THE ISAAC NEWTON GROUP OF TELESCOPES

CAMAC TESTING PROCEDURES

A GUIDE ON HOW TO MANUALLY TEST
CAMAC MODULES

REV 2.0

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TABLE OF CONTENTS

LIST OF FIGURES

DOCUMENT HISTORY

Revision 1.0 - First released - June 2010   E. J. MILLS

Revision 2.0 – May 2014   E. J. MILLS

Added the procedure for testing the ED012 Clock Generator module

OVERVIEW

CAMAC (**C**omputer **A**utomated **M**easurement **A**nd **C**ontrol) is a control/data acquisition system based on CRATES and MODULES which was originally developed in the 1960's for the nuclear research industry (CERNE). It conforms to a standard both in mechanical and electronic specifications.

CAMAC is used to interface the various mechanisms of the telescope to and from the **TCS** (**T**elescope **C**ontrol **S**ystem). The abbreviation TCS is used in a generic sense and refers to both the hardware and software which performs this function. Under normal use, commands to CAMAC are sent or received via a **DEC ALPHA** computer running VMS and performs various tasks such as reading the telescope's position encoders, sending the demanded velocity rate, moving the dome, adjusting the focus, *etc.*

A CAMAC system always consists of a SYSTEM CRATE and normally one or more BRANCH crates. The CAMAC BUS consists of 24 read/write lines which are used to pass data between the TCS and the outside world. The bus also carries lines for module number decoding, module sub-addressing, function codes, control signals and interrupt handling. In CAMAC terminology, these interrupts are known as LAM's (Look At Me). The bus is extended out to the other crates in the system referred to as branch crates using a high density twisted pair DATAWAY cable.

Although commands are sent or read by a computer in normal use, it is possible to run a CAMAC system manually and it is for this **non-standard mode** of operation why this document has been written. It enables many different types of modules to be tested (and likewise repaired) without the need of a computer.

Throughout this document, I will use the standard convention of nomenclature for CAMAC commands. The only difference being that these will now be generated by setting up switch patterns on a test controller rather than being sent by a computer.

According to CAMAC convention, the **BCNAF** protocol is:

B	Branch number	1 to 7	System crate is always B0 C0
C	Crate number	1 to 7	Determined by a switch on the Crate Controller
N	Module slot number	1 to 23	Slots 24/25 reserved for Crate Controller
A	Module sub-address	0 to 15	Input- Output, A or B channels, *etc.*
F	Function	0 to 31	Read, write, test or set LAM, *etc.*

LAYOUT OF RACK FOR CAMAC TESTING AND REPAIRS

The image below shows the test rack used for CAMAC module testing which is located in an office on the first floor of the INT (first door on the left after entering the floor from the east stairwell).

This rack has been left in a state to be usable at any time. It is powered from the mains sockets behind on the wall, but these are switched off when the equipment is not in use. Two crates are used:
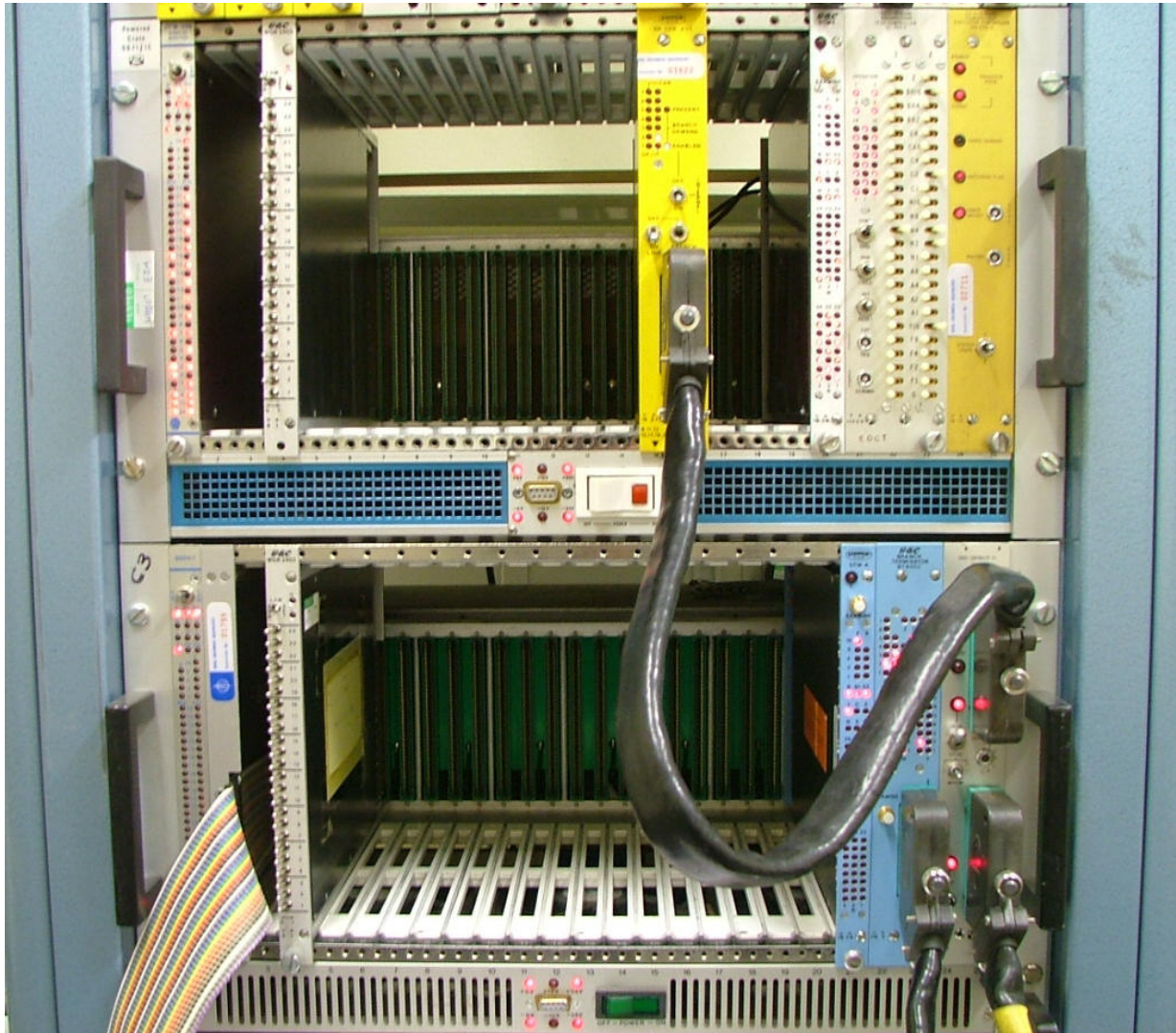
Figure 1 Test crates

THE SYSTEM CRATE

The upper crate is the SYSTEM crate which contains a standard EXECUTIVE CONTROLLER type (MX-CTR-3) and a manual test controller (SC-TST-1). It should be noted that a link cable (with 4 pin LEMO connectors) must be present between the executive controller OUT and test controller IN rear LEMO sockets. This is called the Arbitration Bus and if missing or broken the test system will not work.

A BRANCH COUPLER (BR CPR 4-1) is fitted into slots 15/16. This allows modules in the lower branch crate to be tested when either (or both) of the switches labelled as BR16 on the test controller are toggled to the right.

THE BRANCH CRATE

The lower crate is a BRANCH crate. Although a single system crate can be used to test most of the modules in use at the ING, using a two crate system has the advantage that the more complex modules such as crate controllers, branch couplers and branch terminators can also be checked out if suspect.

The branch crate is fitted with a standard CRATE CONTROLLER which always occupies slots 24/25. It should be noted there are several models of crate controllers in use at the ING. Some are of the earlier CC-A1 types and others are the more recent CC-A2 models. There are also variations between different manufactures (GEC, FISHER, etc). For example, some have C and Z push buttons for performing a crate re-initialisation whilst others use a centre biased C/Z toggle switch. However, they all perform the same function and are interchangeable.

The number of the BRANCH is determined by in which slots the BRANCH COUPLER module in the SYSTEM crate is placed. In the WHT, the branch coupler in the system crate occupies slots 19/20. This when under computer control determines the branch (and the three crates daisy chained from it) to be on B6.

In the test rack, the branch coupler occupies slots 15/16 which would equate to B4 (as used on the INT system). I have used this branch number to simplify the use of the SC-TST-1 test controller in that only toggling the switch B16 will enable read/write operations via the branch crate.

As this test setup is only a two crate system, the branch crate is fitted with a BRANCH TERMINATOR (BT 6502) and mounted as always beside the crate controller and occupying slots 22/23.

The branch crate address is determined by a rotary switch on the crate controller. There are 7 positions thus a maximum of seven crates can be supported on a branch. In the WHT, three branch crates are used C1, C2 and C2 and all are on B6. Each crate controller is therefore setup up accordingly.

On the test branch crate, this can be set to any number between 1 and 7, but normally I have left this to be C2. Changing this number is required to test the functionality of branch couplers and crate controllers. However, whatever branch crate number is selected, the same value <u>must be enabled</u> on the TEST CONTROLLER (TST-1) for data transfers to or from the branch crate.

E.g. The branch and crate selection switches on the TST-1 would be set as thus:

 Read from System crate and write to the Branch crate:
- Operation 1 - left hand column BR and C switches set to '0'
- Operation 2 - right hand column BR and C switches - BR16 and C2 set to '1'

Read from Branch crate and write to the System crate:
- Operation 1 - left hand column BR and C switches - BR16 and C2 set to '1'
- Operation 2 - right hand column BR and C switches set to '0'

Perform read or write operations only within the Branch crate:
- Operation 1 - left hand column switches - BR16 and C2 set to '1'
- Operation 2 - right hand column switches - BR16 and C2 set to '1'

From the above, it can be seen in the case of performing read or write operations only using the **System crate**, the BR and C switches on the TST-1 would be:

- Operation 1 - left hand column BR and C switches - set to '0'
- Operation 2 - right hand column BR and C switches – set to '0'
-

Note – *Switches set to the left = 0 Switches toggled to the right = 1*

CRATE INTER-CONNECTIONS

Connections between the branch coupler in the system crate and the branch crate controller are made using a standard CAMAC DATAWAY cable which comes fitted with Hughes 132 pin connectors. A shorter cable of the same specification connects the crate controller to the branch terminator. The cable connectors are fitted with a polarising sleeve over the fastening screw which ensures the connector can only be fitted in one orientation.

VERY IMPORTANT: *Always take great care when removing or inserting these cables. If the connector is not perfectly aligned with the socket on the module, it is very easy to bend or break a male pin or worst still, damage a female socket. The individual sockets are very difficult to replace and there is __now only one__ extraction tool for Hughes connectors that still works on site!*

Experience has shown it is best to partially insert the connector then carefully 'wiggle' the plug to ensure it will seat squarely before tightening down the screw. The screw only needs to be finger tight.

MODULES GENERALLY LEFT IN TEST CRATES

Both the system and branch crates contain a DTM4 (dataway monitor) and a WGR2403 (24 bit Word generator). These can also be found in the CAMAC systems on all ING telescopes and are left there for test purposes if needed.

The WGR2403 consists of 24 toggle switches (left= 0 - right=1) for generating bit patterns on the bus. There is also a switch at the top for setting the LAM.

The DTM4 displays via LED's, 24 bit read and write operations on the bus. There are also LED's which display the status of the A (module sub address) and F (function) lines. Other signals such as the S1, S2 and Busy lines and the Z and C lines (Initialise and Clear commands) and the X and Q responses are also displayed.

This is a useful module in that data can be also written to it (using A0 F16) which is good for showing if there are any bits stuck (or which refuse to clear) on the bus.

In the branch crate (although in what slot it is located is unimportant) is a FREQUENCY GENERATOR module. This was built *in-house* many years ago (1986) by Nuria, a student who I still remember. This module was made to provide standard frequencies for test purposes that are used by the TCS. Some of these signals are now obsolete, but I recently changed what was the 50Hz output to 20Hz. This is the timing signal used on all telescopes to strobe (clock) the incremental encoder up-down 32 bit counters and would normally come from the Time Service and referenced to UTC. Other useful signals still used and available from this module are the 1MHz square wave and the 1 pulse (of 20mS) per second.

These signals are needed when testing CAMAC modules such as the ED012 pulse generator and the LP34 millisecond generator.

BASIC SETTINGS FOR THE SC-TST-1 TEST CONTROLLER

The SC-TST-1 contains two rows of switches for Operation 1 and 2 (see Fig 2) allowing module address, sub address and functions to be set up or modules in branch crates to be checked. The test module can work in 3 modes determined by a 3 position toggle switch:

1. Up - Continuous (clocking at 1MHz)
2. Down - Slow speed (clocking at 10Hz)
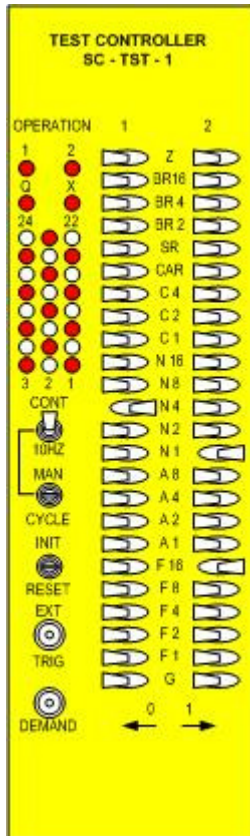3. Centre - Single step operation using the MAN CYCLE switch

Figure 2 SC-TST-1 Test Controller

Normally the continuous mode (CONT switch up as shown) is used. This clocks the CAMAC system at its normal 1MHz rate.

The setup as shown is used to test the read and write bits in the SYSTEM crate. The DTM4 monitor display should be in slot N1 and the WGR2403 word generator in slot N4. As we will be reading from the word generator as the first operation and writing the configuration of the WGR2403 switches to the DTM4 (second operation) and no branch crate used, the TST-1 switches as shown are correct. The BCNAF order would be:

Operation 1 - Read WGR2403 switches in slot N4

B0 C0 N4 A0 F0

Operation 2 - Write result to DTM4 in slot N1

B0 C0 N1 A0 F16

The LED's on both the READ and WRITE displays should show the state of the switches as set on the word generator. *e.g.*:

- Set all bits high   1111111111111111111111111
- Clear all bits low   00000000000000000000000
- Alternate bits   10101010101010101010110 (as shown in image)
- Reverse bits   01010101010101010101101

WGR2403 WORD GENERATOR AND DTM4 DATAWAY MONITOR TESTING

The above test is also useful for checking the correct operation of the WGR2403 and DTM4 modules.

The switches on the word generator can suffer with dirty contacts which may cause bits to fail. LED buffer chips on a DTM4 (or the LED's themselves) rarely fail, but it's not unknown.

A more likely problem with missing or intermittent bits are the gold plated edge connectors which can tarnish or dirty contacts within an edge connector socket mounted on the back plane within the crate.

Simply cleaning the module contacts with a solvent cleaner usually cures these problems. In the case of the internal edge connectors, spray the solvent into the contacts then using a module which is missing the bottom locking screw (there are plenty!) push it in and out several times to ensure the cleaner has worked its way into the contacts.

If there are still problems with either a WGR2403 or a DTM4, these are easy to repair, but these modules are generally very reliable.

IMPORTANT: *These test modules must be in full working order before carrying out tests for suspected faults on either a Branch Coupler or Crate Controller module.*

For this reason it is best to test these modules in the SYSTEM crate. If for some reason bits are missing or stuck when sent across a branch, it's more likely to be a fault with a crate controller or branch coupler rather than with the WGR2403 or DTM4 test modules.

TESTING BRANCH COUPLERS (BC) AND CRATE CONTROLLERS (CC)

The usual method of checking these modules would be to perform a read or write instruction from the system crate to the branch crate and then reverse the procedure. A failure to read or write data over a branch could be due to either module. Experience has shown it is generally the CC which fails, but on rare occasions the BC was faulty.

Figure 3 Branch coupler

BRANCH COUPLER (BC)

In the test system crate this module occupies slots 15/16 and is selected by setting a BR16 switch on the TST-1 to '1'. Ensure both crates are powered up and the branch crate is on-line. The 3 way switch OFF - INTERNAL - ON is usually left in the ON position. This should illuminate the Branch Demand ENABLED led on the BC.

On the CC, rotate the crate number selector switch threw positions 1 to 7. Check the SR Leds 1 to 7 on the BC corresponds to the crate number selected on the CC.

If this works, the Branch Coupler is probably ok, but further tests for reading and writing via the Branch crate to the System crate and then again but in the opposite direction will need to be carried out to confirm that both the BC and CC are functioning correctly.

Figure 4 Crate controller

CRATE CONTROLLER (CC)

Figure 4 shows the Crate Controller and Branch Terminator as fitted in the test branch crate.

The crate number (1 to 7) rotary switch is between the connectors. To the left of this is a locking lever switch for taking the crate ON or OFF line. Below that is a biased toggle switch for performing a crate Clear and Initialise (C/Z) operation. These three switches are present on all makes and models of crate controllers but not necessarily in the positions as shown.

It is always advisable to take the crate off line and execute a C/Z before using the branch crate. This will clear all module data registers and will extinguish any LED's that may be ON from a previous operation.

For example, take the crate off line, perform a C/Z and put the crate back on line again. Any LED's which come back illuminated may signify a stuck bit/s on the bus if no read or write instruction from a module has been set up.

READ AND WRITE TESTS – SYSTEM TO BRANCH – BRANCH TO SYSTEM

As the Branch Coupler is across slots 15/16 in the test rack SYSTEM crate, this determines the branch number to be 16

The branch crate number can be set from 1 to 7. In these tests we will use 2 as the crate number. So ensure the rotary switch is set to this number.

These tests also assume that a DTM4 dataway monitor is in slot N1 and a WGR2403 Word Generator is in slot N4 <u>in BOTH crates</u>.

Set up the SC-TST-1 Test Controller as follows:

TEST 1 - Read WGR2403 in SYSTEM crate and write to the DTM4 in the BRANCH crate:
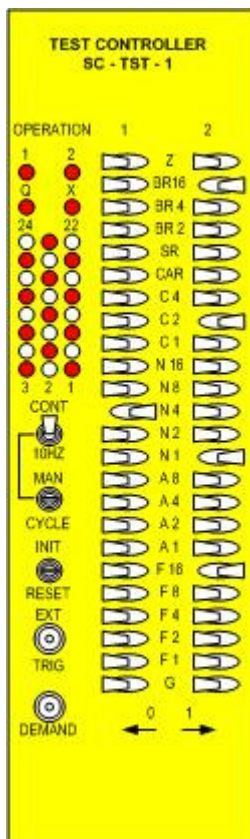

Figure 5 System to Branch crate transfer

- Operation 1 - All switches set to '0' except N4 =1
- Operation 2 - switches BR16 =1 C2 =1 N1 =1 F16 =1

Send the following bit patterns using the 24 switches on the SYSTEM crate WGR2403. Check that the WRITE LED's on the BRANCH crate DTM4 agree.

- Write all ones   111111111111111111111111
- Write all zeros   000000000000000000000000
- Alternate bits   101010101010101010101010
- Reverse bits   010101010101010101010101

If any bits are missing (or refuse to change state), change the CRATE CONTROLLER for a known working spare and repeat the above test.

If the problem persists, change the BRANCH COUPLER for a known working spare and repeat the above test.

Providing the WGR2403 and DTM4 are working ok then changing a CC or BC should resolve the problem of which module is faulty.

TEST 2 - Read WGR2403 in BRANCH crate and write to the DTM4 in the SYSTEM crate:
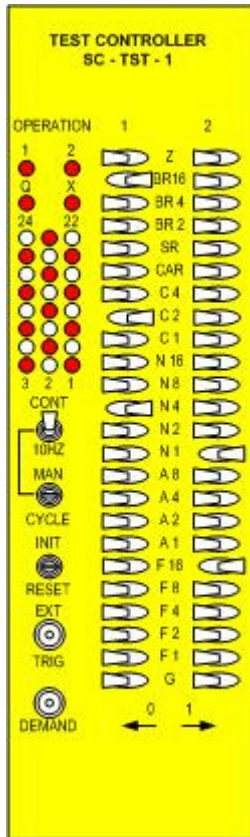

Figure 6 Branch to System crate transfer

- Operation 1 - switches BR16 =1 C2 =1 N4 = 1
- Operation 2 - switches N1 =1   F16 =1

Send the following bit patterns using the 24 switches on the BRANCH crate WGR2403. Check that the WRITE LEDS on the SYSTEM crate DTM4 agree.

- Write all ones   111111111111111111111111
- Write all zeros   000000000000000000000000
- Alternate bits   101010101010101010101010
- Reverse bits   010101010101010101010101

If any bits are missing (or refuse to change state), change the CRATE CONTROLLER for a known working spare and repeat the above test.

If the problem persists, change the BRANCH COUPLER for a known working spare and repeat the above test.

Providing the WGR2403 and DTM4 are working ok then changing a CC or BC should resolve the problem of which module is faulty.

If any of the above tests fail, it will generally identify either a faulty CRATE CONTROLLER or BRANCH COUPLER.

There could be a problem in that a fault situation may exist if the crate number is changed, but the Branch Coupler test as described at the beginning of this section should identify this when the crate number switch is changed and if a corresponding LED on the Branch Coupler does not come on.

It is worth carrying out these tests again using a different crate number if such a problem is suspected.

Another indication of the heath of the system is to check the OPERATION 1 and 2 and Q and X LED's on the TST-1. These should all be on when running the TST-1 in Continuous 1MHz clocking mode.

TESTING INPUT REGISTER AND OUTPUT DRIVER MODULES

There are a variety of these modules in use. Some types are only used in the WHT and others in the INT/JKT systems. These being:

WHT system:
- **HY450-4** - 24 bit (twisted pair) input and output register - (52w D connectors)
- **IR48** - Dual 24 bit input register (31way D connectors)
- **OD48 (or OR48)** - Dual 24 bit output driver (output register - has less current drive)
- **OD2411** - Dual 24 bit output register - (37w D type connectors)

INT/JKT system:
- **PR2402** - Dual 24 bit input register (standard TTL inputs) - also used in WHT
- **PR2403** - Dual 24 bit input register with opto-isolated inputs
- **OD2407** - Dual 24 bit output driver

To test these modules, special test boxes are available which provide a 24 bit input function using switches and a 24 bit output display using LED's. Connections are via 37way D sockets and are labelled as to which is an INPUT or an OUTPUT connection. There is also a third connector, but this is never used and is marked as such.
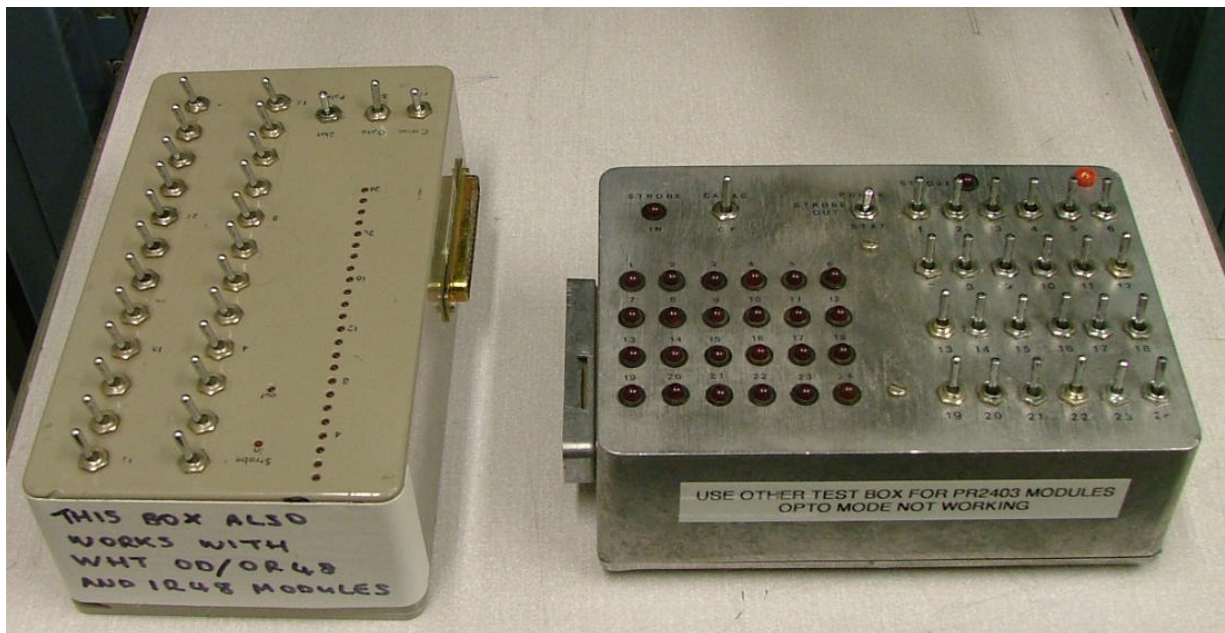

Figure 7 Input Register and Output Driver test boxes

These boxes are essentially the same and both can be used for module testing. However, when testing the WHT OD/OR48 or the IR48 modules use the box shown on the left (referred to as the plastic test box) as the test cables for these modules will only fit into these connectors which are mounted without the clamping plate. The same applies for testing the OD2411 module.

Another caveat is to use this box for testing the PR2403 input registers (opto-isolated inputs). The metal box has this facility also, but no longer works. Unfortunately we have no documentation for these boxes and the circuitry within the metal box is very fragile!

The boxes are also fitted with 3 toggle switches to set the mode of operation. Set these to:

- CAMAC - other position is CF (never used)
- STAT - other position is PULSE
- STD - other position is OPTO (on plastic test box)

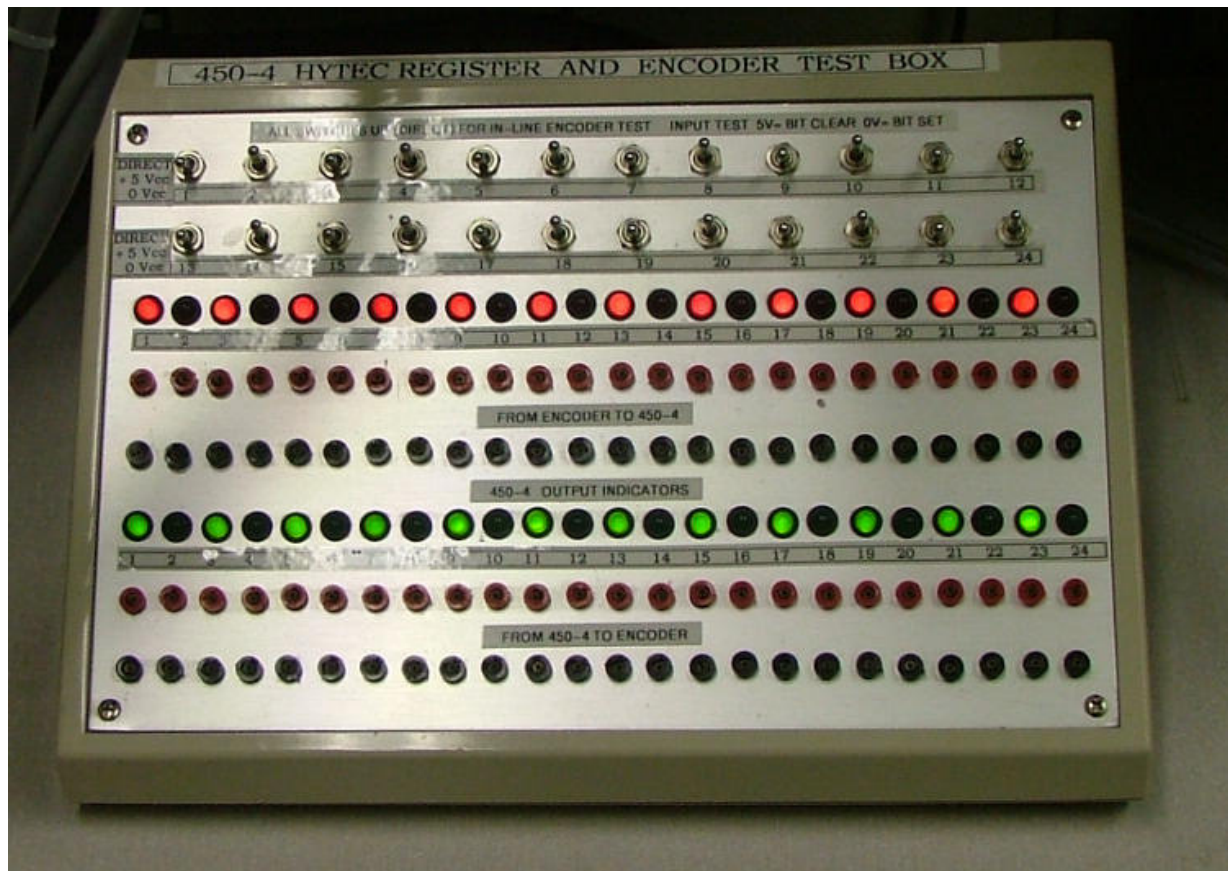For testing the HYTEC 450-4 modules, a special test box is available:

Figure 8 HY450-4 Test Box

This box has a dual function:

1. Using the 2 cables labelled 450-4 INPUT and OUTPUT. It can be used for testing the module in a standalone mode which will be described later.

2. Using all 4 cables (two are marked as TO and FROM encoder) the box can be used to monitor real time encoder data by un-plugging an encoder cable from the 450-4 module and connecting the box in a 'series configuration'. For this to work, all the switches must be set to DIRECT (toggled up).

The centre and bottom switch positions (+5 and 0V) simply generate a logic 1 or 0 state for module bit pattern testing. In the photo the switches have been set to produce an alternate 1010... bit pattern.

TEST CABLES

These are kept in box near the test rack and are as follows:

1. OD/OR48 - Output Driver
2. IR48 - Input Register
3. OD2411 - Output driver
4. PR2402/3 – Input Register
5. OD2407 – Output Driver
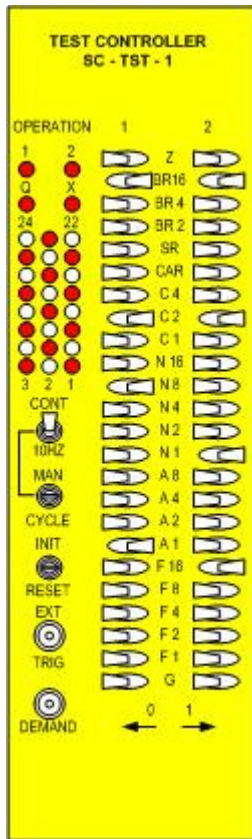
MODULE TEST PRELIMINARIES

Figure 9 IR48 Test Controller setup

For standard module tests, I prefer to use the BRANCH crate. This is simply because the test rack has a pull out tray and cables running between the test box placed on the tray and the module under test are closer together.

As the following tests will be performed using the Branch crate and the module under test will be inserted into slot N8, the SC-TST-1 needs to be configured as shown in Figure 9. That is Operations 1 and 2 are executed using BR =16 and C=2. N8 A1 F0 reads REG 1 of the IR48 and N1 A0 F16 writes the data to the DTM4.

IR48 DUAL 24 BIT INPUT REGISTER

This WHT module has two 24 bit standard TTL input registers. These being:

REG 0 (upper connector) - module sub- address = A0 F0
REG 1 (lower connector) - module sub-address = A1 F0

Using the IR48 test cable and the plastic test box, connect the cable to REG 1 (lower socket). With the SC-TST-1 set up as shown in Figure 9, toggle the switches on the box to produce the following bit patterns:

- Write all ones   111111111111111111111111
- Write all zeros   000000000000000000000000
- Alternate bits   101010101010101010101010
- Reverse bits   010101010101010101010101
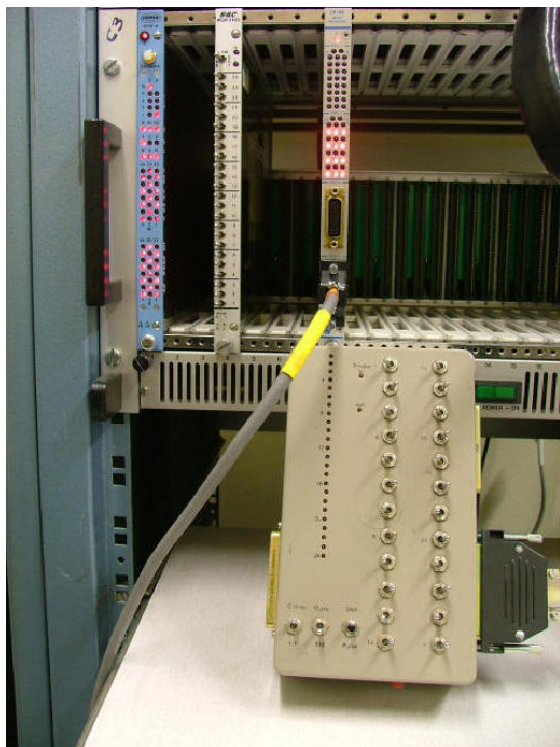
Figure 10 IR48 test setup

Check the lower group of LED's on the IR48 (and also the R/W LED's on the DTM4) agree with the switches.

This is shown in the photo and with an alternate 101010... bit pattern generated.

Now move the cable to the REG 0 connector (upper socket).

Toggle the switch A1 on the SC-TST-1 to the left. This sets A= 0 to read REG 0.

Perform the tests as described above and check the upper group of LED's on the IR48 follow the switches.

Bits failing to be detected are usually caused by a damaged input buffer chip and these are easy to replace.

A similar effect may be produced if the test cable is not fully inserted so check that also before deciding if the module is faulty.

OD48 DUAL 24 BIT OUTPUT DRIVER

Note: There are two versions of this module used in the WHT, the **OD48** and the **OR48**. For test purposes these modules are the same. The only difference being the OD48 can sink more current.

For testing these modules, we use the WGR2403 word generator in slot N4 (A0 F0) to write data to the OD48 in slot N8 A0 (or A1) and F16 being set. The DTM4 will automatically display the read and write data present on the bus and does not need to be addressed as such.
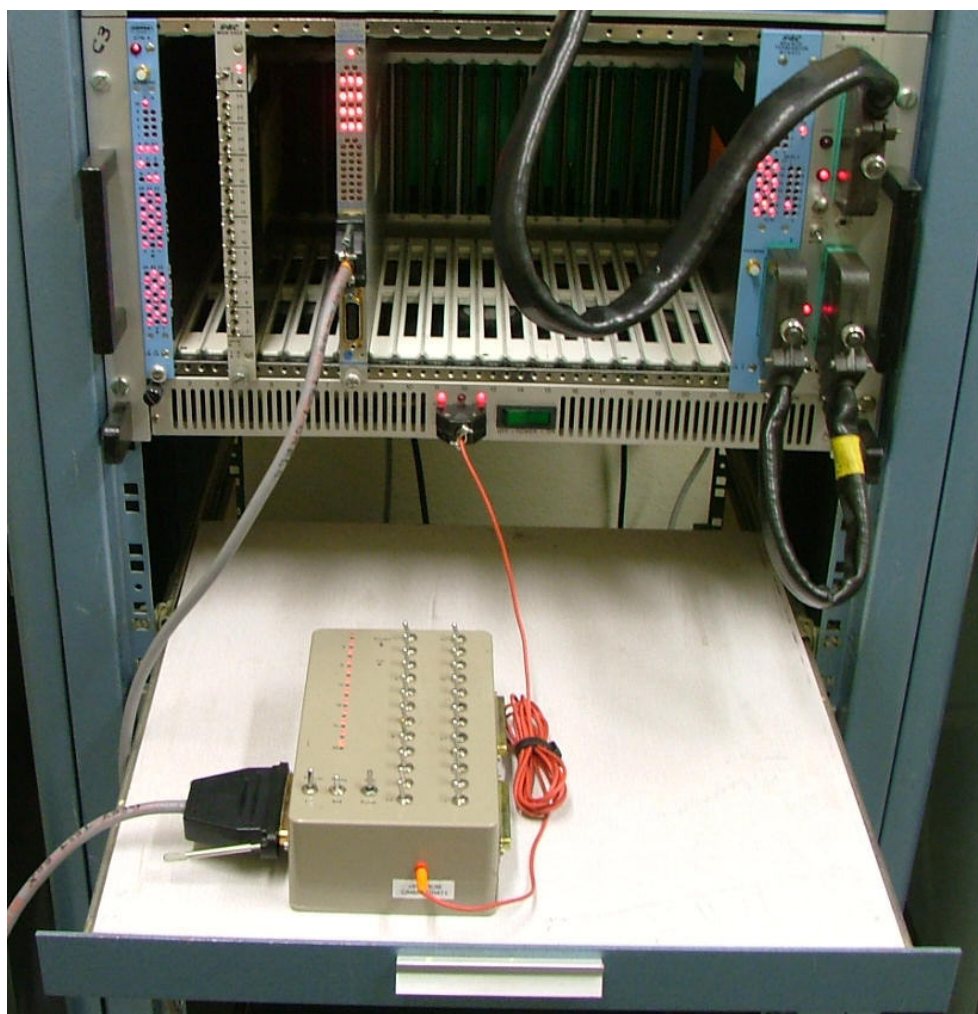
Figure 11 Test setup for OD/OR48 modules

The image above shows the test setup using the plastic test box with the OD48 test cable plugged into REG 0 (upper connector).

The LED's in the test boxes need a +Vcc supply so a special power cable is required which plugs into the CAMAC crate's 9 pin front panel D connector. This is nominally at +6V, but this voltage is reduced to +5 within the test box. The 0V earth return is made via the test cable.
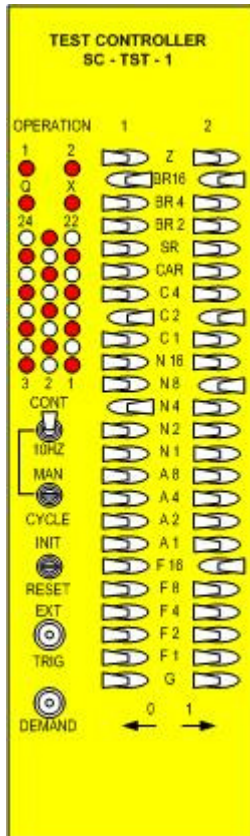
Figure 12 OD/OR48 Test Controller setup

This WHT module has two 24 bit output registers. The output connectors are high density 31way D type. These being:

REG 0 (upper connector) - module sub- address = A0 F16
REG 1 (lower connector) - module sub-address = A1 F16

Test REG 0   A=0   F=16

Using the OD48 test cable and the plastic test box, connect the cable to REG 0 (upper socket). With the SC-TST-1 set up as shown in Figure 12, toggle the switches on the WGR2403 to produce the following bit patterns:

* Write all ones   111111111111111111111111
* Write all zeros   000000000000000000000000
* Alternate bits   101010101010101010101010
* Reverse bits   010101010101010101010101

Check that the upper group of LED's illuminated on the OD48 **and the LED's on the test box** are the same.

This is important as the local display on the module may be working, but the data sent out from the module connector could be faulty. It is not unknown for an output driver chip to be damaged and this test will show if this is so.

Test REG 1   A=1   F=16

Move the test cable to the lower connector on the module.

Toggle the switch A1 to the right – *i.e.* A= 1 and repeat the above tests. If all LED's in the lower group on the OD48 and those on the test box agree, the module is working correctly.

If some of the LED's on the test box are not illuminated, it may be simply a bad cable connection. So check the cable connectors are properly seated before deciding if the module is faulty.

TESTING THE OD2411

This is a 48-channel 40mA/30V O/P Register with handshake and is used in the WHT NASMYTH crate to provide the velocity demand (control bits) to the CW and CCW instrument rotator servos.

This module functionally is the same as the OD48. The difference being that the connectors on the module are standard 37way D types and not the 31way high density D type as used on the OD48 module. The cable labelled OD2411 is required for testing this module and plugs into the plastic test box.

The module connectors are labelled OUTPUTS A and B instead of REG 0 and REG 1, but to test this model, follow the procedure above as for an OD/OR48.

Output A = A0 F16
Output B = A1 F16

HYTEC 450-4 24 BIT INPUT/OUTPUT REGISTER

These WHT modules are used to read the data from the absolute encoders. The inputs and outputs are differential pairs and conform to RS422/423 standards.

To test this module, a special test box is available (see description on page 10). A nice feature about this setup is that both the INPUT and OUTPUT registers can be tested together.
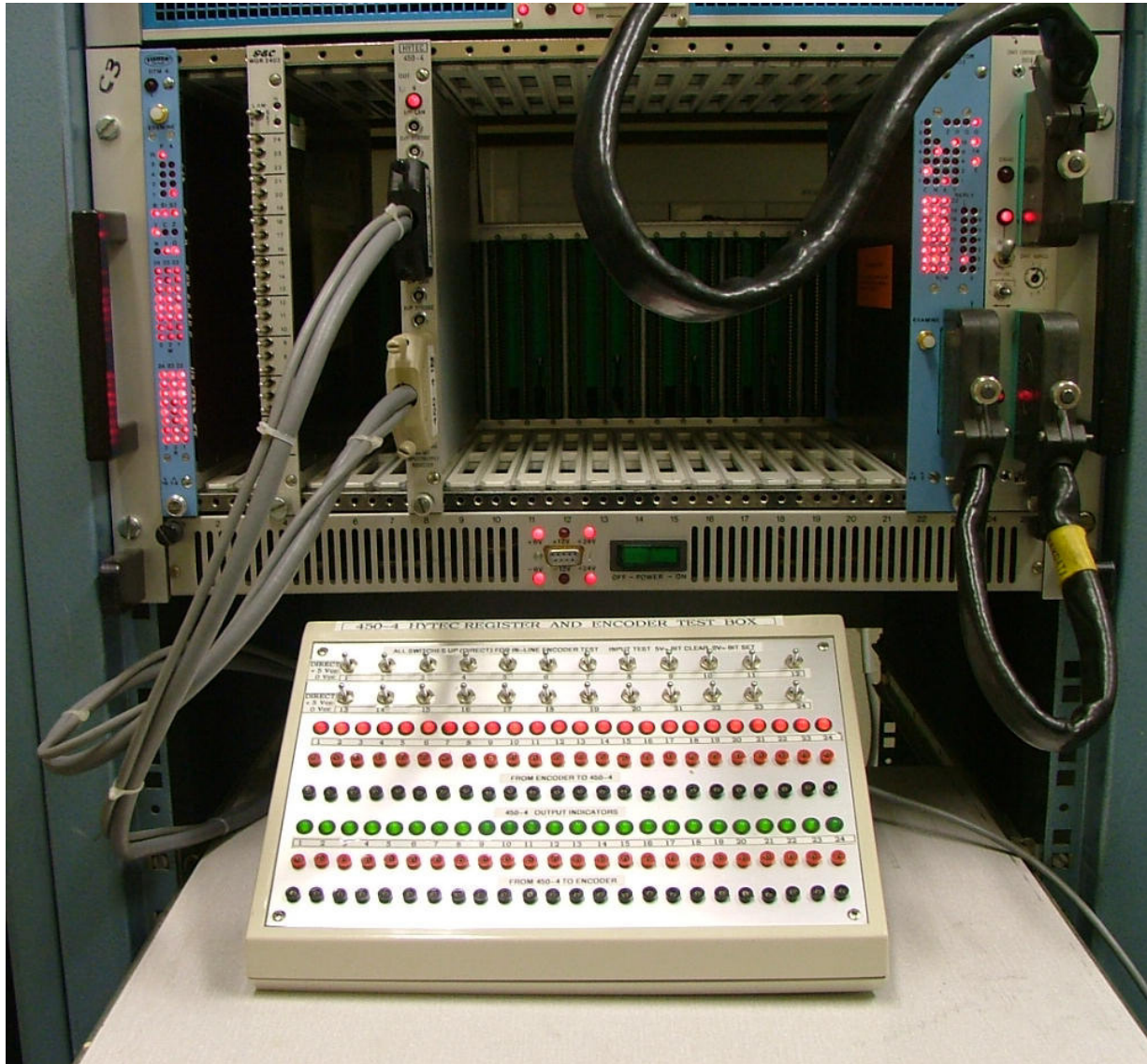
Figure 13 HYTEC 450-4 test setup

The photo shows the test box in use. In this example, all 24 bits have been set which can be seen displayed on the DTM4 and Branch Terminator in the branch crate as well as on the test box.

The 450-4 OUTPUT connector is the upper one, the INPUT connector being the lower. Ensure the cables labelled as 450-4 OUT and 450-4 IN are inserted into the appropriate connectors. There are two more cables coming from the test box labelled TO and FROM ENCODER, but for this test they are not required.

Below the LED's are test points for the 24 differential input and output connections and can be used for monitoring purposes using a meter or oscilloscope.

The test box requires a +5V supply (of at least 2A) and the power cable seen to the right connects to a bench PSU.

The input signals are derived from 24 toggle switches on the box, their state being shown by the row of red LED's below. The green LED's are driven from the module's output register.

The toggle switches have 3 positions, but only the centre and down positions are used. These are labelled as +5V and 0V. However due to internal buffering and chip inversion, the logic states sent to the 450-4 input register are:
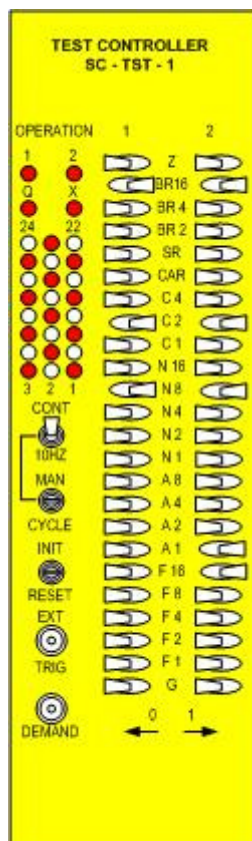
Switch Centre Bit = 0
Switch Down   Bit =1

Figure 14 450-4 Test Controller setup

Both read and write data operations are performed simultaneously on the same module

Operation 1 - To read the switch data:

N8 A0 F0 (read input register)

Operation 2 - To write data to LED's:

N8 A1 F16 (overwrite output register)

Use the switches on the 450-4 test box to generate the following bit patterns

- • Write all ones   111111111111111111111111
- • Write all zeros   000000000000000000000000
- • Alternate bits   101010101010101010101010
- • Reverse bits   010101010101010101010101

Because the input data is being passed back out of the module, both the GREEN and RED Leds should be in agreement.

As mentioned for the previous I/O module tests. A bad connection between the test cable and module connector can cause problems with bits missing so ensure these connectors are pushed in fully.

The 450-4 is quite a complex module with a host of CAMAC commands for performing other operations such as clearing, setting or testing the LAM bit. There are also commands for clearing a register after reading it. A full set of instructions along with the connector pin details are readily available.

The usual problems with 450-4 modules are missing or stuck bits and the above test is more than adequate to show this type of fault.

PR2402 AND PR2403 PARALLEL INPUT REGISTERS

These modules are used extensively in the INT (and JKT) for providing input signals to the TCS from many of the telescope's mechanisms and console push buttons that are still in use. PR2402 modules are also used in the WHT 'CLIP CENTRE' crate for reading some of the engineering console switches and status from the dome and shutters. In all telescope SYSTEM crates, a PR2402 is used to supply the TCS with UTC data from the Time Service.
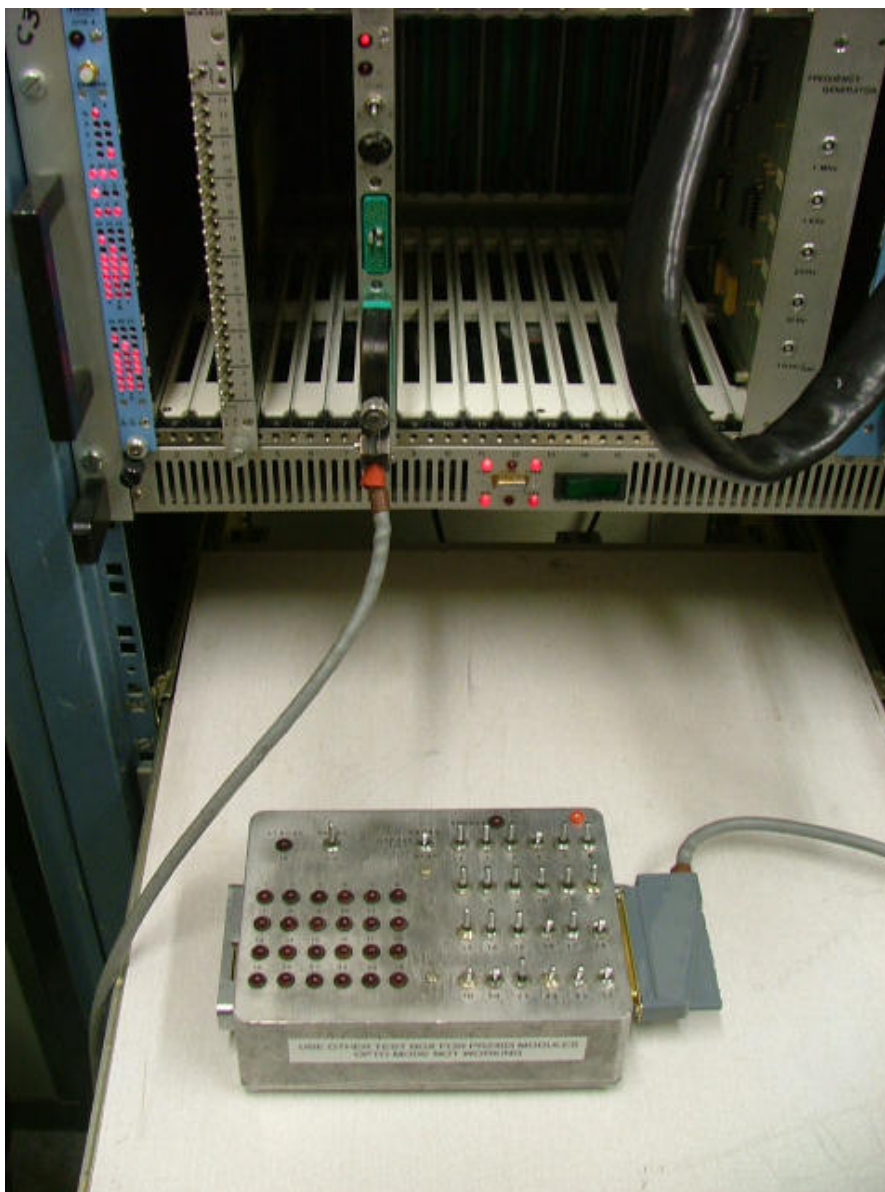
Figure 15 PR2402 test setup

This photo shows a PR2402 under test using the metal test box. As only the switches on the box are used, the box doesn't require the +Vcc supply derived from the crate's 9 pin D connector.

In this example, the switches have been set to random ON or OFF positions and the bits activated can be seen displayed on the DTM4 in slot N1. The two toggle switches at the top on the box are set to CAMAC and STAT. n.b. *The OPTO/STD option doesn't work. Leave the switch on the side of the box set to STD.*

IMPORTANT – As these modules use Hughes connectors, the pins or sockets on the connectors can be easily damaged. Ensure the test cable connector is squarely aligned before clamping down the finger screw.

Figure 16 PR2402 Test Controller setup

The PR2402 has two 24 bit input registers. The 58way Hughes connectors are labelled INPUT A (upper) and INPUT B (lower). There is also a push button for clearing out the data from the input registers. The modules sub-addresses are:
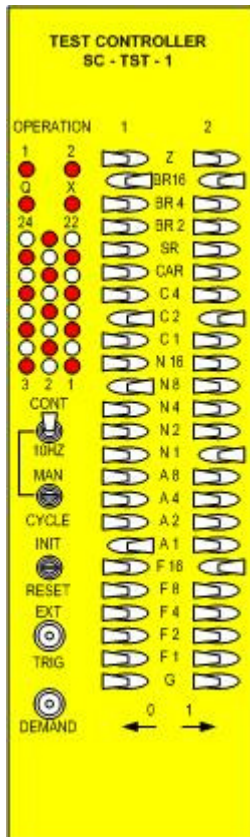
INPUT A (upper connector) = A0 F0
INPUT B (lower connector) = A1 F0

Using the PR2402 test cable and either the metal or plastic test box, connect the cable to INPUT B (lower socket). It should be noted that the 58way Hughes connectors on this module have the polarising sleeve reversed between INPUT A and INPUT B. On the upper connector, the cable is at the top of the plug, on the B side the cable is at the bottom of the plug as shown in the photo.

With the SC-TST-1 set up as shown in Figure 16, toggle the switches on the box to produce the following bit patterns:

- Write all ones   111111111111111111111111
- Write all zeros   000000000000000000000000
- Alternate bits   101010101010101010101010
- Reverse bits   010101010101010101010101

Check the Read and Write LED's on the DTM4 conform to the switch settings.

Now move the cable to INPUT A (upper socket).

Toggle the switch A1 on the SC-TST-1 to the left. This sets A= 0 to read from INPUT A.

Perform the tests as described above and again check the LED's on the DTM4 follow the switches.

Bits failing to be detected are usually caused by a damaged input buffer chip and these are easy to replace.

A similar effect may be produced if the test cable is not fully inserted so check that also before deciding if the module is faulty.

TESTING A PR2403 PARALLEL INPUT REGISTER

These modules are only used in the INT/JKT CAMAC system. The difference being the A and B inputs are OPTO-ISOLATED whereas on the PR2402 the input circuitry accepts standard TTL signals.

Testing the PR2403 module uses the same procedure as above. However, use the plastic test box for these modules and change the middle toggle switch (in the group of three) from STD to OPTO.

OD2407 DUAL 24 BIT OUTPUT DRIVER

These modules are only used in the INT/JKT CAMAC systems. They are used for driving hardware such as relays and generating commands for moving the dome, focus and instrument turntables.

For testing this module, use the WGR2403 word generator in slot N4 (A0 F0) to write data to the OD2407 in slot N8 A0 (or A1) with F16 being set. The DTM4 will automatically display the read and write data present on the bus and does not need to be addressed as such.
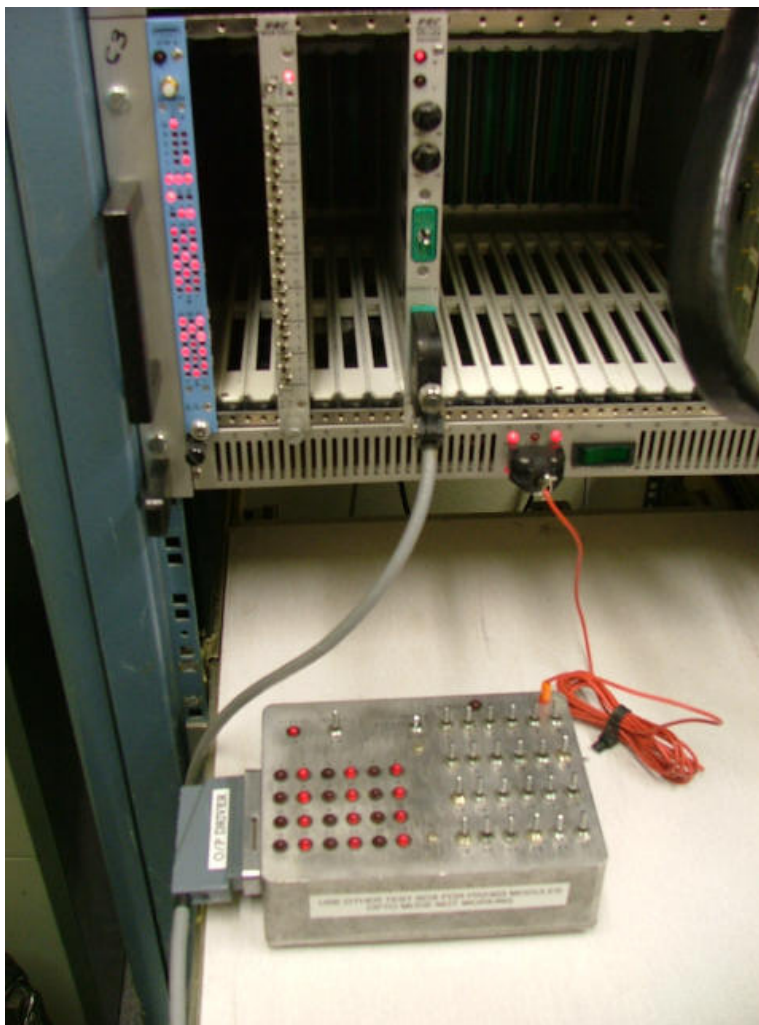
Figure 17 OD2407 test setup

This photo shows the OD2407 module under test using the metal test box. As with the plastic test box, the LED's on the metal box require a +Vcc supply also. Connect the special power cable as shown in the photo.

In this example, OUTPUT B (lower connector) is being tested and the switches on the word generator set to produce an alternate 010101... bit pattern. This can be seen displayed on both the read and write groups of LED's on the DTM4 as well as on the test box.

IMPORTANT – as these modules use Hughes connectors, ensure the test cable connector is squarely aligned before clamping down the finger screw.

Figure 18 OD2407 Test Controller setup

This INT module has two 24 bit output registers. The output connectors are 38way Hughes types. These being:

OUTPUT A (upper connector) - module sub-address = A0 F16
OUTPUT B (lower connector) - module sub-address = A1 F16

Test OUTPUT A   A=0   F=16

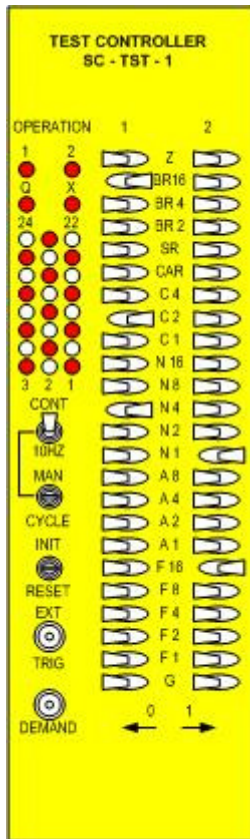Using the OD2407 test cable and either the metal or plastic test box, connect the cable to OUTPUT A (upper socket).

It should be noted that the 38way Hughes connectors on this module have the polarising sleeve reversed between OUTPUT A and OUTPUT B. On the upper connector, the cable is at the top of the plug, on the B side the cable is at the bottom of the plug as shown in the photo.

With the SC-TST-1 set up as shown in Figure 18, toggle the switches on the WGR2403 to produce the following bit patterns:

- Write all ones   111111111111111111111111
- Write all zeros   000000000000000000000000
- Alternate bits   101010101010101010101010
- Reverse bits   010101010101010101010101

Check that both the read and the write groups of LED's displayed on the DTM4 **and the LED's on the test box** conform to the word generator switches.

This is important as the data displayed on the DTM4 module may be correct, but the data sent out from the module connector could be faulty. It is not unknown for an output driver chip to be damaged and this test will show if this is so.

Test REG 1   A=1   F=16

Now move the test cable to the lower connector. This is the setup as shown in Figure 17.

Toggle the switch A1 (Operation 2 group) to the right – *i.e.* A= 1 and repeat the above tests.

If the LED's on both output channels are in agreement with the word generator switches then the module is working correctly.

If some of the LED's on the test box are not illuminated, it may be simply a bad cable connection. So check the cable connectors are properly seated before deciding if the module is faulty.

TESTING THE RGO 32BIT COUNTER MODULE

GENERAL INFORMATION

These modules are used on all telescope CAMAC systems and convert the data from the INCREMENTAL encoders to an UP/DOWN binary count which the TCS requires to determine the angular position of where the telescope is pointing.

An incremental encoder produces two trains of pulses known as LEAD and LAG. The optical plate (or tape band) is made in such a way to produce these 90 degree phase shifted signals. Depending on what signal is detected first by the steering logic within the counter module e.g. LEAD > LAG or LAG > LEAD determines whether the encoder is moving in a CW or CCW direction. The electronics used for this is known as a QUADRATURE DETECTOR.

Another consideration is that an incremental encoder needs a datum or reference point to set the counter module to a known value or starting position. Along with the lead and lag tracks, there is also a 1 pulse per revolution (1ppr) signal generated by the encoder. The BEI incremental encoders used on the INT produce 16,000 bits (counts) from the lead and lag tracks plus a very narrow 1ppr pulse for every revolution completed.

However, in the case of a telescope, a more precise reference is required and this is achieved by an external signal sent from either a proximity switch (usually an inductive sensor) or a slotted opto-switch. In both of these systems, a metal flag attached to the telescope axes moves past (or through) the sensor thus generating a pulse known as the ZEROSET signal. As this signal can only occur when the telescope axes are in a certain position, we now have a way of determining exactly where the telescope is pointing and a means for the TCS to set the encoder count to a known value. In practice, the ZEROSET pulse is logically ANDED (within the encoder line driver box) with the encoder 1ppr, so that a very accurate angular position is determined for the telescope axes.

In the case of the INT/JKT the ZEROSET occurs when the telescope is vertical (at the ZENITH) and the Hour Angle at ~0 degrees and the DEC axis ~+28 degrees.

With the WHT (being an Alt-azimuth mounting) this is determined with the ALTITUDE (elevation) axis at ~90 degrees (89° 48') and the AZIMUTH axis at ~300 degrees (298° 35').

To set the RGO32BIT COUNTER to an initial known value, there are inputs for both the encoder 1ppr and ZEROSET pulses.

The encoder data needs to be continually updated, thus the counter module needs to be CLOCKED at a constant rate. This also needs to be referenced to Universal Time (UTC) due the rotation of the Earth and the apparent movement of celestial objects across the sky. A 20Hz (50mS) signal which comes from the Time Service and thus referenced to UTC is used to clock the RGO32BIT COUNTERS for this purpose.

There are 3 GREEN Leds below the main 32 bit display to show these actions. These being labelled from the bottom up:

- 1PPR
- ZERO
- CLOCK

The main 32 bit LED display uses RED Leds set in blocks of four which show the binary weighting of the counts.

TEST SETUP USING A BEI INCREMENTAL ENCODER

The image below shows the test setup using a BEI incremental as the pulse generating source. A co-axial lead with LEMO connectors takes the 20Hz output from the FREQUENCY GENERATOR to the CLOCK input connector of the module. This emulates the 20Hz signal from the Time Service.
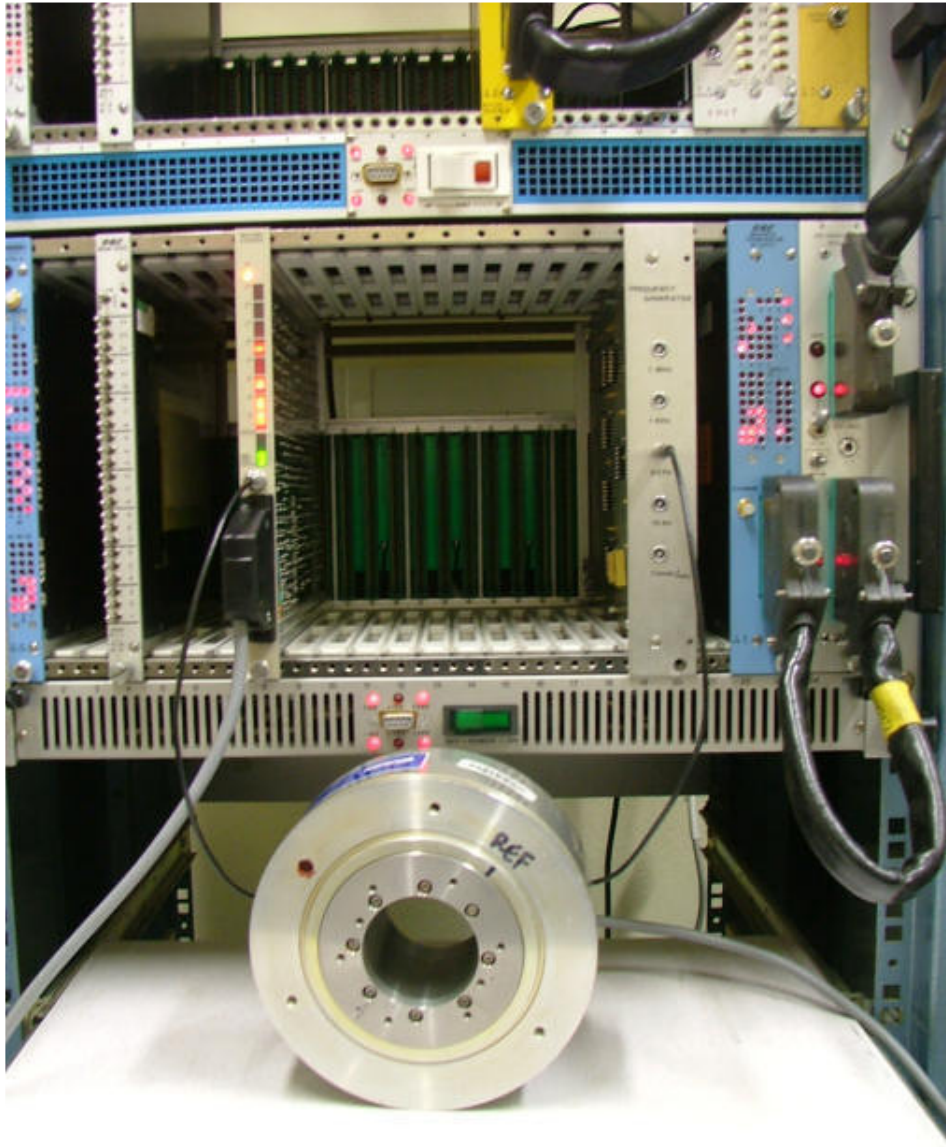
Figure 19 RGO32bit counter test setup (1)

Between the encoder and the counter module, a special line driver box is used to convert the TTL outputs from the LEAD, LAG and 1PPR of the encoder to differential pair (opto-isolated) inputs which the counter module requires. The input connector is standard 37way D type.

The line driver box requires a +5V supply and a bench PSU is used for this.

To simulate the ZERSET pulse, a push button the line driver box provides this signal.

Figure 20 RGO32bit counter setup (2)

The above image shows the line driver box, bench PSU and sitting above that, the GAEBRIDGE ENCODER SIMULATOR which I will describe how to use later.

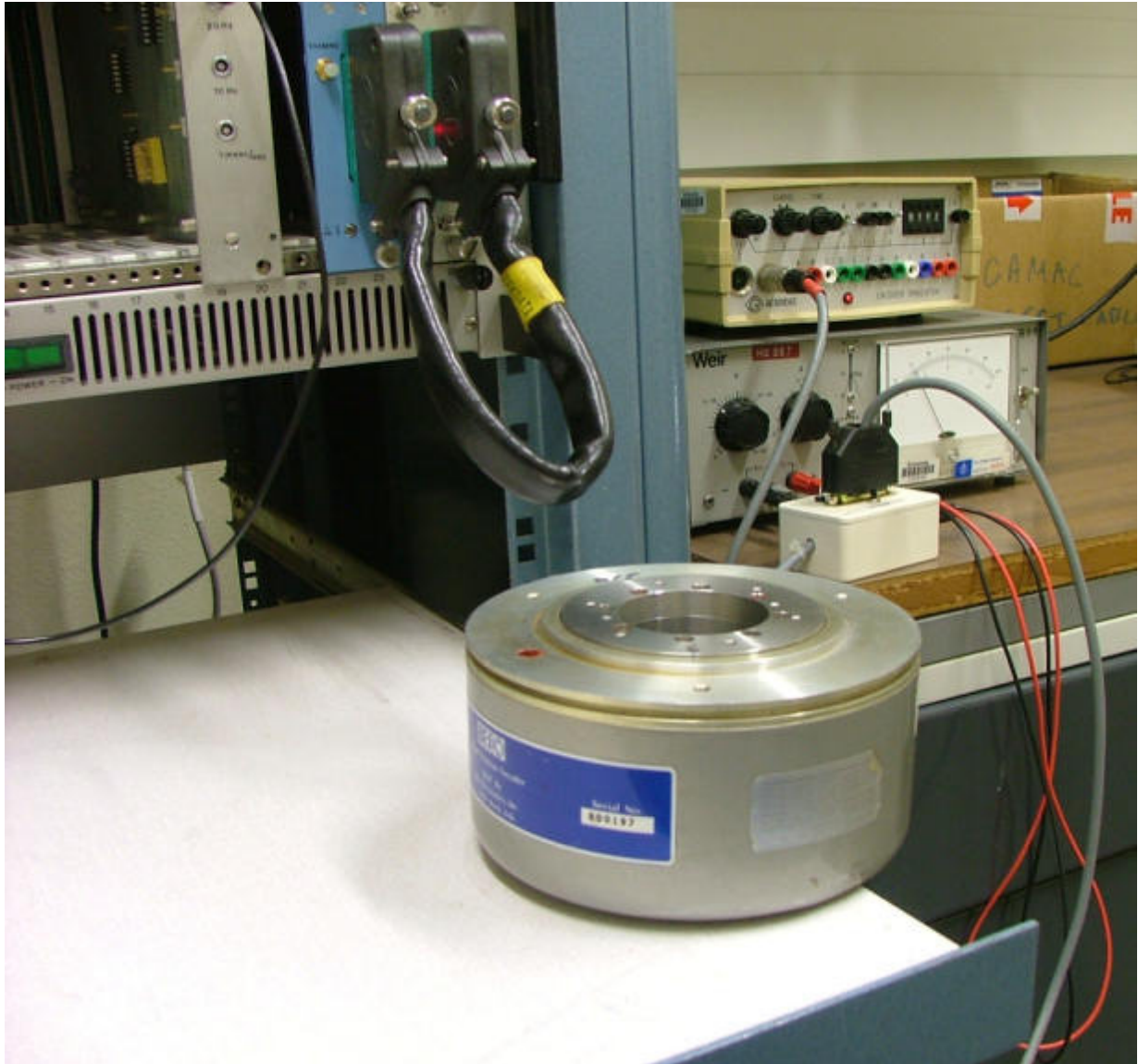When testing this module, there is an important point to take into consideration. A standard CAMAC bus has 24 read and write lines, but this module reads in 32 bits of data. To achieve this, the data is transferred to the bus by reading in two 16 bit blocks. The module's sub-address lines being set to either A=0 to read the lower 16 (or LSB) bits or A=1 to read the upper 16 (or MSB) bits.

There are also two modes of reading the encoder data into the RGO32bit counter:

1. Clocked in continuously at 20Hz (normal operation)
2. The data is read in when a Strobe Pulse from either the 1PPR or ZEROSET signal is detected.

In practice, the second mode of operation would only be required when the telescope is ZEROSET at the start of observing and from then on, the encoder modules are STATICISED from the 20Hz signal from the Time Service.

It should also be noted that when a 1PPR or ZEROSET pulse in (or the CLOCK signal) is detected, the green LED's on the 32 bit counter will stay illuminated. Only by taking the branch crate OFF LINE and performing a C/Z will these bits (and displays) be cleared. As the 20Hz signal is being supplied from the Frequency Generator, the CLOCK Led should re-appear once the crate is brought back on line.

Using the BEI encoder to test the module is simple. Just rotate the shaft and depending on the direction, the red LED's on the module's 32 bit display will move either UP or DOWN. However, if the SC-TST-1 is not setup to address the module, although the red LED's will change with movement, the data from the module will not be transferred to the bus and that is what we need to test.

Note: On the encoder body and shaft are marked two reference lines. The point where these two lines cross is when the 1ppr signal is generated.
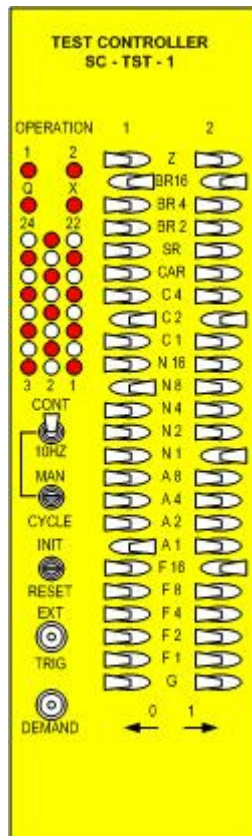

Figure 21 RGO32bit counter test Controller setup

The diagram shows for Operation 1, the address of the module at N8 and sub-address A1 F0 selected. The sub-address will be changed from A=0 to A=4 during the test procedure. Operation 2 is set to write data to the DTM4 module (N1 A0 F16)

Test the Clock, 1ppr and ZERSET signals.

- Take the crate off line and perform a C/Z. All the LED's on the module should be OFF.

- Put the crate back on line again and the CLOCK Led should come on.

- Move the encoder shaft slowly and when the 1ppr reference lines pass, check the 1ppr LED comes on.

- Now push the ZEROSET button on the line driver box. Check that the ZERO Led comes on.

If all this works ok, the module is detecting these pulses correctly.

Test the LSB bits are being read onto the bus in continuous mode - Using Register 1

- A=0 F=0 (switch A1 in diagram toggled to the left)

- Take the crate off line, do a C/Z and put the crate back on line.

The red LED display should be blank. If the encoder is just even lightly touched, either most (certainly the MSB upper 16 bits) will be displayed or just a few of the low order bits displaying.

- Now move the encoder shaft rapidly. The LED's will either count up down (in pure binary) depending on the direction of rotation.

- Check the DTM4 displays show the same bit pattern as the red LED's on the RGO32bit counter module.

If all looks ok the LSB encoder bits are being read correctly.

Test the MSB bits are being read onto the bus in continuous node – Using Register 1

- A=1 F=0 (switch A1 set as in Figure 21)

- Perform the test as above. The bits displayed on the DTM4 will now be changing much more slowly. This is because the encoder needs to complete a full 16 bit (65,535 counts) before bit 16 (the lowest order bit in the MSB range) will change state.

- Check again that the DTM4 and LED display on the RGO32bit counter are in agreement.

When the encoder is rotated and the bits are counting UP, it would take many turns of the encoder shaft to check out the full 32 bit range, but doing this for a minute or so is good enough to show that the MSB bits are being read onto the CAMAC bus.

A further test is to rotate the encoder shaft so the bits count DOWN. All the MSB will then be displayed when a 32 bit zero count is passed. To reset the counter registers, take the crate off line and perform a C/Z. This will return the counter displays to a cleared condition.

Another way to clear the counter is by sending the CAMAC command F9 A0. To do this, set the switches on the SC-TST-1 (Operation 1 column) to A0 and F9 and the counter should reset to zero.

Test the LSB bits are being read onto the bus in strobed mode - Using Register 2

These tests are basically the same as before, the difference being that <u>data will only be transferred to the bus when a 1ppr signal or a ZEROSET pulse is received.</u>

- Set the SC-TST-1 to A=2 F=0

- Turn the encoder shaft. Data will now only be transferred when the 1ppr is detected. *i.e.* Once for each rotation of the encoder shaft.

- Check that the DTM4 and the LED display on the RGO23bit counter are in agreement

- Turn the encoder shaft for a time then stop and push the ZERSET button on the line driver box

- Check that the DTM4 and the LED display on the RGO23bit counter are in agreement

Test the MSB bits are being read onto the bus in strobed mode - Using Register 2

- Set the SC-TST-1 to A=3 F=0

- Turn the encoder shaft. Data will now only be transferred when the 1ppr is detected. *i.e.* Once for each rotation of the encoder shaft.

- Check that the DTM4 and the Led display on the RGO23bit counter are in agreement

- Turn the encoder shaft for a time then stop and push the ZERSET button on the line driver box

- Check that the DTM4 and the Led display on the RGO23bit counter are in agreement

This completes the general data transfer tests on the RGO32bit counter using the test BEI encoder.

More information and the full set of CAMAC commands can be found in the RGO 32BIT CAMAC COUNTER USER MANUAL. A copy of which is in the office where the CAMAC testing is done.

GAEBRIDGE ENCODER SIMULATOR

This piece of test equipment can also be used for testing RGO32Bit counter modules. Although using the BEI incremental encoder in my experience is a better method, this unit can be set up to send a given number of pulses to the encoder module. This is useful if missing bits are suspected as it is very difficult to move the BEI encoder shaft to generate a known number of counts.

The simulator is very easy to use. The cable plugs directly into the 37way D connector on the counter module.
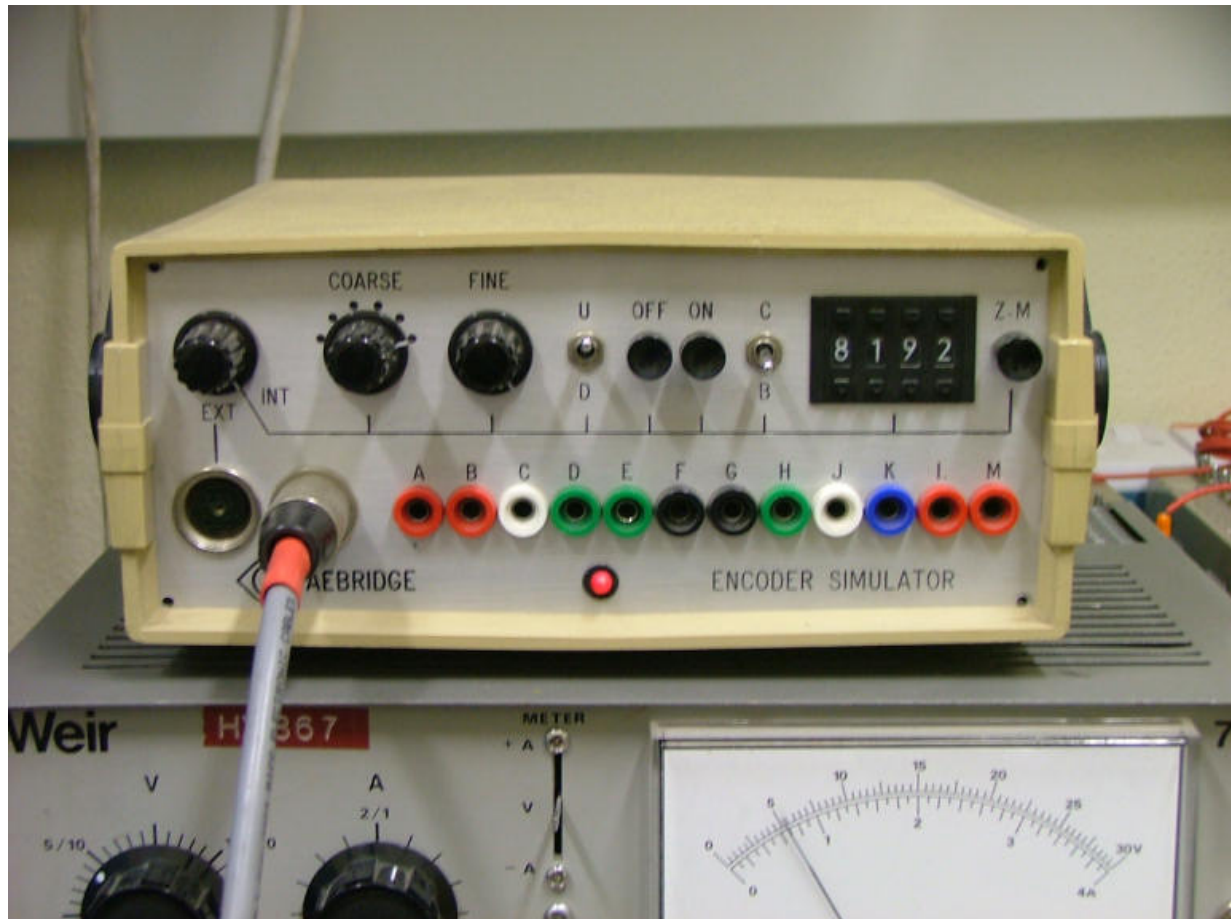

Figure 22 GAEBRIDGE encoder simulator

In the photo, the simulator is setup to send 8192 pulses to the counter module. The thumb wheel switch can be set to any value up to 9999, but its common sense to select a value which equals a standard binary value, *e.g.* 1024, 2048, 4096 and the highest value with this unit - 8192.

The COARSE and FINE knobs control the velocity of the bit rate sent. These I set usually to their maximum values.

The two toggle switches are:

1. Count direction - UP (U) or DOWN (D)
2. Mode of operation - CONTINUOUS (C) or BURST (B)

The push buttons ON and OFF will start or stop the counts being sent to the encoder module.

In the photo, the settings correspond to an UP count of 8192 with BURST mode selected. Thus when the ON button is pushed, a single stream of 8192 pulse will be sent at full velocity rate to the module under test.

USING THE SIMULATOR

To use the simulator, after the cable has been connected to the module, take the crate off line and perform a C/Z. This resets all the counter registers to zero.

Make sure the RGO32Bit counter is receiving the 20Hz clock signal from the frequency generator.

Put the crate back on line and push the ON button. With the value of 8192 selected, the LED's on the module will count up in binary fashion, but finally stopping with just one displayed. This being bit 15. See photo below.
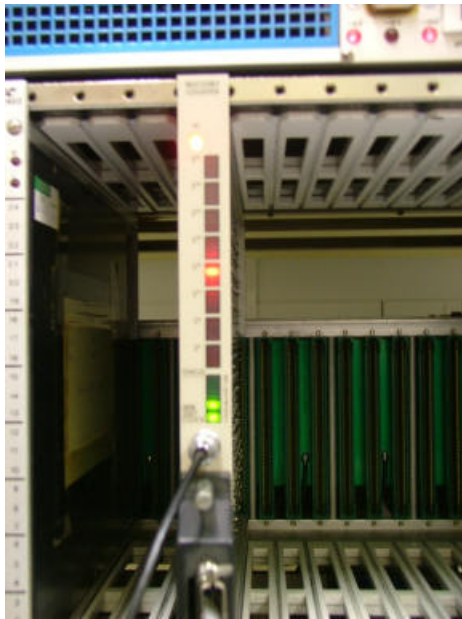

Figure 23 Bit 15 displayed

Another point regarding the operation of the simulator and demonstrated in the image is the CLOCK and ZEROSET green Leds are illuminated but not the 1PPR indicator.

There is a push button on the simulator labelled Z.M. (Zero Marker) for emulating the ZEROSET pulse, but there is no switch or push button for a 1PPR test.

For this reason, it is best in the first instance to use the BEI encoder for testing as this sends out a REAL 1ppr signal.

If the simulator is put in CONTINUOUS mode with the 8192 count selected, this is a good method of testing for changes in the MSB bits as it can be left running for a long period which would be laborious if rotating the BEI encoder shaft by hand.

 This completes the use of the encoder simulator and RGO32Bit counter tests.

TESTING MISCELLANEOUS MODULES

MULTIDAC (Digital to Analogue Converter)

The 9085 MULTIDAC modules as used in the INT/JKT are easy to test. All that is required is a LEMO cable with an open end which can be connected to a MULTIMETER. This is set on a low voltage range.

The DAC uses 12 bit sampling and generates a +5 and –5V output voltage. These modules are setup as such that a binary word of 2048 gives a 0V (zero volts) output. A data word of 4096 gives a +5V output and 0000 a minus -5V output.

Use the WGR2403 word generator (in slot N4) to produce the binary word for the DAC to output these voltages. The DAC under test would be setup (say in slot N8) with an F16 or A0, A1, A2 or A3 set on the SC-TST-1 to write to the appropriate output channel. There are 4 channels used on the INT

There is a trim-pot on the module for output voltage calibration. The user manual will explain how to adjust this.

It should be noted the 9085 is no longer made and a HYTEC 640VSL substitutes for this. Refer to the User Manual for more information.

ED012 (Clock Pulse Generator)

Equipment needed:

1. CAMAC Frequency Generator module (as used for the RGO 33bit counters)
2. WGR-241 Word Generator
3. An oscilloscope and the Marconi DFM (Set to Period/Milliseconds)
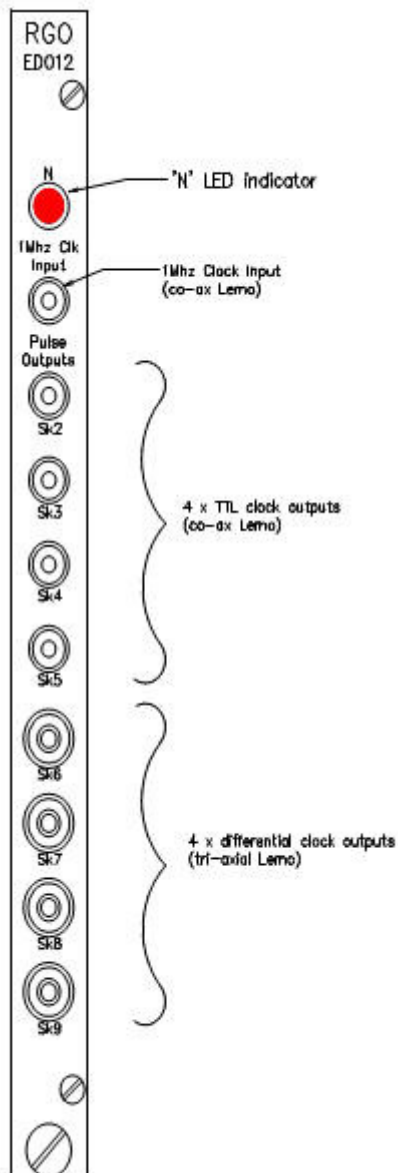
PROCEDURE

1. Connect a Lemo cable between the 1MHz output of the frequency generator and the 1MHz input socket of the ED012. A cable with a large and small LEMO connector fitted for this use is in the box of test cables.

2. Set up the BCNAF for the ED012 and Word generator e.g. WGR -   N4 A0 F0
   ED012 - N8 A0 F0

3. Initialise the test crate (using the C and Z switch)

4. Set the WG switch 7 to bit=1 all the rest at 0 (i.e. set the word to 64)

5. Enable the ED012's internal rate multiplier with setting switches on the test module to - F26 A1

6. Now reset the ED012 for a normal write cycle – F16 A0

7. Plug in a test lead from SK2 to the oscilloscope and DFM (these are connected in parallel) and check a 500nS pulse is present and the DFM (set to PER A – Ms) reads a value of ~156.24milliseconds

8. Now set the WGR switches 4, 7 and 8 (bit=1) i.e. bits 8+64+128 set to generate a word of 200. This equates to a generated 500nS pulse of 20Hz (50mS). See BIT MAP below:

   ```
   0    0    0    1    0    0    1    1    0    0  = 20Hz
   1    2    4    8    16   32   64  128  256  512
   ^                                            ^
   Bit 1      --- Word generator switches---    Bit 10
   ```

9. Check the DFM shows a value of 49.999mS

10. Check the remaining outputs SK3 to SK9 that this 20Hz signal is present. If so, the ED012 is working correctly.

HYTEC ADC1232 (Analogue to Digital) Module

There are several versions of ADC modules in use, but they all have similar characteristics and use the same CAMAC commands for addressing them. The HYTEC ADC1232 being the most common one in use. There are 32 input channels. Channels 1 to 16 are on the upper 37way D connector and channels 17 to 32 on the lower 37way D connector. The ADC1232 samples to 12 bits resolution.

These ADC modules are primarily used for measuring the temperature sensors fitted on the trusses of the telescopes and on the mirror.

To test these modules, there is a special Break Out Box (BOB). This allows input voltages from the Precision Voltage Generator (which has a thumbwheel switch for selecting voltages in small increments) which can be applied to the input channels of the ADC module.

The BOB cables are fitted with 37way standard D type connectors (one male the other female) so the box can also be used in series with the ADC to measure for example the voltages coming in from the temperature sensors. The terminal pins on the BOB are arranged as such that pins 1 to 16 are the ADC input channels (+Ve) and pins 20 to 36 are the OV returns.
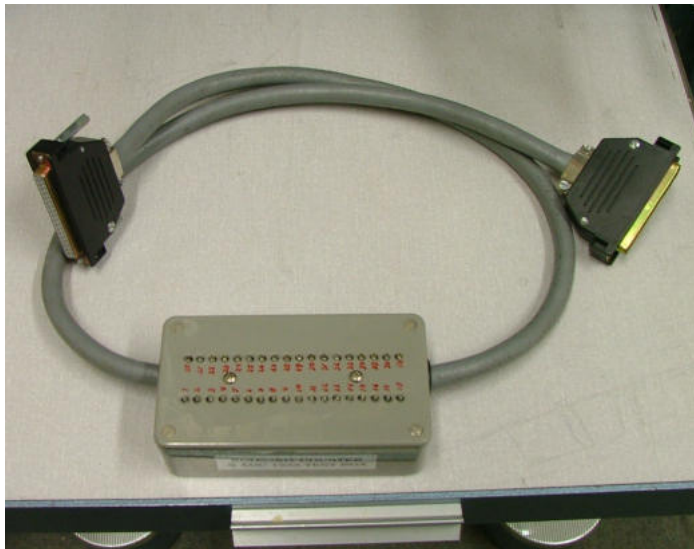

Figure 24 Break out box for ADC modules

Pins 1 and 20 are Channel 1   F=0 A=0
Pins 2 and 21 are Channel 2   F=0 A=1
Pins 3 and 22 are Channel 3   F=0 A=2
Pins 4 and 23 are Channel 4   F=0 A=3
Etc...

To test channels 17 to 32 (on the lower connector) the F bit is changed to F=1

Pins 1 and 20 are Channel 17   F=1 A=0
Pins 2 and 21 are Channel 18   F=1 A=1
Pins 3 and 22 are Channel 19   F=1 A=2
Pins 4 and 23 are Channel 20   F=1 A=3
Etc...

To test the ADC, as with previous tests - Insert the module into slot N8

e.g. To test ADC Channel 3. Toggle the switch A2 on the SC-TST-1 to '1'. All other A and F switches are set to '0'

Operation 1 - N8 A2 F0 (read ADC channel 3)   **Operation 2** - N1 A0 F16 (write to the DTM4)

1. Connect the +Ve and – Ve leads from the Precision Voltage Source across pins 3 and 22 of the BOB.

2. The User Manual will give the information regarding binary counts for a particular voltage input. I think 10mV (LSB - bit 0) is the lowest voltage change that the ADC will detect.

3. Step through the voltage increments using the thumbwheel switches on the Precision Voltage Generator and check what bits are displayed on the DTM4. The binary counts should match the voltage selected +/- 1 bit. The Users manual gives instructions on how to calibrate the ADC if required.

To test Channels 17 to 32, use the lower connector and toggle the F1 switch to '1' and set the A switches to the number of the channel to be tested - This completes the ADC test.

Conclusion

In this document, I have covered the testing of most of the CAMAC modules in use at ING.

Those I have not being the LP34 millisecond generator and the 3340 RS232 communications modules (as used in the INT/JKT).

The LP34 modules are easy to test using the in-house built CAMAC Frequency Generator and the User Manuals for these modules are readily available.
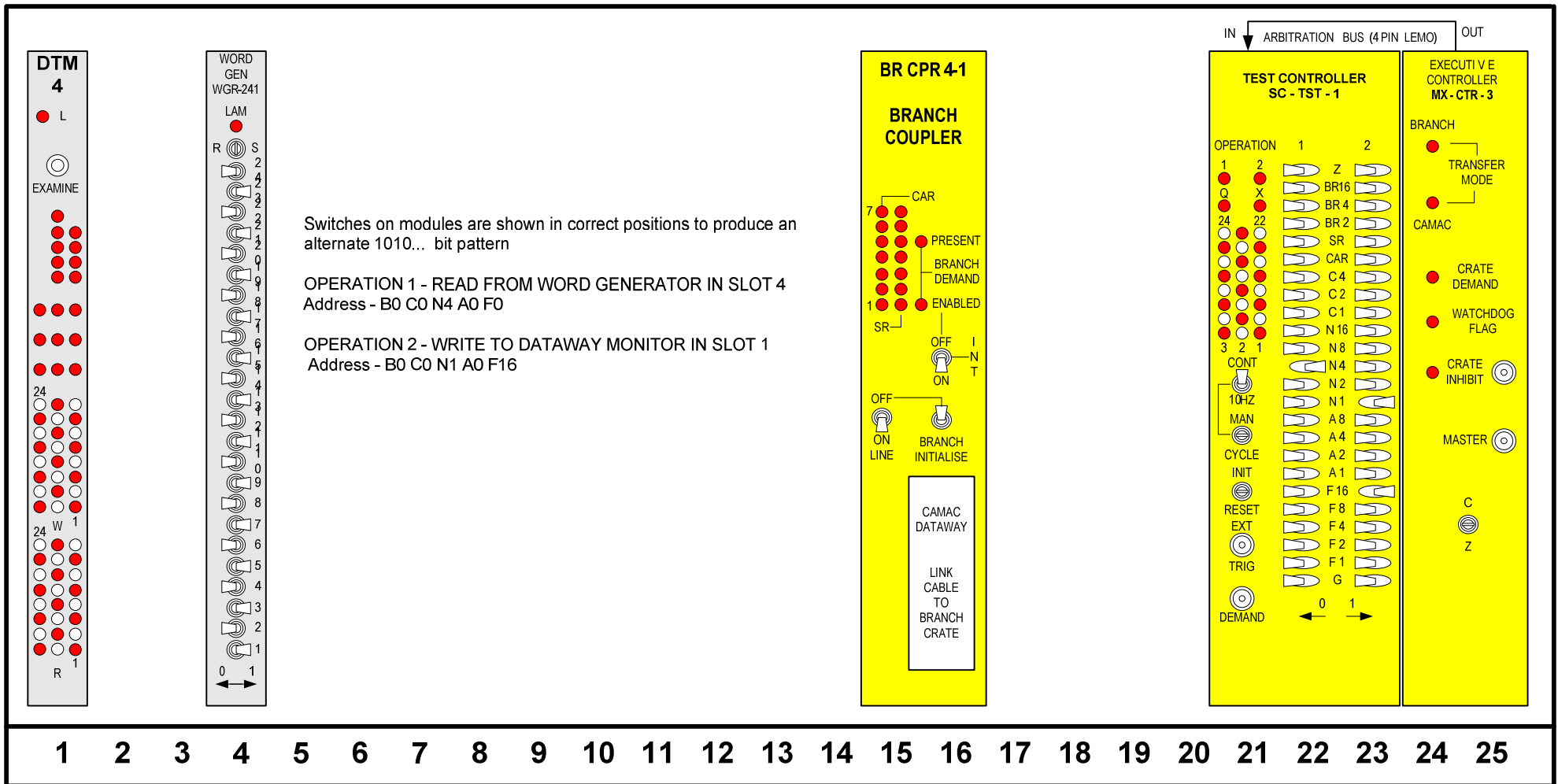
The 3340 RS232 serial communications modules are somewhat difficult to test and require a VT220 terminal or similar to be connected to the 25way D socket on this module. Carlos Martin knows how to test these modules ☺

John Mills

Rev 2.0 May 2014

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CAMAC TESTING   TESTING THE SYSTEM CRATE

Switches on modules are shown in correct positions to produce an alternate 1010... bit pattern

OPERATION 1 - READ FROM WORD GENERATOR IN SLOT 4
Address - B0 C0 N4 A0 F0

OPERATION 2 - WRITE TO DATAWAY MONITOR IN SLOT 1
Address - B0 C0 N1 A0 F16

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

DRAWING No :	System crate test	REV :	1.0	AUTHOR :	E. J. Mills
FILENAME :	test system crate.vsd	SYSTEM :	CAMAC	DATE :	30/5/2010

Figure 25 Testing the System crate

CAMAC TESTING   BRANCH CRATE

Figure 26 Branch crate
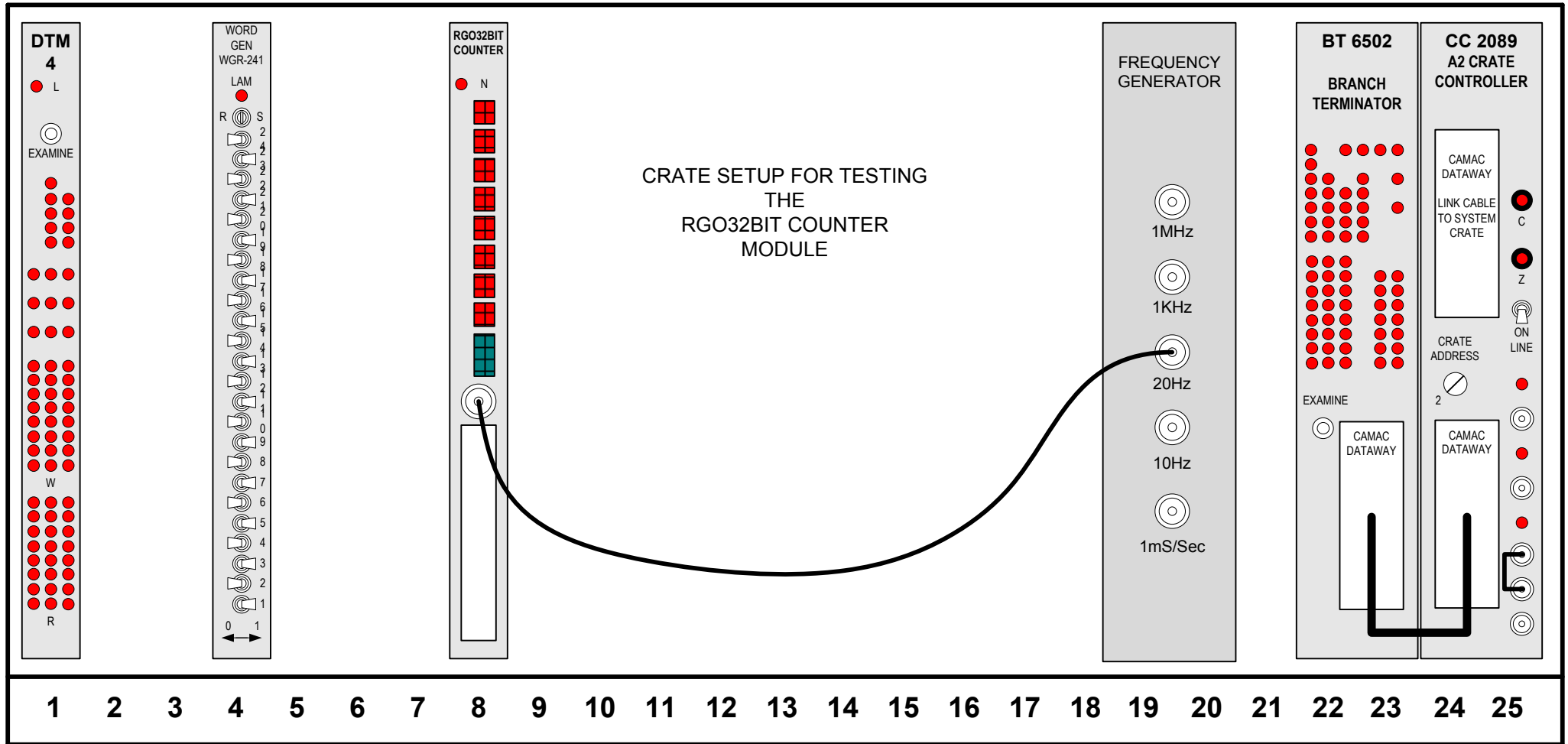
DRAWING No :	Branch crate	REV :	1.0	AUTHOR :	E. J. Mills
FILENAME :	test branch crate.vsd	SYSTEM :	CAMAC		DATE : 7/5/2010