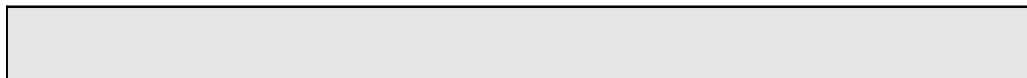


## MAC III 6502 Microcomputer User Manual

MP600/C



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## **Introduction**

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The MAC III 6502 is a complete, working microcomputer system based around the Rockwell 6502 microprocessor.

A keypad/display unit may be connected to provide simple memory edit/display and debug functions, plus direct entry of short programs written in *machine code*.

For more advanced program development work, the MAC III board may be used in conjunction with the Merlin Development System, to allow students to design, develop and download programs written in *assembly language* using a personal computer (PC).

An optional Applications Module may be connected to the MAC III board. This provides a number of devices that may be controlled by programs written by the student.

*Chapter 1* of this User Manual provides a hardware description for each of the main features of the MAC III board.

The MAC III board may be connected in one of two ways: in a Digiac 2000 system, or as part of a Digiac 3000 system. *Chapter 2* and *Chapter 3* explain how to connect the MAC III board and related hardware when using these systems. You should refer to the appropriate chapter for the system you are using.

*Chapter 4* provides an overview of the software features of the MAC III board, while *Chapter 5* details the programming memory map that will be essential when writing programs to run on the MAC III.

Finally, *Appendix 1* explains how to control the Applications Module using the programs provided in EPROM on the MAC III board.

The following teaching manual provides further, detailed instruction on developing applications programs for the MAC III board:

*A Introduction to 6502 Microprocessor Applications*

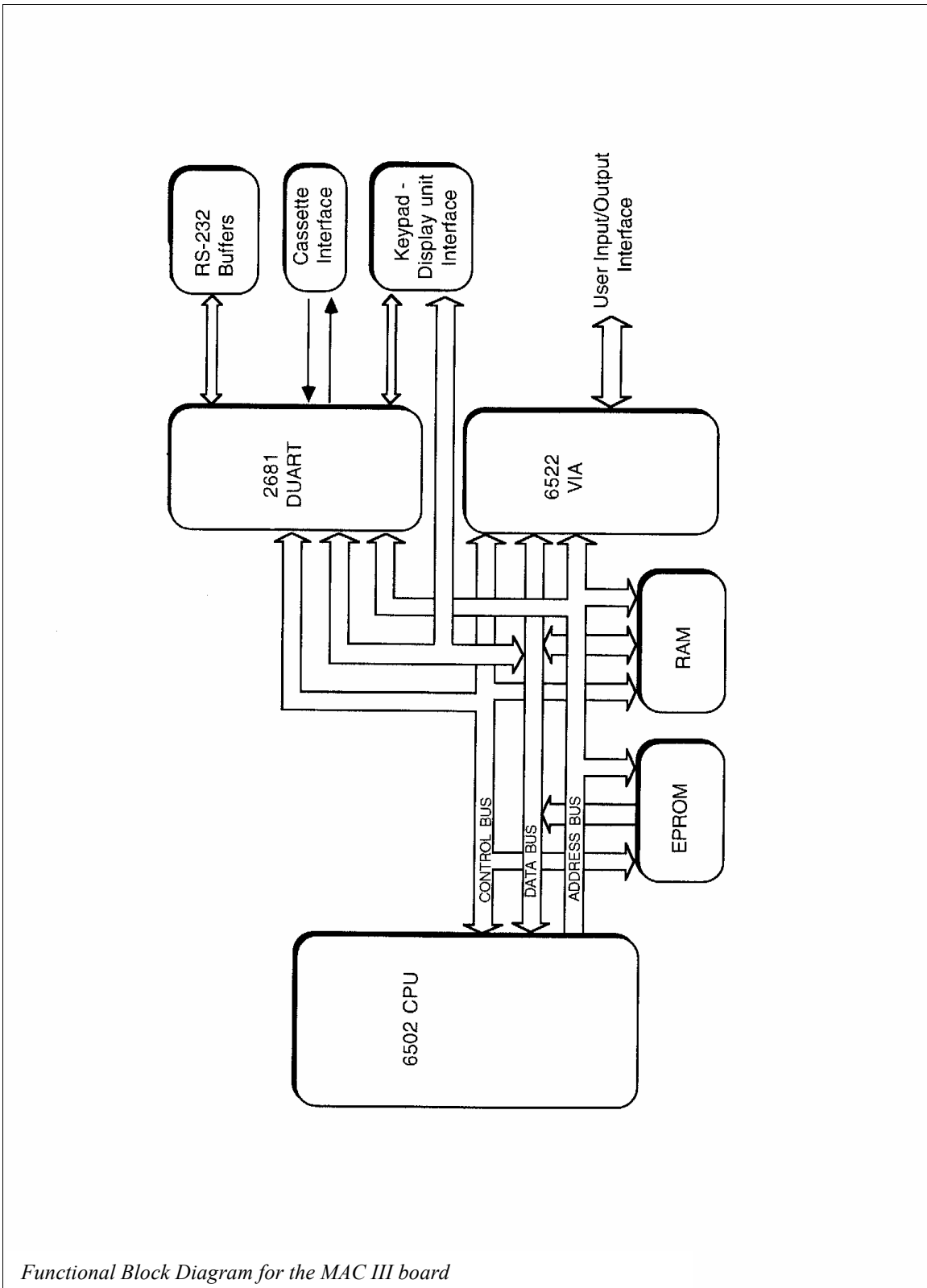


## Chapter 1 Hardware Description

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This chapter provides a hardware description of the main features of the MAC III board. A functional block diagram is shown on the following page.

<b>Microprocessor</b>	The MAC III system uses a Rockwell 6502 microprocessor operating at a clock frequency of 1 MHz.
<b>Monitor EPROM</b>	Memory space for 16 kbytes of EPROM is provided. This can be fitted with a 27128 16k EPROM or a 27256 32k EPROM (in this case only half of the device is used). This EPROM contains the monitor software.
<b>User EPROM</b>	A socket is provided for an 8kbyte 2764 type EPROM which can be used for application programs.
<b>RAM</b>	An 8kbyte 6264 type RAM is fitted to the board. This provides 7kbytes of memory for user programs, the remainder being used for system variables.
<b>User Input/Output</b>	A 6522 VIA provides 16 TTL-compatible user input/output lines for controlling external devices.
<b>Counter/Timer</b>	The 6522 also provides two programmable counter/timer channels.
<b>RS-232 Interface</b>	A 2681 DUART provides two independent RS232 channels for serial communication with other devices.
<b>Switched Faults</b>	Eight on-board fault switches are provided under a lockable cover. These allow faults to be switched into the system for fault-finding exercises.



Functional Block Diagram for the MAC III board



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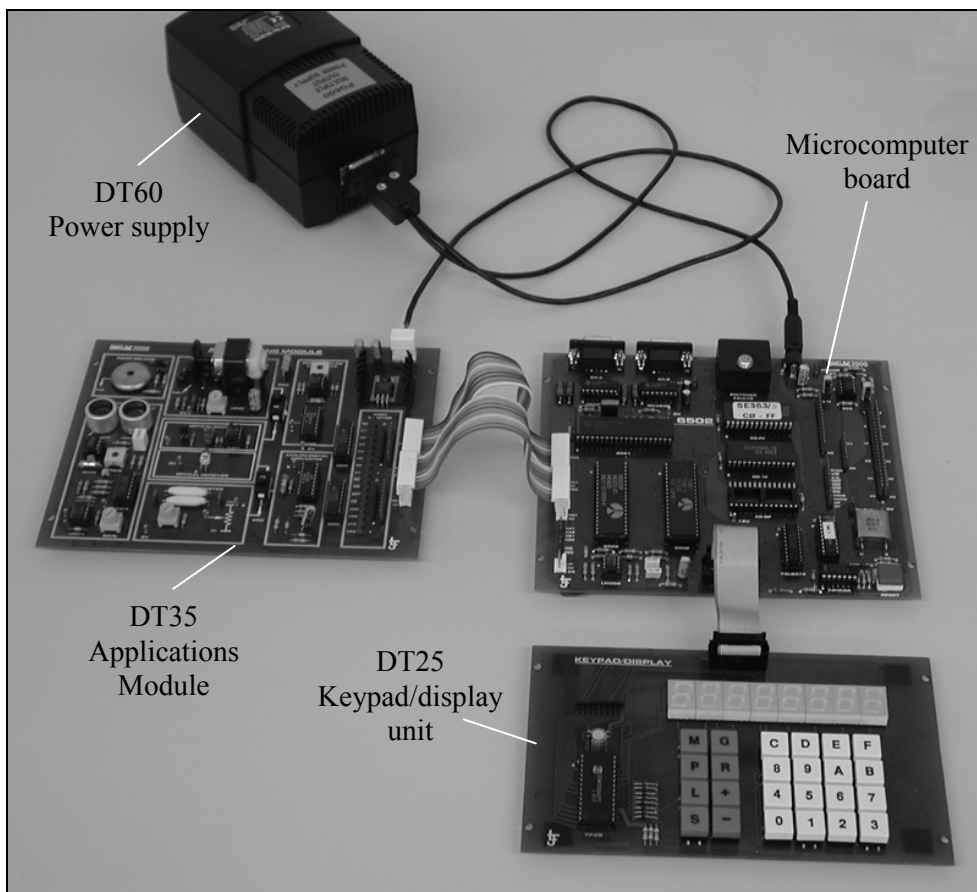
## Chapter 2

### Digiacc 2000 Connections

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When used as part of a **Digiacc 2000** system, the MAC III Microcomputer board is powered from a DT60 Power Supply unit. A DT25 Keypad/display unit may be connected to the MAC III to allow simple display/editing of memory locations and machine code programming, and the optional DT35 Applications Module provides a range of devices that may be controlled by user programs.

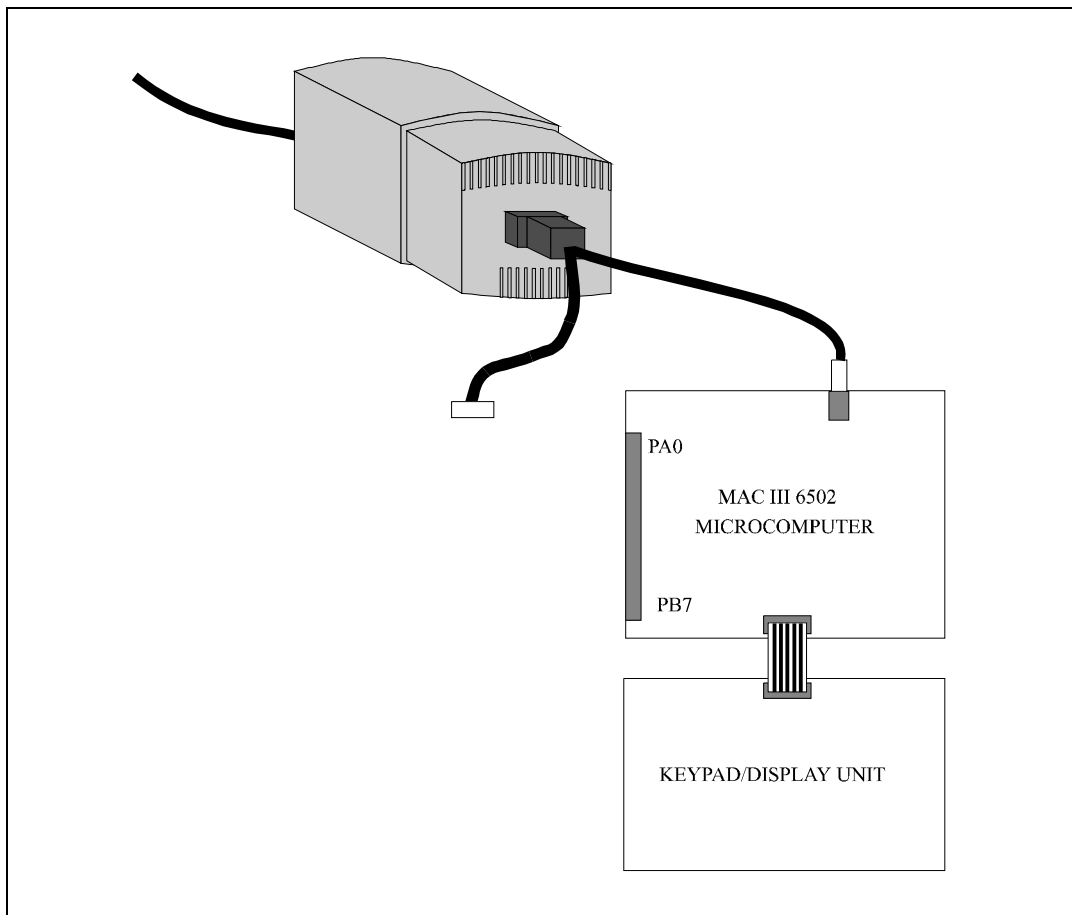
The following picture shows a Digiacc 2000 system:



Full instructions for connecting the MAC III Microcomputer board in a Digiacc 2000 system, are provided on the following page.

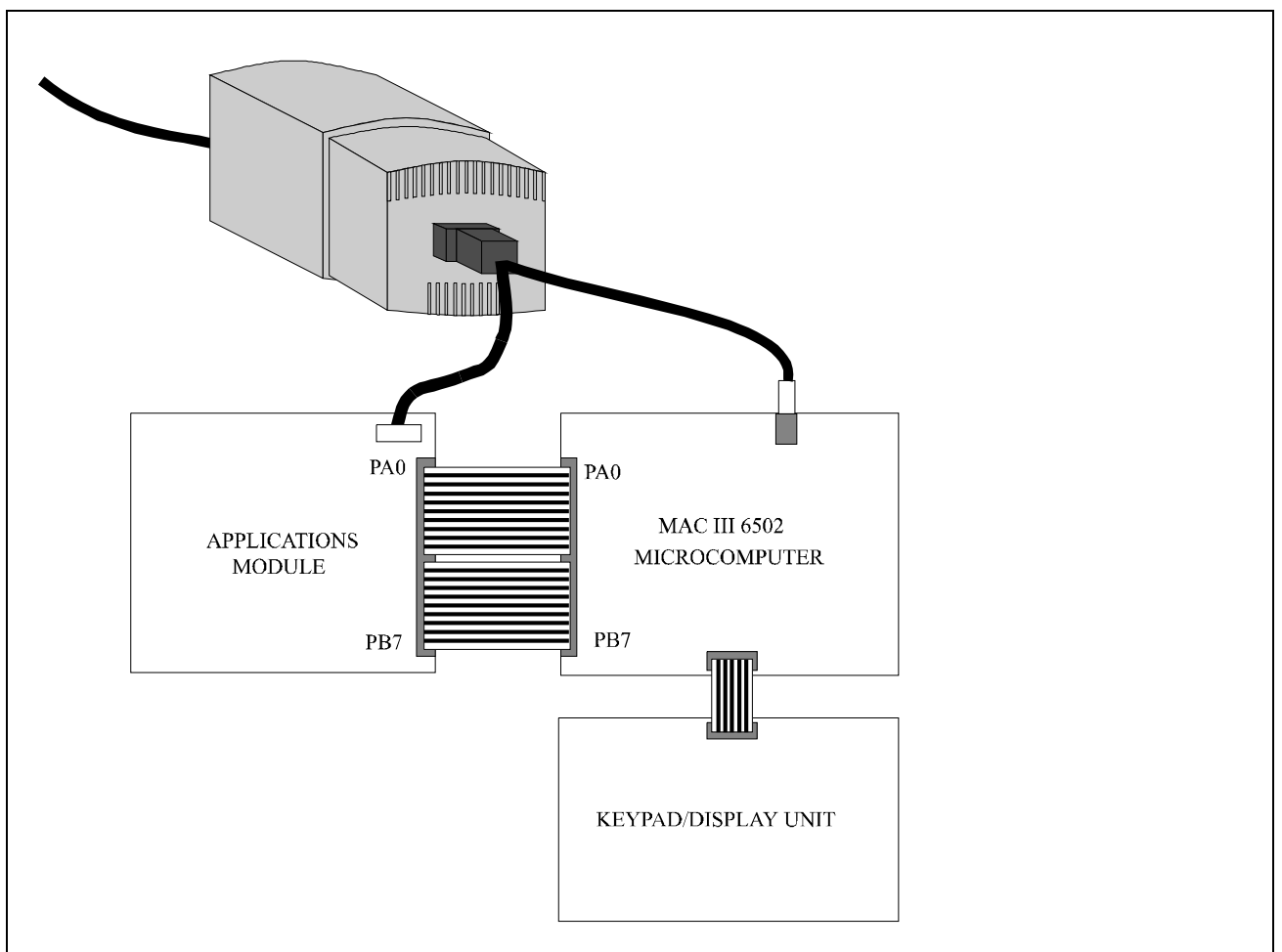
**Connecting Power and Keypad/display to the MAC III board**

- Ensure that the power supply is switched OFF.
- Connect the DT60 Power Supply to the MAC III board as shown below. Note that the power supply cable with the ‘barrel’ connector is used for this purpose.
- Connect the Keypad/display Unit to the MAC III Microcomputer Board as shown in the diagram.



### Connecting the Applications Module

- Ensure that the DT60 Power Supply unit is switched OFF (the power switch is located at the rear of the unit).
- Connect the DT60 Power Supply to the Applications Module as shown below. Note that the power supply cable with the 5-way connector is used for this purpose.
- Connect the Applications Module to the MAC III Microcomputer Board using the two 9-way ribbon cables provided.



### **Connecting the MAC III board to a student workstation computer**

- If you are using the Merlin Development System software, then you will need to connect the MAC III board to your student workstation computer using the RS232 cable provided with the software.

*For further information, please refer to the 'Getting Started' manual provided with the Merlin Development System.*

### **Switching on power to the MAC III board**

- To apply power to the MAC III board (and to the Applications Module, if connected), switch ON the power switch located at the rear of the DT60 Power Supply unit.

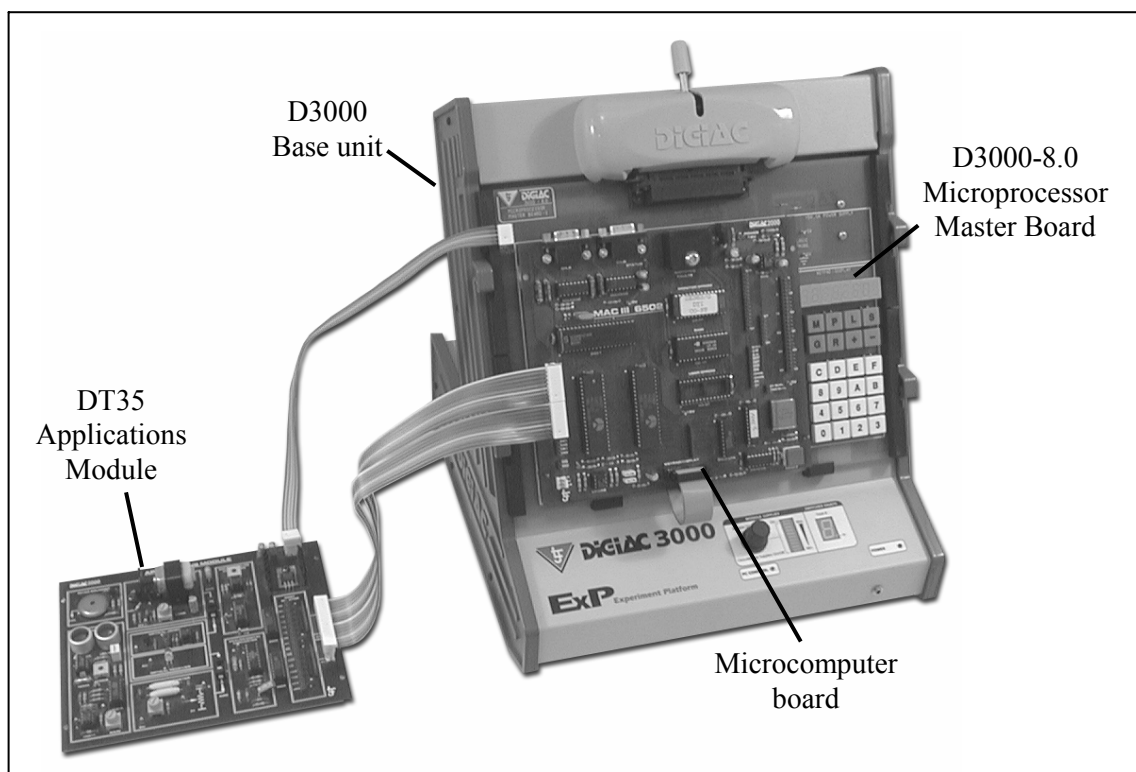
## Chapter 3

### DigiAc 3000 Connections

When used as part of a **DigiAc 3000** system, the MAC III Microcomputer board is fitted onto a D3000-8.0 Microprocessor Master Board, which is in turn mounted on one of the following DigiAc 3000 base unit options:

- D3000 Experiment Platform (EXP)
- D3000 Virtual Instrument Platform (VIP)

The following picture shows a DigiAc 3000 system based on a D3000 Experiment Platform:



Full instructions for connecting the MAC III Microcomputer board in a DigiAc 3000 system, are provided on the following page.

### **Connecting Power and Keypad/display to the MAC III board**

- Ensure that the base unit Module Power Supplies switch is in the OFF position.

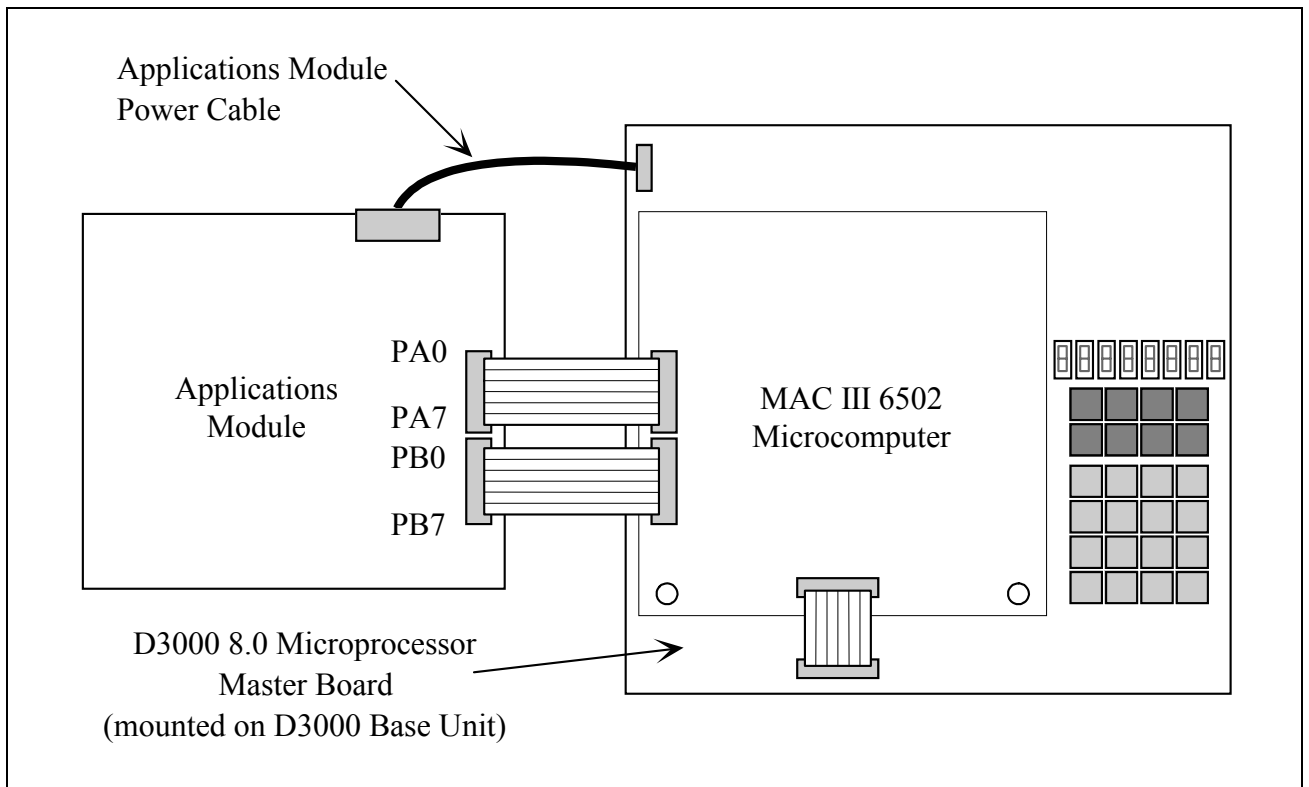
If your base unit is the D3000 Experiment Platform type, you will find this switch on the base unit front panel. If you are using a D3000 Virtual Instrument Platform, then the switch is activated from the screen of your PC.

*Further information on the Module Power Supplies switch can be found in your base unit user manual.*

- Mount the Microprocessor Master Board onto the base unit, and lock it securely in position using the locking mechanism provided.
- Unfold the ribbon cable on the Microprocessor Master Board, so that the connector hangs over the front edge of the base unit.
- Locate the two holes, in the bottom left and bottom right corners of the MAC III board, over the two brass pins mounted near the bottom edge of the Microprocessor Master Board. The top part of the MAC III board should rest on the plastic support pillars.
- Connect the Microprocessor Master Board to the MAC III Microcomputer Board using the ribbon cable that is hanging over the front of the base unit.

### **Connecting the Applications Module**

- Connect the Applications Module to the MAC III Microcomputer Board using the two 9-way ribbon cables provided.
- Connect the Applications Module Power cable from the Microprocessor Master Board to the Applications Module, as shown in the diagram opposite.



### **Connecting the MAC III board to a student workstation computer**

- If you are using the Merlin Development System software, then you will need to connect the MAC III board to your student workstation computer using the RS232 cable provided with the software.

*For further information, please refer to the 'Getting Started' manual provided with the Merlin Development System.*

### **Switching on power to the MAC III board**

- To apply power to the MAC III board (and to the Applications Module, if connected), switch ON the base unit Module Power Supplies switch.

*Further information on the Module Power Supplies switch can be found in your base unit user manual.*





## Chapter 4

### Monitor Functions

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The MAC III Microcomputer is supplied complete with a comprehensive monitor program. As well as initializing the system for operation, reading the keypad and driving the display, the monitor program provides a range of functions for the user.

The monitor program can operate in either of the following modes:

- **Keypad Mode**
- **Terminal Mode**

In **Keypad Mode**, the user interacts with the monitor program using the 24 keys of the Keypad/display unit.

*For information on how to connect the MAC III board to the Keypad/display, please refer to Chapter 2 or Chapter 3 of this manual.*

If the MAC III board is used in conjunction with the Merlin Development System, the monitor program can also operate in **Terminal Mode**. In this mode a personal computer (PC) is connected to the MAC III board using an RS232 connecting lead. Any commands entered at the PC keyboard are transmitted to the MAC III board, while the PC screen displays any characters that are output from the MAC III. In effect, Terminal mode allows the keyboard and screen of the PC to become the input and display devices of the MAC III board.

*The 'Getting Started' manual provided with the Merlin Development System provides further information on:*

- *Connecting the MAC III board to a PC*
- *Installing the Merlin Development System*
- *How to enter Terminal mode*

The following pages provide further information on **Keypad Mode** and **Terminal Mode**, including the most commonly used functions. The available options for resetting the MAC III monitor program are described at the end of the chapter.

## **Keypad Mode**

When you switch on power in Keypad Mode, the MAC III monitor program will display the following message on the keypad/display unit:



This message indicates that the MAC III monitor program is ready to receive commands via the keypad.

The main functions available to the user when the MAC III is being used in Keypad Mode, are outlined below:

### **Memory display and edit**

This facility allows the user to examine the contents of memory and to edit the contents of locations in RAM for the entry of machine code programs.

On the first press of the **M** key a 4-digit (16-bit) memory address is displayed. This address can be altered using the 16 hexadecimal keys. Pressing the **M** key a second time displays the data at this address and allows it to be edited using the hex keys once again (the contents of the memory location are updated as each digit key is pressed). Repeated presses of the **M** key toggle between these two functions.

When in memory display/edit mode, the **+** and **-** keys may be used to step up and down through memory. An auto-repeat facility on the keys of the keypad allows the user to scroll through memory using the **+** or **-** key. The longer the key is held down, the faster the display scrolls.

### **Input/output port display and edit**

This facility allows the user to examine and edit input/output ports, such as the 6522 ports. For example, the user can initialize and write to or read from the User port using the keypad.

Pressing the **P** key allows a 4-digit port address to be entered using the hexadecimal keys. Pressing the **P** key a second time displays the data at this port address and allows it to be edited. Due to the 'write-only' nature of some port registers, data is only written to the port after the full 8-bit (2-hex digit) number has been entered.

When in this mode, the **+** and **-** keys may be used to step up and down through input/output space. An auto-repeat facility on the keys of the keypad allows the user to scroll through the port registers using the **+** or **-** key. The longer the key is held down, the faster the display scrolls.

### **Program run facility**

User programs can be executed by pressing the **G** key and entering a 4-digit start address. Pressing the **G** key again causes execution to start from this address.

### Register display/edit facility

To make it easier to debug programs, a copy of the 6502 registers may be viewed at any time.

Press the **R** key **once**. The display will show 'r.' followed by the register name (in this case 'PC' for 'Program Counter'), followed by the contents of the register. To modify the contents, simply press the appropriate hexadecimal keys.

To display and modify the other registers, use the + and – keys to step through the list.

### Program single step facility

User programs can be single stepped one instruction at a time. After each step, the contents of memory or the registers can be examined and modified if required.

To single step through a user program, press the **G** key and enter a 4-digit start address. Then press the + key to single step through the instruction at the specified address.

After the instruction has been executed, the display will show the program counter address (i.e. the address of the next instruction to be executed), together with an **S** to indicate single stepping.

Continue pressing the + key to execute further instructions. The register and memory contents can be examined and modified at any time using the **R** and **M** commands described previously. Having used either of these commands, press the **G** key followed by the + key to continue single stepping.

### Breakpoint facility

The breakpoint facility allows up to 8 separate breakpoints to be inserted into a program. When a breakpoint is encountered during program execution, the program is halted and the internal registers of the CPU can be examined and modified if required. The breakpoint can then be removed and program execution continued, or alternatively single stepping can start from this point.

Note that:

- Breakpoints can only be inserted into programs running in RAM.
- A breakpoint must be inserted at the address of the start of an instruction, that is at the op code field and not the operand or data fields.

To insert or remove breakpoints in a program, or just to examine the addresses of those currently set, press the **R** key **twice**. The display will show 'b.1' (the first entry in the breakpoint table), followed by the address of the breakpoint. The other seven breakpoints can be examined by stepping through the table using the + and – keys.

To set a breakpoint, just enter the required address using the hexadecimal keys. Breakpoints can be set in any order, although it is recommended that breakpoints are inserted into the table in ascending order, starting with breakpoint b1.

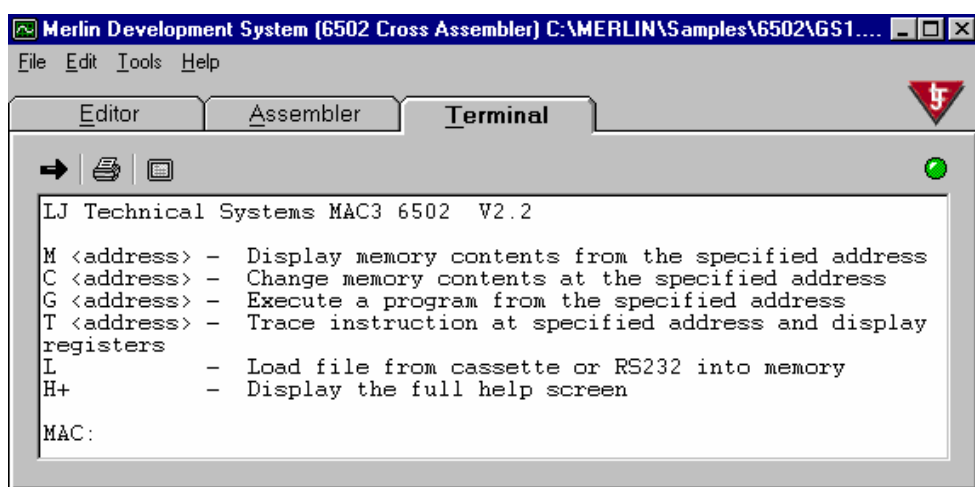
To remove a breakpoint, enter the address **0000** into the table at the appropriate point. Note that the same breakpoint table is used in both Keypad/display Mode and Terminal Mode.

### Switch to Terminal Mode

If RS232 Channel A of the MAC III is connected to a PC, the user can re-enter Terminal Mode from Keypad Mode at any time by pressing the RESET button on the MAC III board. The contents of memory and registers are not affected.

## Terminal Mode

When you switch on power in Terminal Mode, the MAC III monitor program will display the following message in the Terminal window on the PC screen:



The message contains a short list of basic MAC III commands, followed by the MAC: prompt. The prompt indicates that the MAC III monitor program is ready to receive commands via the PC keyboard.

The main functions available to the user when the MAC III is being used in Terminal Mode, are outlined below.

### Memory and Input/Output Port display

The 'm' command is used to display the contents of memory and input/output ports. For example, entering the following command:

**m 400 [Return]**

will cause 80 bytes of memory to be displayed starting from hexadecimal address 0400 (the leading zero of '0400' does not need to be entered). Note that the memory contents are displayed in both hexadecimal and ASCII form.

Pressing the [Return] key again displays the next 80 bytes of memory (this is the 'repeat last command' facility).

To display a specific number of bytes, add a semicolon followed by the number of bytes to be displayed:

**m 400;20** [Return]

In the above example, the number of bytes displayed will be 20 hex (or 32 in decimal).

### **Memory and Input/Output Port edit**

To enter data directly into a memory location or input/output port, use the 'c' (change) command, followed by the 4-digit address of the first memory location (or input/output port) into which data is to be entered.

For example, to change the byte of data at memory address 0400 hex, enter the command:

**c 400** [Return]

The MAC III displays the address and current contents of the memory location, and allows you to enter the new contents. Entering a one or two digit hexadecimal number, then pressing the [Return] key, replaces the contents of the location with the entered value. You will then be moved forward to the next location.

Pressing [Return], without entering anything, moves you forward to the next location without changing the contents of the current location.

Pressing [Esc] aborts editing mode and returns you to the MAC III: prompt. Note that all characters typed on the current line will be ignored if the [Esc] key is pressed; to ensure the line is entered correctly, press the [Return] key first.

### **Program run facility**

To execute a program from a specified address, use the 'g' command. For example:

**g 400** [Return]

begins program execution from hexadecimal address 0400.

**Register display facility**

To make it easier to debug programs, a copy of the 6502 registers may be viewed at any time, by entering the command:

**r** [Return]

- On the left side of the resulting display, the names of the 6502 registers (A, X, Y, PC, SP, SR) are shown, together with the contents of each register. Note that the Status Register (SR) is displayed in both hexadecimal form and as a series of flags between brackets (if a flag is clear, the '-' character is shown; if it is set, the character representing the flag is displayed, e.g. 'Z' indicates zero flag set).
- The right side of the display shows the machine code instruction at the Program Counter (PC) address, plus the disassembled version of that instruction.

Using the 'r' command with a register name allows the contents of any register to be changed. For example:

**r a 55** [Return]                Sets register A (the accumulator) to the hexadecimal value 55.

**Program single step (trace) facility**

User programs can be single stepped, or 'traced', one instruction at a time, by using the 't' command. After each step, the contents of the internal registers are displayed and may be edited before executing the next instruction. For example, the command:

**t 400** [Return]

will execute the instruction at hexadecimal address 0400, then display the status of the internal registers. The next instruction can then be traced by pressing the [Return] key again ('repeat last command' facility).

### **Breakpoint facility**

The 'b' command allows up to 8 separate breakpoints to be inserted into a program. When a breakpoint is encountered during program execution, the program is halted and the internal registers of the CPU are displayed. The breakpoint can then be removed and program execution continued, or alternatively tracing can start from this point.

Note that:

- Breakpoints can only be inserted into programs running in RAM.
- A breakpoint must be inserted at the address of the start of an instruction, that is at the op code field and not the operand or data fields.

The command:

**b 405** [Return]

will insert a breakpoint at hexadecimal address 0405.

When you insert a breakpoint, the monitor program adds the address to the table of breakpoints. To view the table, type 'b' without an address. The addresses of all previously inserted breakpoints will be displayed.

To remove a previously inserted breakpoint, use the 'k' (kill) command followed by the address of the breakpoint.

To remove the breakpoint inserted in the previous example type:

**k 405** [Return]

To remove all breakpoints that have been set, type:

**k \*** [Return]

Note that the same breakpoint table is used in both Keypad/display Mode and Terminal Mode.

**Disassembly**

Disassembly involves reading machine code instructions held in memory, and displaying them in assembly language format. The 'd' command performs this function. For example, the command:

**d 400** [Return]

will disassemble the first few instructions of the program starting at address 4400 hex. To disassemble the next few instructions, simply hit [Return] again ('repeat last command' function).

A semicolon may be used to identify the number of instructions to be disassembled; for example:

**d 4400;8** [Return]

will disassemble the first eight instructions only.

**Switch to Keypad Mode**

If a keypad is connected, the user can switch to Keypad Mode at any time by using the command:

**p** [Return]

The contents of memory and registers are not affected.

**The Help command**

To display a short list of the basic MAC III commands, use the command:

**h** [Return]

For a full list of commands and additional help information, type:

**h+** [Return]



## Reset Options

You may encounter certain situations where the MAC III monitor program does not respond in either Keypad mode or Terminal mode.

This could happen if, for example:

- You execute a program that performs a ‘continuous loop’.
- You execute a program that accidentally corrupts the system variables - that is, variables that are held in RAM and used by the MAC III monitor program.

In such situations you need to be able to **reset** the MAC III monitor program. There are three types of reset:

- Cold Start Reset
- Warm Start Reset
- Monitor Restart

Starting the MAC III by switching on the power supply is called a **cold start**. A cold start sets all system variables to their start-up values, and **clears the contents of RAM**.

You can also reset the MAC III by pressing the RESET button **once** on the MAC III board. This will not destroy any programs or variables that are set up in memory, and is termed a **warm start**.

If your program crashes, it is possible that system variables stored in RAM may have been corrupted. If you suspect that this has happened, or if the machine appears to be working incorrectly, then you can perform a **monitor restart** as described below:

- Press and release the RESET button on the MAC III board.
- Within approximately half a second, while the red STATUS LED is still illuminated, press and release the RESET button a second time.

A monitor restart will set variables to their start-up values but will **not** clear the contents of RAM.

If you are unsure of which type of reset to use, then:

- Try a **warm start** first and see if the MAC III monitor program responds.
- If it does not, try a **monitor restart**.
- If all else fails, switch off the power supply, wait ten seconds, then switch it on again. A **cold start** will be performed. But remember that any user program stored in RAM will be lost!

## Further Information...

This chapter has provided a brief overview of the most commonly used functions in Keypad Mode and Terminal Mode. Information has also been provided on the available Reset options. Further guidance on these topics, with practical examples, can be found in the following teaching manual:

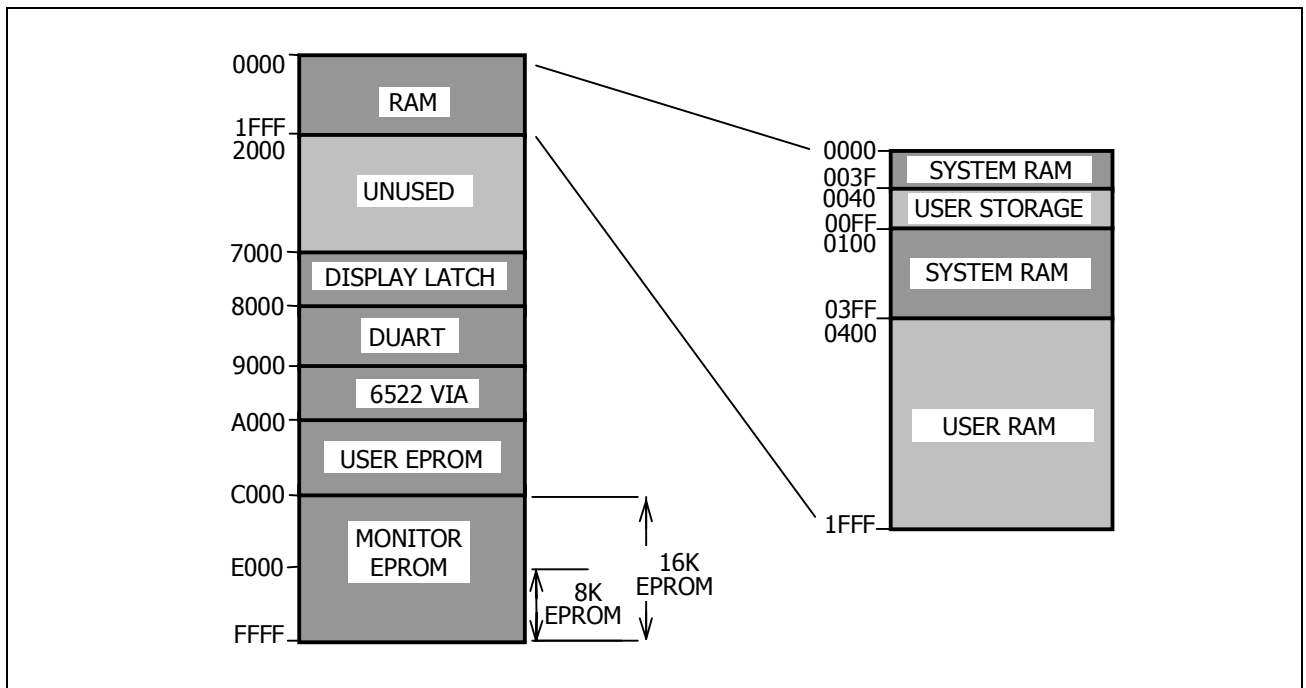
*An Introduction to 6502 Microprocessor Applications*



## Chapter 5 Memory Map

Before a program can be entered into a microcomputer system, it is necessary to know which areas of RAM are available. A **memory map** shows memory usage in a diagrammatic form.

The memory map for the MAC III is shown below:



All of the addresses shown in the memory map are in hexadecimal, allowing each address to be represented by a 4 digit number.

The MAC III Memory Map shows, for example, that the monitor EPROM has an address range from C000 to FFFF and that the MAC III RAM occupies addresses from 0000 to 1FFF.

Note that the area of RAM has been expanded in the diagram to show that:

- addresses 0040 to 00FF are available for user zero page storage.
- addresses 0400 to 1FFF are available for user programs.
- other addresses below 0400 are used by the system.

Further information can be found in the following teaching manual:

*An Introduction to 6502 Microprocessor Applications*

## Appendix 1

### Applications Module Programs

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#### Introduction

Programs have been written for the MAC III Microcomputer, to demonstrate each area of the DT35 Applications Module. These programs are provided in the MAC III monitor EPROM.

The programs are accessed from a menu that can be scrolled through using the Keypad/display unit. This Appendix describes how to select and run each program.

Throughout these notes the two switches on the Applications Board are referred to as follows:

- The upper switch, which directs the output of the Digital to Analog Converter to either the motor or the optical sender, is referred to as the **DAC switch**.
- The lower switch, which is used to select either the optical receiver or the potentiometer as the input to the Analog to Digital Converter, is referred to as the **ADC switch**.

#### Running the software

First connect the MAC III, Keypad/display, Applications Module and power supply as described in *Chapter 2* or *Chapter 3* of this manual.

To run the software, proceed as follows from the READY condition:

- Press **G** followed by **F 6 0 0**, the start address of the program.
- Press **G** again to run the program - the message APPLICATIONS SELECT will move across the display followed by AnLoG - this is the mnemonic for 'analog', the first of the demonstration programs.
- Pressing the **+** and **-** keys will display the mnemonics for the remaining demonstration programs - a brief description of each is given below together with the operating instructions.
- To run a program, select the mnemonic using the **+** and **-** keys, then press the **G** key.
- To halt the program, press the **G** key again (in some cases it may be necessary to hold it down for a short period). This will then allow further selections to be made.

### **AnLoG (analog to digital conversion)**

This program continually reads the potentiometer output via the ADC and displays the hexadecimal value.

Set the **ADC switch** DOWN to connect the potentiometer to the analog to digital converter.

With AnLoG selected press **G** - a 2-digit hex number will be displayed. Adjust the POTENTIOMETER control over its full range and note that the hex display varies from 00 to FF.

### **LInK (link)**

Reads the ADC input and writes this data out to the DAC acting as a 'wire link'. The data is displayed in hex and the Port A LEDs give a binary display of the byte sent to the DAC. For example, the potentiometer can be used to control the brightness of the optical sender.

Set the DAC and ADC switches DOWN.

With **LInK** selected, press **G** - a 2-digit hex number will be displayed. Adjust the POTENTIOMETER control over its full range and note that the hex display varies from 00 to FF, that the Port A LEDs count from 00 to FF and that the optical sender brightness varies in sympathy.

### **ProX (proximity detector)**

Uses the ultra-sonic transmitter and receiver as a proximity detector. The piezo sounder is used as an alarm and the display changes when an object is detected. The sensitivity of the detector is set by the GAIN control.

Initially set the GAIN control fully counter clockwise.

With **ProX** selected, press **G** .

Adjust the GAIN control clockwise until the alarm sounds and then turn it counter clockwise until the alarm is just switched off. An object placed directly above the ultra-sonic devices will be detected up to a distance of approximately 20 cm.

### **dISt (distance measurement)**

Measures the distance of an object above the board using the ultra-sonic transmitter and receiver. The distance in centimeters is calculated by measuring the time delay between the transmission of an ultrasonic pulse and its reflection being received. The "gain" control should initially be set fully **counter-clockwise**.

The ultra-sonic devices are optimized to work at 40 kHz. The **FREQ** control is adjusted to this value on test and should not be adjusted during normal operation.

With **dISt** selected, press .

Turn the gain control clockwise from the fully counter-clockwise position until the display shows '000', then turn the control slowly counter-clockwise until '---' is once again displayed. The display will now show the height of an object above the board (in centimeters).

### **Motor (closed-loop speed control)**

Uses closed-loop control to run the motor at a constant speed of 100 revs per second. The motor **LOAD** control can be used to vary the motor load and the program will compensate to maintain the set speed. The LEDs on Port A give a binary indication of the data being sent to the DAC which will vary as the load on the motor is increased or decreased. The motor speed is shown on the 7-segment displays in revolutions per second.

Set the DAC switch to the UP position.

With **Motor** selected, press . The motor will run and settle to a speed of 100 rps.

Vary the **LOAD** control - initially the motor speed will increase or decrease but you will then see the output to the DAC, on Port A, vary to maintain the speed of 100 rps.

Hold down the  key to stop the motor.

The motor speed is stored in RAM location 0040 and this is loaded with 64 hex (100) when the software is first run. Therefore the set speed can be changed by editing this location but, if you try this, note the following:

- If too low a speed is selected (<0A hex) the motor will not run at all.
- If too high a speed is selected the DAC will not be able to compensate for full loading because the maximum output voltage will be reached.

### **rPS (motor revolutions per second)**

Allows the motor speed to be controlled by the potentiometer and displays the current speed in revolutions per second.

Set the DAC switch to the UP position and the ADC switch DOWN.

Initially set the POTENTIOMETER fully counter clockwise.

With **rPS** selected, press **G**. The display will show 000 and the motor will not move. Gradually turn the potentiometer clockwise and the motor will rotate with the speed set by the potentiometer position.

Note that because of the time taken to read the slotted disk the speed cannot be updated more than twice a second, therefore, if the control is turned quickly the speed will increase in steps. Also note that if the motor is physically stopped, the message STALLED will be displayed and control will return to the program selection routine. The exception to this is if the potentiometer is set to minimum so that the motor is intentionally stopped.

Because of the loading and inertia of the motor, it may not reliably start with a hexadecimal output less than 60 hex. For this reason the STALLED message will only be displayed if the motor is stationary and the hexadecimal output is greater than 63.

Hold down the **G** key to stop the motor.

### **bEAm (Broken beam detector)**

In this exercise the optical sender is switched on fully, via the DAC, and the output of the optical receiver is read into MAC III via the ADC. This value (representing the light level) is displayed and compared with an arbitrary level of 15 hex. If the received level falls below this threshold, (for example, if a piece of paper is introduced between the sender and receiver) the piezo sounder generates an alarm signal.

Set the DAC switch to the DOWN position and the ADC switch UP.

With **bEAm** selected, press **G**. The display will show the current received light level in hexadecimal. Introduce a piece of paper between the sender and receiver and note that alarm sounds and that the displayed light level decreases.

The alarm threshold is set to 15 hex and is stored in RAM location 0041. This may be changed by the user to allow for varying ambient light levels. For example, if the ambient level is high, the receiver may detect levels above the threshold even with the sender blocked off. In this case the threshold level should be raised.



### **OPtIC ( optical feedback)**

This program uses the optical sender and receiver and regulates the light level at the receiver to a preset level. It is analogous to the motor closed-loop speed control routine.

With **OPtIC** selected, press G . The display will show the current received light level in hexadecimal - this will gradually increase to 15 (the preset level to be maintained).

If the sender and receiver are covered so that the light level falls below the preset intensity, then the brightness of the sender is increased to compensate.

Similarly, if a light source is brought near to raise the ambient level, then the brightness of the sender is decreased.

The received light level is displayed at all times as a hexadecimal number.

The preset intensity is stored in RAM location 0042 and is initially set to 15 hex. This value may be changed by the user to suit ambient light levels.



## DECLARATION OF CONFORMITY



**Manufacturer's name  
and address:** LJ Technical Systems Limited  
Francis Way  
Bowthorpe Industrial Estate  
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United Kingdom

*declares that the product*

**Product name:** DT1 and D3000 8.1

**Model number:** TA350

*conforms to the following Product Specifications:*

**EMC:** Electromagnetic Compatibility Directive  
(89/336/EEC) under UK Statutory  
Instrument (SI) 1992 No. 2372, regulation 8,  
Educational electronic equipment as  
amended by SI 1994 No. 3080.

### **Supplementary Information:**

The use of this apparatus outside the classroom, laboratory, study area or similar such place invalidates conformity with the protection requirements of the Electromagnetic Compatibility Directive (89/336/EEC) and could lead to prosecution.

A handwritten signature in black ink that reads 'T. D. Whiting'. The signature is written in a cursive style with a horizontal line underneath the name.

T. D. Whiting, Works Director.

September 22, 2005

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