY mode before and during a test, the display indicates true-RMS output current in real time. After completion of a test, in MEMORY mode, the display shows the true-RMS value as computed over the entire length of the pulse. This mode is indicated by a flashing LED on the MEMORY key. If a reading exceeds the maximum value for the selected range, the display will read "OVER".

This display is also used to indicate peak RMS and last average current. After a test, when the timebase is in cycles mode, press the STOP key to display the value of the RMS current based on the highest peak reading. This peak value is also used for the trip current reading if the breaker trips before the preset time. This may be higher than the true RMS value of the entire pulse, because of spikes and DC offset, or current dropoff as the breaker trips. When the timebase is in SECONDS mode, press the STOP key to display the last average RMS value displayed in CONTINUOUS mode. This is useful for pickup tests. It may not be accurate for times less than 1 second.

INITIATE key: This key is used to turn ON the output of the test set. The LED in the key indicates that the MAC-20 is attempting to turn the output ON, but other conditions (such as interlocks) could keep the output from actually turning on. In MOMENTARY mode, the key must be held to keep output current on. In MAINTAIN mode, once current is detected, the output will stay on until the breaker trips, or the STOP or RESET button are pressed. The MAC-20 must be RESET in order to initiate output, and in N.C. or N.O. contact modes, the contact status (continuity) must indicate that the breaker is closed. If the output on time exceeded the PRESET time, as indicated by flashing of the PRESET key LED, the INITIATE key will automatically reset the MAC-20 and turn the output on.

STOP key: This key is used to turn the output of the test set OFF. Its LED

indicates that output is not being turned on by the MAC-20, but other conditions could cause output voltage to be ON. Use of this key is usually necessary only when in MAINTAIN mode, and it is necessary to abort the test before the breaker trips. NOTE: It is important to realize that the interlock system of the circuit breaker test set may also turn the output off, but it will turn back ON when the interlock condition is cleared (in N.O. and N.C. modes only).

The STOP key is also used to access peak RMS and last average RMS values. See description of CURRENT DISPLAY for details.

RESET key: This key resets the displays on the MAC-20, and arms the pulse reading system. The LED on the key indicates that the system is reset and armed. RESET also takes the unit out of PRESET ADJUST mode.

PRINT key combination: On models equipped with a printer option, the STOP and RESET keys may be pressed simultaneously to send the time and current readings in ASCII format to a printer or other device, via the serial port.

MAINTAIN key: This key toggles the MAINTAIN mode for initiation; its LED indicates that this mode is enabled. When in MAINTAIN mode, the INITIATE key need only be pressed briefly to turn output on. MAINTAIN must be set in order to read pulse current when output is initiated by means other than the MAC-20.

For test sets with motorized vernier, the MAINTAIN key may be pressed while output is ON to provide automatic current hold. The LED in the MAINTAIN key will blink while this mode is set, and the vernier motor will be activated whenever the current varies more than 5 amperes from the value displayed when the key was pressed. The key may be pressed again to return to normal mode. STOP or RESET will also discontinue current hold.

SIMULATOR key combination: Pressing the LATCH and RESET keys simultaneously toggles the SIMULATOR mode. In this mode, the INITIATE key produces a simulated current pulse of 2.4 cycles, or 0.040 seconds, with an amplitude about ½ full scale. When in SIMULATOR mode, the unit will beep once every three seconds.

N.O. key: This key is used to set the Normally Open contacts mode. In this mode, lack of continuity on the CONTACTS binding posts indicates that the protective device under test is in its normal (non-tripped) mode, and ready to accept current. In N.O. mode, after the INITIATE key is pressed, the timer starts when current (about 3% of range) is detected. The timer stops when the STOP key is pressed or continuity is sensed at the CONTACTS binding posts. Timing accuracy in this mode is typically +/- 0.01 seconds.

N.C. key: This key is used to set the Normally Closed contacts mode. In this

mode, continuity on the CONTACTS binding posts indicates that the protective device under test is in its normal (non-tripped) mode, and ready to accept current. This mode may be used for testing multi-pole breakers by connecting the CONTACTS binding posts to an unused pole. In N.C. mode, the timer starts as soon as current (about 3% of range) is detected after the INITIATE key is pressed, and stops when the STOP key is pressed or a break in continuity is sensed at the CONTACTS binding posts. Timing accuracy in this mode is typically +/- 0.01 seconds.

C.L. key combination: When the N.O. and N.C. keys are pressed simultaneously, both LEDs light, indicating C.L. mode (Current Latch). This is the normal power-up default mode for the test set, and is recommended for all tests, unless there is a good reason for using contacts to sense trip. In this mode, current is continuously sampled, and when it exceeds approximately 10% of the current range value, the timer starts, and calculation of pulse current begins. When current stops (or drops below a dynamically determined threshold value), the timer stops running, and the final value for pulse current is calculated and displayed. If the output was initiated by the MAC-20, it is turned OFF. NOTE: in C.L. mode only, the contacts jacks may be used for remote initiation (see below).

PRESET key: This key toggles the PRESET ADJUST mode, indicated by illumination of its LED. When PRESET ADJUST is active, the adjacent SECONDS and CYCLES keys respectively lower and raise the preset time in seconds or cycles, depending on the timebase that was selected. Both keys may be pressed simultaneously to reset the time limit to zero, which disables the time limit function. When not in PRESET mode, the LED will flash if the displayed time exceeds the preset limit.

SECONDS key: This key normally selects the SECONDS timebase. If the PRESET mode is selected, this key is used to LOWER the preset time limit by decrements of 1.000 second (5.000 seconds above 10.00) with the SECONDS timebase, or 1.0 cycles with the CYCLES timebase. If it is held, the reading will decrease at a rate of about 5 intervals per second. If a preset time limit was set in SECONDS mode, the output will be turned off within 200 milliseconds of the limit. SECONDS or CYCLES timebase may be selected at any time before, during, or after a test.

CYCLES key: This key normally selects the CYCLES timebase. If the PRESET mode is selected, this key is used to RAISE the preset time limit by increments of 1.000 seconds (5.000 seconds above 10.00) with the SECONDS timebase, or 1.0 cycles with the CYCLES timebase. If it is held, the reading will increase at a rate of about 5 intervals per second. If a preset time limit was set in CYCLES mode, the output will be turned off within several milliseconds after the limit

has been reached. SECONDS or CYCLES timebase may be selected at any time before, during, or after a test.

MEMORY key: This key toggles the MEMORY mode, indicated by illumination of its LED. When in CONTINUOUS mode (LED off), the current display always reads the real-time continuous output current of the test set. In MEMORY mode (LED on), the current display will read the continuous output current until the test is complete. At this time, the LED will flash, and the display will read the computed true-RMS value of the entire current pulse for the duration indicated on the TIME display. This key may be pressed at any time before, during, or after the test, to toggle between the two modes.

As described above, pressing the STOP key provides access to display of peak RMS and last average RMS current.

1000 A range key: This key selects the 1000 ampere range, which provides best accuracy of readings up to about 1000 amperes. Nominal currents close to this limit, when applied to the device under test, will sometimes cause higher peak currents, causing the display to read "OVER", indicating an overrange condition. If this happens, select the next higher range. Pressing any range switch will also RESET the MAC-20.

5 KA range key: This key selects the 5.000 KA range, for output currents up to about 5,000 amperes. See above for information common to all ranges.

25 KA range key: This key selects the 25.00 KA range, for output currents up to about 25,000 amperes. See above for information common to all ranges.

100 KA range key: This key selects the 100.0 KA range, for output currents up to about 100,000 amperes. See above for information common to all ranges.

CONTINUITY lamp: This LED lights when continuity is detected at the CONTACTS binding posts in N.O. and N.C. modes. The beeper will also sound whenever contacts change state.

CONTACTS/REMOTE jacks: These jacks provide a low-power AC signal which detects continuity in N.O. and N.C. modes, or is used with a pushbutton cord switch for remote initiate function (see below). A resistance of about 100 ohms or less will be interpreted as continuity. Although the signal is low power and transformer isolated, it is good practice to avoid touching any conductive surface connected to these terminals. CAUTION: NEVER CONNECT THESE TERMINALS TO ANY LIVE CIRCUIT!

REMOTE INITIATE: In C.L. mode only, the CONTACTS jacks provide a remote initiate function. For safety reasons, this function is disabled in MAINTAIN mode,

unless a preset value is set in CYCLES timebase.

SERIAL port: This standard serial port may be connected to a printer, computer, or other device to print or store time and current values of test results in ASCII format. It is set for 9600 baud, 8 bits, 1 stop bit, no parity. This information is sent at the end of each test, or by pressing the Stop and Reset keys.

REMOTE TERMINAL JACK: This RJ-12 modular jack provides a six wire connection to a remote serial terminal, which provides complete monitor and control functions as well as advanced features such as serial number entry and date/time functions. Complete details will be provided with special firmware for this option.

MAC-20 Internal Parts

INPUT CONNECTOR: This connector, located on the upper rear corner of the MAC-20, provides 120 VAC control power, and connects to the air core CT (current sensor), and initiate circuitry of the test set. The wiring of this connector is essentially compatible with that of the EIL Accu-Amp, and is designed to facilitate removal of the MAC-20 for service or shipment. Additional pins are used to provide isolated logic level control for motorized vernier raise and lower for the current hold feature.

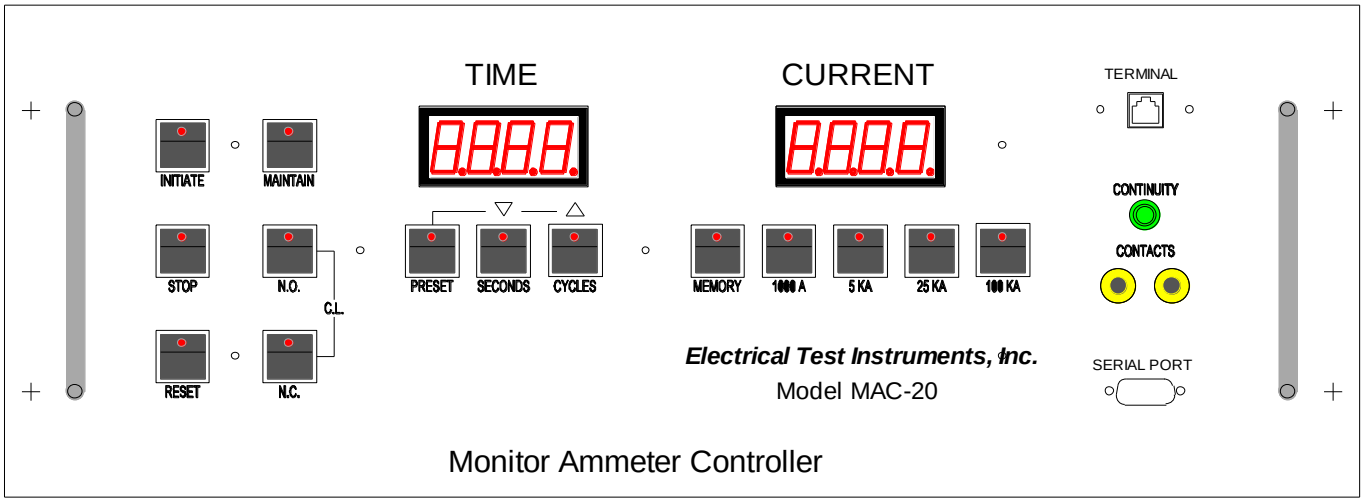
ANALOG INTERFACE PC BOARD: This PC board, located near the input connector, contains all of the MAC-20 analog circuitry. It has two potentiometers for zero offset, and one potentiometer for gain. On older versions, it also provides unregulated 10 VDC for the I/O board

MICROPROCESSOR I/O BOARD: This PC board, located adjacent to the analog interface, contains a regulated power supply and support circuitry for the microprocessor core module, and programmable peripheral interfaces for the analog board and keyboard / display board. It also supplies regulated 5 VDC for the keyboard / display board. Its power supply is derived from a 16 VCT AC source, which is also used for zero crossing detection required for programmable initial phase angle. There are also two serial ports, one of which is used for the remote serial terminal, and the other used for interface to a computer or serial printer.

MICROPROCESSOR CORE MODULE: This small PC board, manufactured by ZWorld Engineering and called the SmartCore, contains a Zilog Z-180 microprocessor, crystal controlled clock, support circuitry, static RAM, and socketed program EPROM. If changes to firmware are required, the EPROM must be replaced. THIS SHOULD BE DONE ONLY BY PERSONNEL EXPERIENCED IN HANDLING STATIC SENSITIVE ELECTRONIC COMPONENTS.

KEYBOARD / DISPLAY BOARD: This large PC board, located on the front panel, contains both LED displays and all keys used in the MAC-20. It also contains an audible beeper, and circuitry for the continuity light, contacts sensing, and output initiation. It connects to the motherboard with a 26 pin ribbon cable and a two conductor power cable.

Figure II-2: MAC-20 Front Panel



SERVICE INFORMATION AND DOCUMENTATION

MAINTENANCE AND CALIBRATION OF THE MAC-20

The MAC-20 is manufactured using solid state components that should not require extensive maintenance. However, the accuracy of the MAC-20 is critical to the testing of circuit breakers, and is dependent upon the output of an air-core current sensing coil, which could change due to movement caused by shock or vibration encountered in transporting the test set. Other factors which may affect calibration are contact resistance in the control cable, unusual magnetic fields, insulation leakage, and aging of electronic components in the MAC-20. Therefore, proper operation and calibration should be checked at regular intervals, and adjusted if proper equipment is available.

The inherently delicate nature of electronic circuitry and metering make it generally inadvisable to leave the MAC-20 fastened into the breaker test set while it is being transported, and subject to shock and vibration. The standard rack-mount hardware and twist-lock connector make it simple to remove the MAC-20 and carry it separately. Suggested periodic maintenance consists of the following:

1. Clean the lenses of the LED displays with a plastic cleaner.
2. Clean the front panel with a soft brush and cloth.
3. Perform basic field operational check as described below.

Field calibration of the MAC-20 may be performed as follows:

1. Obtain a current measuring calibration standard capable of reading TRUE-RMS current up to at least 1000 Amperes to an accuracy of at least 0.25%. This may consist of a shunt or current transformer, in conjunction with a digital multimeter or laboratory grade AC ammeter.
2. Set up the breaker test set for normal breaker testing. If adjustments are anticipated, remove the MAC-20 from the test set and remove the top cover.
3. Connect the calibration standard to the desired output tap. If cables are used, it is recommended that they be twisted so as to minimize radiation and pickup of stray magnetic fields.
4. Apply power to test set, and allow at least one minute for circuits to stabilize.

5. Check ammeter zero in all ranges. If reading on current meter is greater than 1% of range, internal zero adjustment may be required.
6. Set MAC-20 Range to 1000 A, and adjust output of breaker test set to exactly 800 Amperes. If Coarse Tap is 1, and Output Control Vernier is less than 50%, additional resistance must be added to output circuit. This is important, because waveform distortion is more prevalent at lower levels.
7. If the MAC-20 reading differs from the standard by more than rated accuracy, adjust the gain potentiometer on the analog board for proper reading. If an error of more than 5% is noted, and unit has been in service, the accuracy and validity of previous tests may be questionable; otherwise, there may be a problem in the test setup.
8. Check calibration at 200, 400, 600, and 1000 Amperes.
9. Adjust the current to zero, and press RESET key.
10. Raise the current slowly, until the timer begins to run. This is the Current Latch Threshold, which should be about 10% of range.
11. Set the current at 50% of full scale (500 A), and stop the current.
12. Set the MAC-20 to MEMORY mode, and press the RESET Switch.
13. Initiate a fast momentary pulse of no more than 6 cycles (0.1 Sec) duration. The meter should read the same value, within 1% of reading + 1% of range, that was set in step 11 above.
14. Check pulse reading operation in this manner for currents of 200, 400, 600, and 1000 Amperes, and varying duration.
15. Set Timer Timebase to SECONDS. Press Master Reset Switch. Set N.O. mode. Using a stopwatch, initiate for exactly ninety (90) seconds. Timer should read 90.00 Seconds, +/- 0.01 Seconds. (Note: actual reading may vary because of inability to control and measure pulse length.)
16. If everything checks out, the MAC-20 can be assumed to be in calibration, and no other adjustments are required.

PARTS LIST (MAC-20):

The overall schematic is on the following pages. The parts list is provided below. Please refer to both when ordering replacement parts.

ITEM	QTY	DESCRIPTION	REF DES	Part Number
1	1	Connector, Male, 16 pin	J1	M-C134
2	11	Connector Pin, Male	J1	M-A127
3	1	Fuse Holder, Chassis	XF1	M-B177
4	1	Fuse, 2A, 250 V, SloBlo	F1	M-B178
5	1	Transformer, 120 VAC/16VCT	T1	M-C145
6	1	LED lens, Green	XDS1	M-B133
7	2	Banana Jack, Yellow	BP1,2	M-B175
8	1	PC Board, Display/Keypad	PCB1	S-B101
9	1	PC Board, MAC20 I/O	PCB2	S-B102
10	1	PC Board, Analog sign processing	PCB3	S-B103
11	1	Ribbon Cable Ass'y, DB25		S-A102
12	1	Ribbon Cable Ass'y, 26 pin		S-A103
13	1	Serial Interface cable ass'y		S-A106
14	1	RJ12 jack ass'y		S-B116
15	2	Handle, brass, nickel plated, 4"		M-C103
16	2	Display frame, red lens		M-B136
17	14	Push Button LED Indicator Switc		M-B137
18	1	Line Filter		M-C177
19	4	Spacer, 4-40X3/4		M-A122
20	1	MAC-20 Front Panel		M-D105
21	1	MAC-20 Chassis Enclosure		M-D107
22	1	MAC-20 Top Cover		M-D108

OVERALL SCHEMATIC (MAC-20):

WARRANTY

Electrical Test Instruments, LLC, will correct any defect in workmanship or material for two years after date of purchase of any Electrical Test Instruments product. Such corrective measures will be limited to repairing or replacing the unit, at Electrical Test Instruments' option. This limited warranty shall not apply to equipment which has been subjected to negligence, accident or damage by operation, maintenance or storage, or to non-normal use or service. This limited warranty does not cover reimbursements for transportation, removal, installation, repair or replacement, except as may otherwise be specifically agreed to in writing by Electrical Test Instruments. The foregoing is in lieu of all other warranties expressed or implied, and all other obligations or liabilities whether arising under contract, negligence or otherwise, on the part of Electrical Test Instruments. In no event shall Electrical Test Instruments be liable for consequential or special damages, including but not limited to loss of use, loss of income, loss of profit or cost of replacement.