System/360 model 85 microdiagnostics

by NEIL BARTOW and ROBERT MCGUIRE

*International Business Machines Corporation*
Kingston, New York

INTRODUCTION

System/360 Model 85 is a large central processing unit, (CPU), which contains a machine cycle of 80 nanoseconds and a main storage access of 1.2 microseconds. It has the capability of executing 12,500,000 add register to register type instructions per second. Its major parts are the Instruction Preparation Unit, (I Unit), Instruction Execution Unit, (E Unit), and Storage Control Unit, (SCU). In addition to these three main parts, there is also another portion of the hardware dedicated to maintenance controls. The IBM Model 85 computer has high speed buffer storage and hardware capable of initiating and executing Instruction Retry. There are two major control storage elements. Read Only Storage, (ROS), and Writeable Control Storage, (WCS). ROS consists of 2,048 decimal control words while WCS consists of 512 control words for a standard Model 85 or 1024 control words for a Model 85 with an emulator feature. Each control word is 128 bits long and consists of 33 control fields as illustrated in Figure 1—Model 85 Control Word. Approximately 450 microorders have been implemented in the Model 85 for use in microprogramming.

DEFINITIONS

Microprogram—a computer based program whose microinstruction set is geared to one or more logical hardware functions which are executable in 'one machine cycle.' Two or more microinstructions are normally required for the execution of one instruction of the standard instruction set.

Microdiagnostic—a microprogram designed specifically to test a predefined portion of hardware.

*Microdiagnostic Example*

Figure 2—Microdiagnostic Test (STAT 'A')—is an illustration of a microdiagnostic test. The test uses the

Control Automated System, (CAS), output for its descriptive representation. Each block of the test, of which there are four, represents one machine cycle. The purpose of the test is to confirm that the hardware required to set a latch called STAT 'A' is working properly. If it is not, to stop at control storage address A02.

Cycle 1 is defined by the control word located at control storage address A12 (Hex). This control word will reset a latch called STAT 'A' and fetch the control
word located in control storage address A0C to the control registers. Cycle 2 is defined by this control word at control storage address A0C. This control word will set the latch called STAT 'A' and cause the control word at control storage address B21 to be fetched to the control register. Cycle 3 is defined by the control word at address B21 which will set the 12th bit of the next address field to 1 making the next address A03 if a latch called STAT 'A' is in the set state. Or, the 12th bit of the next address field will remain 0 if the latch called STAT 'A' is in the reset state. Assuming STAT 'A' is reset the control word at control storage address A02 will be fetched to the control register. Cycle 4 is defined by the control word A02 and will set the 8th bit of the next address field to 1 if the Latch call STAT 'C' is in the set state making the next address A12. Or, the 8th bit of the next address field will remain 0 if the latch called STAT 'C' is in the reset state causing the next address to be A02.

STAT 'C' can be set or reset by a toggle switch labeled 'Loop Test' on the maintenance console. Since diagnostics are run with the loop test switch in the off position this test will stop at address A02 if STAT 'A' fails to set and the test can be looped simply by setting of the loop test switch.

**MICROPROGRAMMING USAGE**

*Base machine functions*

The System/360 Model 85's basic machine functions are defined by control words contained in Read Only Storage. They consist of control words for machine instruction execution and sequencing of manual control functions which are initiated from the maintenance console. Other functions include control words for the retry of failing instructions, interrupt sequencing and provisions for handling of invalid instruction operation (op) codes.

**Loading of WCS**

*Load WCS routine*

WCS loading for microdiagnostics is handled from a routine in ROS and is designed to load 512 control words from main storage into WCS. This routine can be executed from one of two entry points—either by using the address contained in the double word starting with main storage address 8 or by establishing a value in one of the internal working registers and bypassing that part of the routine which fetches main storage address 8.

*LMP instruction*

WCS loading for purposes other than microdiagnostics is normally handled by the Load Microprogram Instruction. This instruction is a privileged member of the System/360 instruction set. It is capable of loading one to four control words into WCS from main storage. The control words are indexed by the operand field of the instruction.

**Emulators**

The IBM 7090/7094 Emulator is a prime application for System/360 Model 85 microprogramming. When emulators are installed on the machine it is necessary to modify the instruction preparation unit in order to handle the additional operation codes required for emulator instruction. WCS must be expanded to two times its basic size, that is, 1,024 decimal control words, and must be loaded with the control words which are required for the execution of each emulator instruction.

**Multiply Algorithm**

The low speed multiply algorithm contained in WCS is an alternate way of executing the multiply instruction when the high speed multiply feature is installed on the machine. The high speed multiply feature requires its own dedicated circuitry in the E unit. The low speed multiply algorithm is used when there is a failure or malfunction in the high speed multiply hardware. The low speed multiply algorithm is activated by setting of a system mode latch which is done normally via the Diagnose instruction.

**Hybrid diagnostics**

Hybrid diagnostics are another form of microprogram usage with the System/360 Model 85 as shown in...
Figure 3—Hybrid Diagnostics. The first set of instructions (SET UP) is conventional System/360 code which is used for all initialization required prior to executing the test.

The next step is the Load Micro Program, (LMP), instruction which loads the test control words into Writable Control Storage. The Diagnose instruction indicated by DIAG is a privileged instruction of the System/360 instruction set. It is used to branch from System/360 code into WCS and turn control over to those control words which have just been loaded via the LMP instruction. These control words, illustrated by the CAS diagram in Figure 3 are executed in sequence. At the end of the sequence, a pseudo machine check takes control from WCS and returns the program to the normal System/360 mode at the point indicated by RETURN FROM WCS. Conventional code is then used for an analysis of test results. This is one way of writing the hybrid diagnostic test.

The control words used for this test could just as well have been used for the test setup or they could have been used to analyze test results, with conventional code used for the other two parts of the diagnostic.

### Microdiagnostics

Microdiagnostics are microprograms specifically designed to test a given hardware function. Their main purpose is to detect basic machine malfunctions and to isolate the failing components. There are three parts to microdiagnostics:

- **First**, the resident diagnostics which are located in ROS
- **Second**, the non-resident diagnostics which are found in WCS.
- **Third**, the loader which is used to bring non-resident diagnostics into main storage. The loader is also executed from WCS.

### Resident microdiagnostics

Resident microdiagnostics are used to test all the data paths and microorders needed to execute the **Initial Program Load**, (IPL), and the **Load WCS** routine.

### Non-resident microdiagnostics

Non-resident microdiagnostics are used to test the remainder of the basic machine functions. They start testing the E unit and progress to the I unit and then the SCU. At the end of execution of these diagnostics, control is turned over to the the diagnostic monitor and conventional System/360 diagnostics are executed. Non-resident microdiagnostics can be loaded into WCS from card, tape or disk I/O devices.

There are approximately 30 sections of non-resident microdiagnostics. Each section contains a maximum of 512 control words.

### Microdiagnostic Loader

The microdiagnostic loader is part of the first non-resident microdiagnostic program found on the diagnostic I/O device. It is used to load into main storage the non-resident microdiagnostic programs during the execution of the entire microdiagnostic package. The
The loading sequence is illustrated in Figure 4—Load Sequence Flowchart.

The flowchart shows microdiagnostics are initiated with the depression of the Load Microdiagnostic Pushbutton (LMD), found on the maintenance console at Reference 1. The depression of this pushbutton causes a system reset and control to be given to the resident microdiagnostics in ROS. Resident microdiagnostics are then executed at Reference 2. If the resident microdiagnostics are successful, a modified Initial Program Load, (IPL), will cause the first non-resident microdiagnostic program to be loaded into main storage from the I/O device at Reference 3. This microdiagnostic contains the first microdiagnostic and the microdiagnostic loader. At the end of the modified IPL, the first non-resident microdiagnostic is loaded into WCS by the 'LOAD WCS ROUTINE' in ROS at Reference 4. This diagnostic is then executed at Reference 5. If it is successful, control is given to the 'LOAD WCS ROUTINE' and the loader is brought into WCS, overlaying the first microdiagnostic at Reference 7. The loader is then executed at Reference 8. This causes the second non-resident microdiagnostic to be brought into main storage from the I/O device. The loader then gives control to the 'LOAD WCS ROUTINE', Reference 4, which will load the second non-resident microdiagnostic into WCS. This microdiagnostic is then executed at Reference 5 and if it is not the last microdiagnostic, Reference 6, it will give control to the 'LOAD WCS ROUTINE' again, and bring the loader into WCS at Reference 7. If it is the last non-resident microdiagnostic at Reference 6 it will start the I unit and give control to the conventional System/360 diagnostics at Reference 9.

Using this loading technique, resident microdiagnostics, non-resident microdiagnostics and conventional System/360 diagnostics can be executed in sequence without manual intervention simply by depressing the Load Microdiagnostic pushbutton.

It should be noted that the time in which all of the non-resident microdiagnostics are executed is approximately 20 seconds. It should also be noted that conventional System/360 diagnostics which follow the non-resident microdiagnostics are by no means redundant tests. The conventional diagnostics provide functional tests which have not been attempted in the non-resident and resident microdiagnostics. In addition to this, they provide systems tests and tests of channel and control unit hardware, again, not attempted in the microdiagnostics.

ADVANTAGES OF MICRODIAGNOSTICS

Start small philosophy

Of prime importance in microdiagnostics is a philosophy called "START SMALL". The "START SMALL" philosophy is a building block approach to diagnostics which uses an assumption of a solid hardware failure. The object is to establish a known portion of the hardware to be operating properly so that it may be used to check additional hardware whose condition is unknown. Using this technique it is only necessary to compare one test result against one result generated by tested hardware.
**Initial hardware required**

The “START SMALL” philosophy as implemented under conventional diagnostics, requires that a large part of the storage control unit and I unit and a significant portion of the E unit be working before an instruction of the System/360 set can be executed. In comparison, the hardware required for resident microdiagnostics to be executed is only a small portion of the E unit. This is why a “START SMALL” philosophy as implemented with microdiagnostics is considerably more effective than the technique implemented with conventional diagnostics.

**Load path**

The second advantage of microdiagnostics is the ability to check out the load path from the I/O channel to WCS. This path, shown in Figure 5—Load Path Data Flow—is from the channel to the channel data register and into main storage. Data is moved from main storage through the F register into the E unit operation register, then to the B register to the shifter and WCS. Conventional diagnostics require that the data path from the channel to main storage be working before data can be loaded into memory prior to execution. In the case of microdiagnostics, the residents have the ability to check the data path from the I/O device all the way to WCS prior to executing and I/O operation. This procedure insures that the path is operational and that non-resident microdiagnostics can be loaded successfully. In addition to checking the load path, the resident microdiagnostics have the ability to disable the I unit and the high speed storage buffer in the SCU. This procedure avoids certain portions of the circuitry which would be used during a normal IPL sequence. As a result, the possibility of errors occurring from that circuitry not essential to load data from an I/O device into WCS is reduced.

**Increased isolation**

Microdiagnostics provide for increased isolation in the I unit, E Unit and SCU by taking advantage of the fine control which they can exert on the CPU hardware.
In order to eliminate the necessity of using untested hardware only the simplest of registers are used for CE communications. In conjunction with this technique, the Model 85 has implemented a cross reference list (CRL), as shown in Figure 6—Microdiagnostic Cross Reference List—that uses a register, Reference 1, and a control word address Reference 2. This information is displayed on the maintenance console to direct the Customer Engineer, (CE), to a list of two to ten Field Replaceable Units, (FRU), for any one error point, Reference 3. In addition, the cross reference lists include logic pages for hardware being tested, Reference 4, as well as a flow diagram page number of the test at Reference 5.

**Tight scoping loop**

Scoping loops are program loops used by Customer Engineers to scope failure areas in a machine. The Customer Engineer has the option of implementing a scoping loop in the event the cross reference list does not indicate the correct Field Replaceable Unit (FRU). These loops are considerably shorter on the System/360 Model 85 microdiagnostics than in conventional diagnostics. The upper portion of Figure 7—Tight Scope Loop—indicates 15 machine cycles for a scoping loop in conventional diagnostics as opposed to four machine cycles required for a loop in microdiagnostics found in the lower portion of Figure 7. The total fifteen cycles for conventional diagnostics is highly conservative since the instructions chosen to illustrate the loop are short and require few machine cycles. The microdiagnostic loop, however, is quite typical of those tests implemented in System/360 Model 85. The maximum number of machine cycles that would be found in the microdiagnostic loop is in the order of ten. In the case of conventional diagnostics, the maximum number of machine cycles could be in the hundreds.

**Manual controls**

Special microorders implemented in the System/360 Model 85 have made manual control over the microdiagnostics very effective. All tests implement a branch of a maintenance control switch which loops a diagnostic test to provide a scoping loop for the Customer