

HESS Mirror Motor Control

Manual

Content

- I. Introduction
- II. Hardware Layout
 - a) Motor Addressing
 - b) Branch Cable
 - c) Branch Driver Board
 - d) Branch Driver Crate
 - e) Branch Control Board
- III. Local Control
- IV. Computer Control via VME
 - a) Block Diagram
 - b) VME Instructions
- V. Wireless Control
- VI. Appendix

I. Introduction

The HESS Telescope is constructed of 384 single mirrors, each adjustable by two actuators driven by simple Bosch motors for car window movement. The electronics for steering that large number of motors has been designed with respect to the following aspects:

- Addressing of one motor at a time.
- Monitoring of movement by counting the step signals provided by the motor.
- Movement of a predefined number of steps (Interval Mode).
- Detection of an unexpected motor halt (end switches are not foreseen).
- Manual and computer controlled steering.
- Design optimisation with respect to costs.

This manual at first gives a short overview of the hardware layout and topology. Then the three different operation modes are described: manual control by front panel switches, computer aided control via VME board and wireless control by means of an rf unit.

The appendix provides a documentation of all helpful schematics, drawings and tables.

II. Hardware Layout

a) Motor Addressing

The total amount of 768 motors is divided into 12 segments of 64 motors each. All motors of one segment are connected by a **Branch Cable** and driven by a so called **Branch Driver Board**. The motor addressing in the segment has been implemented by an eight times eight matrix formed by sixteen wires **X0..X7** and **Y0..Y7**. The matrix signals are decoupled by diodes.

Each motor contains a hall sensor which generates two signals with 90 degrees phase shift. 220 quadrature coded pulses per revolution are generated at the output of the gear. The 64 hall-signal pairs are collected on two lines **K1** and **K2** as wired OR. The scheme of the layout is shown in figure 1.

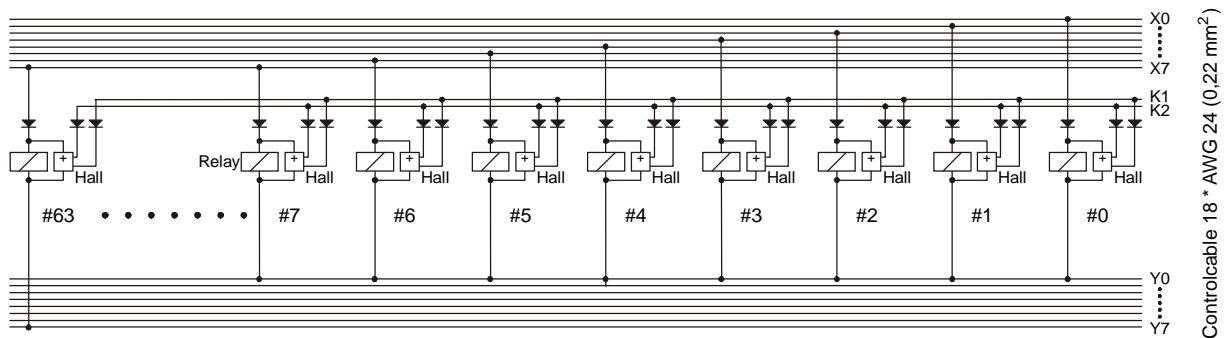


Figure 1: Matrix Selection of 64 Motor Relays and wired OR of the Hall-Signals

b) Branch Cable

The Branch Cable consists of the Control Cable of 18 wires (24 AWG), as shown in fig.1, and a Power Cable ($2 \times 2,5 \text{ mm}^2$). Every 0,7 meter a resin knot forms a T-stub with a one meter long cable, which by means of a seven pin socket watertight plug connects to a relay box at the mirror mounting plate. This relay box contains two relays for the motors of one mirror. One branch cable contain 32 resin knots. The total over all length is 50 m.

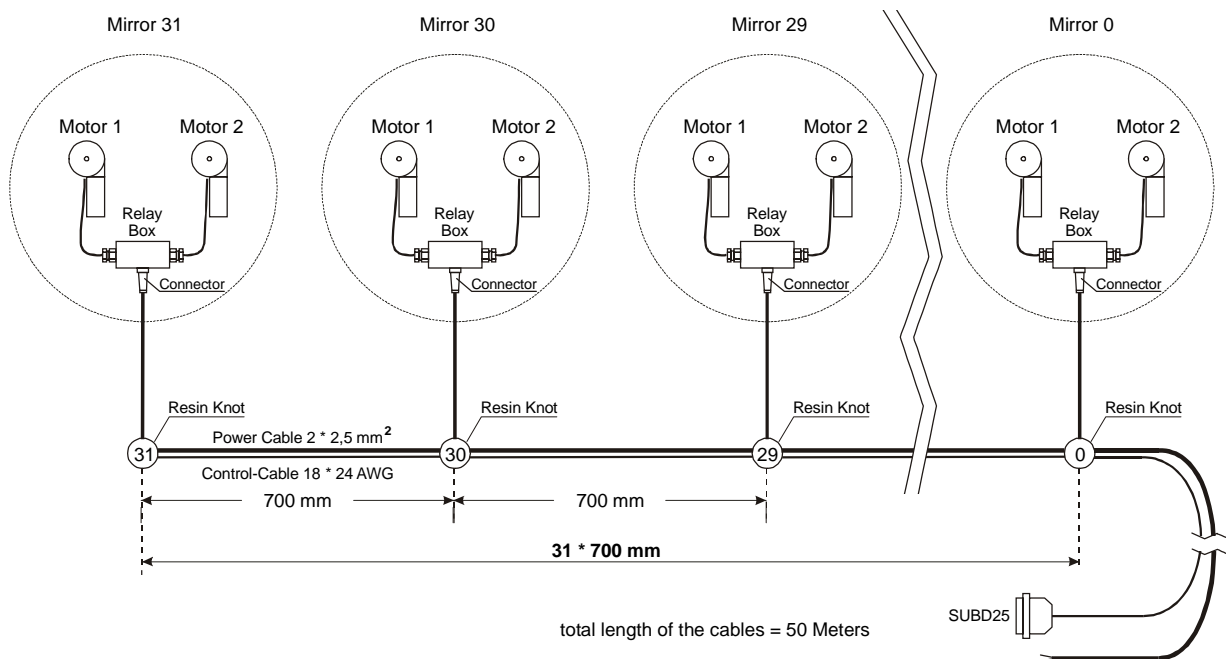


Figure 2: Mirror Motor Connections (one Branch of 32 mirrors)

c) Branch Driver Board

Each Branch is connected to one Branch-Driver-Board. The Control Cable part is plugged at the front via a DSUB 25 connector, while the Power Cable is fixed at a screw terminal on the rear side. Fig.3 shows a schematic view of the board.

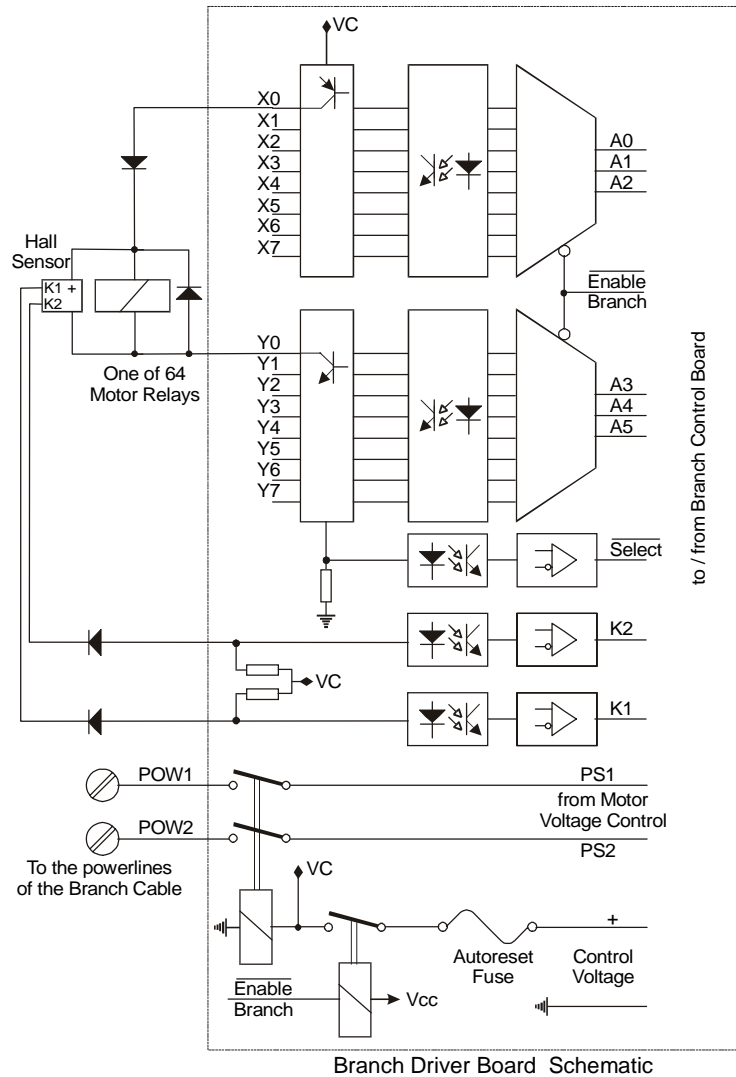


Figure 3: Branch Driver Board Schematic

Only one motor of all branches is selectable at a time. The address bits **A0..A5** coming from the Branch Control Board are decoded to two groups of 8 matrix lines, which are driven by transistors and isolated from the control logic by optocouplers. The successful selection of a motor is acknowledged by the **Select** Flag.

The Branch Driver Board itself is addressed by the **Enable Branch** signal, which also switches the power relay and connects the Power Cable of the Branch to the motor driving chip at the Branch Control Board.

The two Hall Sensor signals **K1,K2** are received on the board and after passing optocouplers are transmitted to the Branch Control Board.

At the front of each Branch Driver Board eight LED's for signals **X0..X7** and eight LED's for signals **Y0..Y7** are indicating the selected matrix co-ordinates. Table 1 shows the co-ordinates for the 64 motor relays.

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7
X0	# 0	# 8	# 16	# 24	# 32	# 40	# 48	# 56
X1	# 1	# 9	# 17	# 25	# 33	# 41	# 49	# 57
X2	# 2	# 10	# 18	# 26	# 34	# 42	# 50	# 58
X3	# 3	# 11	# 19	# 27	# 35	# 43	# 51	# 59
X4	# 4	# 12	# 20	# 28	# 36	# 44	# 52	# 60
X5	# 5	# 13	# 21	# 29	# 37	# 45	# 53	# 61
X6	# 6	# 14	# 22	# 30	# 38	# 46	# 54	# 62
X7	# 7	# 15	# 23	# 31	# 39	# 47	# 55	# 63

Table 1: Motor Numbering by two Groups of 8 Matrix Lines

d) Branch Driver Crate

A Branch Driver Crate can contain sixteen Branch-Driver-Boards, twelve for 768 motors and four spare for further 256 motors (see fig. 4). As indicated the slot defines the Branch Number (geographical addressing).

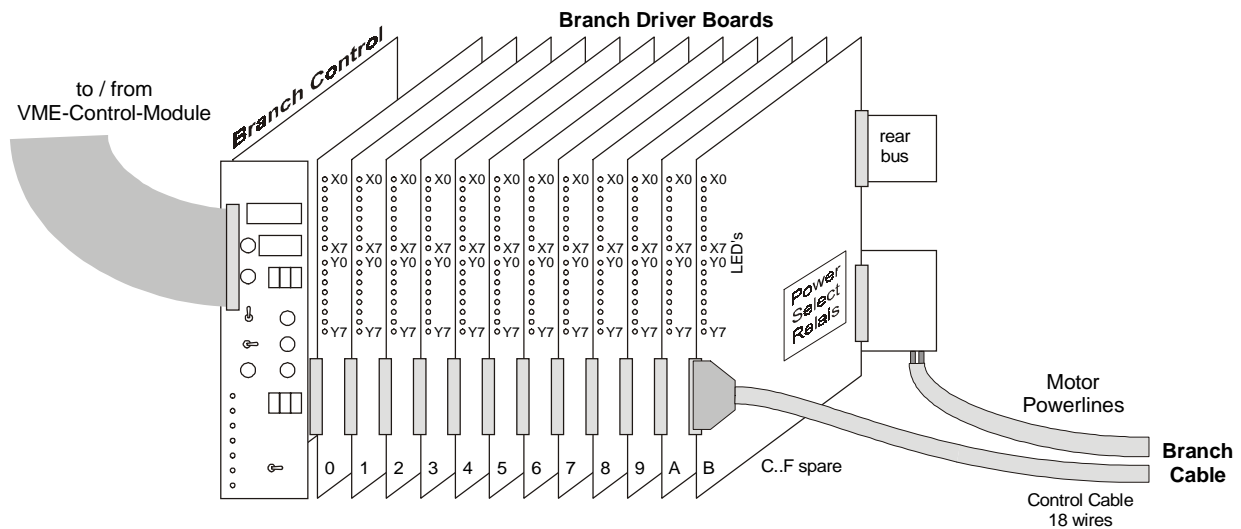


Figure 4: Branch Driver Crate

The left slot of the crate is occupied by the **Branch Control Board**, which addresses all Driver Boards.

e) Branch Control Board

The Branch Control Board mainly contains two counters for position monitoring (**Position Counter**) and predefined distance movement (**Interval Counter**), the start/stop logic and some registers necessary for selecting a motor and its speed and direction. Additionally it generates the pulse width modulated power signals for driving the motor. All the logic has been integrated in one large Complex Programmable Logic Device (CPLD) of type Lattice M4-256/128.

The Mirror Motor Control can be operated in three different modes:

- Local Mode: Control is given to the board's front panel.
- Remote Mode: Via the HMMS VME Board computer control is provided.
- Radio Mode: A reduced control (start, stop, direction) is given to a wireless rf unit

The operation mode can be selected by means of a three position switch at the front panel.

In the following the different components of the board are described in more detail:

Reset

A global system reset has been implemented in order to set the board into a well defined state after power-on or after an error condition. It immediately stops a motor and resets the Command Registers, the Motor Selection Register, the Speed Register and the Status Bits **RUN**, **Select**, **NoMot** and **OverTemp**. Additionally a dedicated reset of error flags is provided.

In Local Mode the global reset is issued by pressing the Reset button. In case of an error the first push clears the error flags only and the second one performs the global reset.

In Remote Mode both global and dedicated resets are issued by VME commands.

In Radio Mode the Reset function is not available.

Command Register

The Command Register contains two bits:

- Run Mode
0: Start/Stop Mode: The motor is halted by the Stop function.
1: Interval Mode: The motor is halted by the Stop function or by the Interval Counter at zero.
In Local Mode the Run Mode is selected by a switch on the front panel.
In Remote Mode the Run Mode is selected by writing to the Command Register via VME.
In Radio Mode only the Start/Stop Mode is available.
- Motor Direction
In Local Mode direction is selected by a switch on the front panel
In Remote Mode direction is selected by writing to the Command Register via VME.
In Radio Mode direction is selected by a switch on the rf unit.

Motor Selection Register

The Motor Selection Register contains 10 bits. The six least significant bits are defining one out of 64 addresses in a branch and the four most significant bits are selecting one out of 16 branches. In principal the register content cannot be modified, while a motor is running.

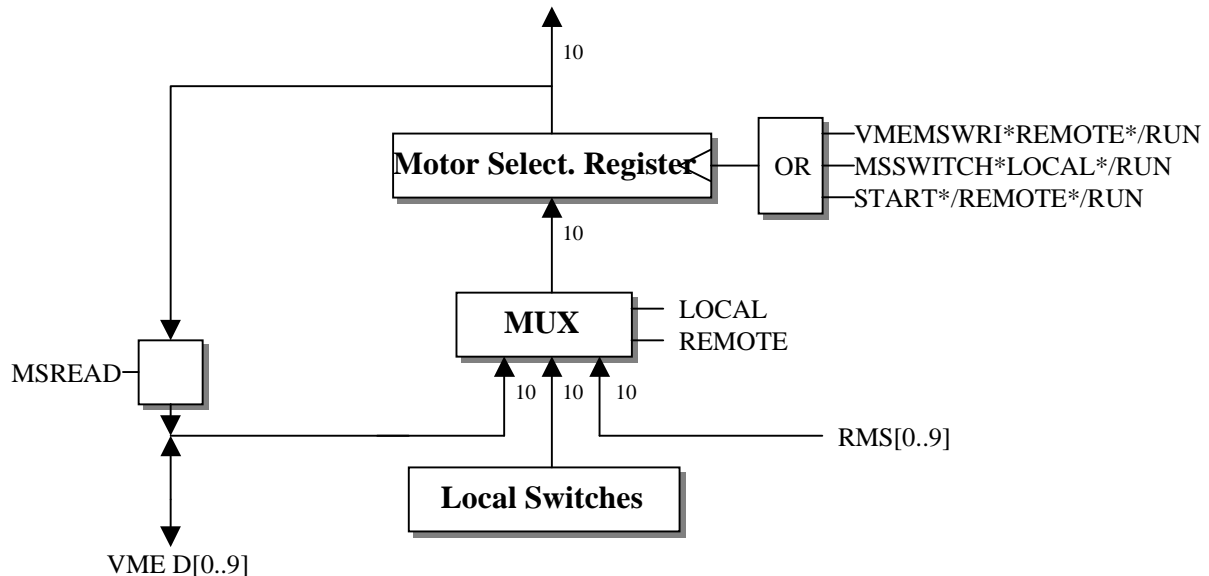


Fig. 5: Motor Selection Register Configuration

In Local Mode motor selection is done by means of three push button switches at the front panel: one hexadecimal switch for the branch and two hexadecimal switches for motor addressing. The actual state of the switches is clocked into the register after pressing the Motor Select Button (MSSWITCH) and once again after pressing the Start Button.

In Remote Mode the Motor Selection Register is written by means of a dedicated VME command. The actual content of the register can be read back via VME.
In Radio Mode the motor selection data RMS[0..9] are multiplexed to the register input and stored by the start procedure.

Speed Selection

For selection of 8 different motor speeds three bits SPEED[0..2].are implemented

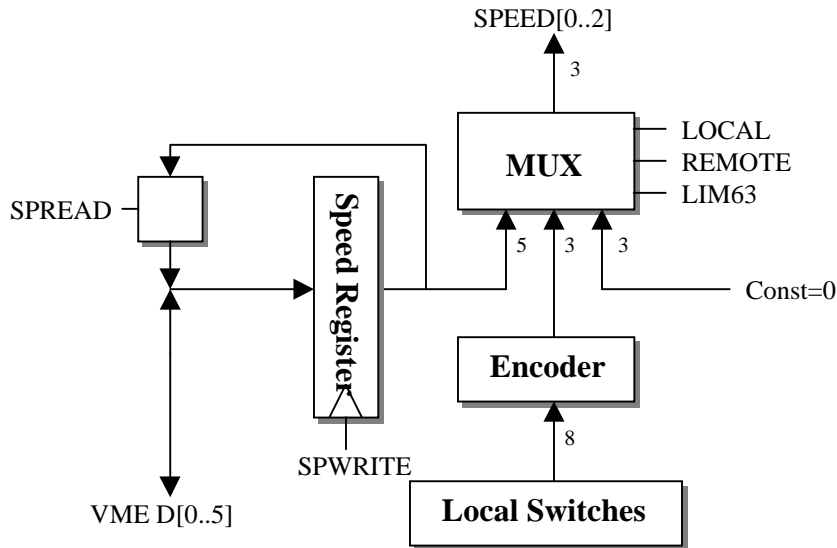


Fig. 6: Speed Selection

In Local Mode and in Radio Mode the speed is given by an 8 position rotary switch on the front panel. The switch states are encoded to the actual speed bits.

In Remote Mode the three least significant bits of the Speed Register determine the actual speed value. The Speed Register can be written and read back by VME. It is cleared by the Reset Function.

If the motor is running in Interval Mode, the speed is changed to the so called creep speed, when the Interval Counter reaches a value less than 64 (LIM63). In Remote Mode the creep speed is given by the three most significant bits of the Speed Register, while in Local Mode it is set to half the actual speed.

The different speeds are implemented by pulse width modulation at constant amplitude. The following table shows the correlation between speed code and duty cycle:

Speed Code	Duty Cycle
0	1:3
1	2:4
2	2:3
3	4:4
4	4:2
5	3:1
6	4:1
7	1:0

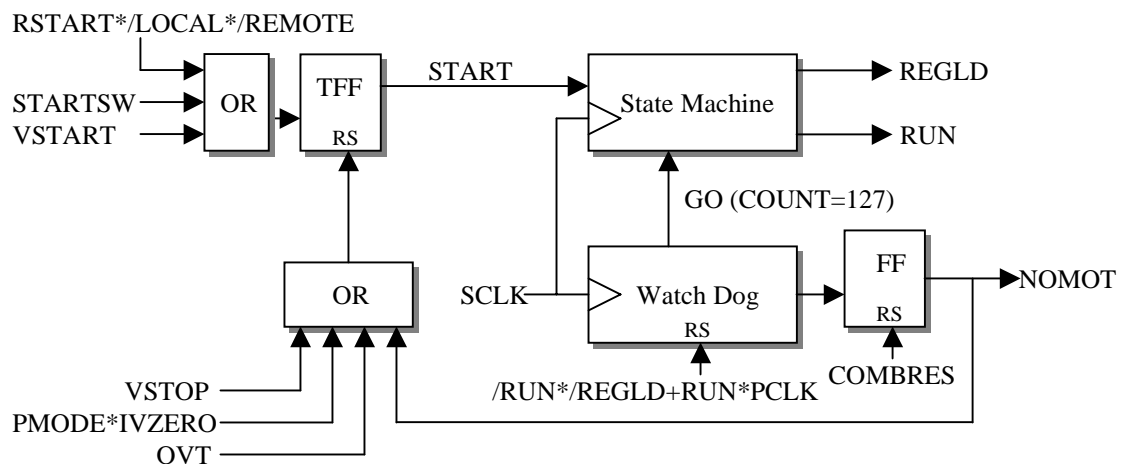
Table 2: Pulse Width Modulation at different speeds

The Status Register contains 6 bits, the state of which is displayed by LED's on the front panel. In Remote Mode it can be read via VME. The following bits are provided:

- | Speed Code | Delay [msec] |
|------------|--------------|
| 0 | 768 |
| 1 | 512 |
| 2 | 256 |
| 3 | 192 |
| 4 | 128 |
| 5 | 96 |
| 6 | 64 |
| 7 | 1016 |

- **OverTemp:** It indicates, that the dedicated power driver chip did become too hot and switched off. It has to be acknowledged by the Reset function.
- **CV:** It monitors the Control Voltage (+15V), which is used to switch the motor relays.
- **MV:** It monitors the Motor Voltage (+15V), which drives the motor.

The Start/Stop logic is shown in the following diagram:



7

The start procedure is initiated by pressing the Start/Stop switch on the front panel (Local Mode), issuing the VME start command (Remote Mode) or sending the start code (Radio Mode). At first a state machine updates the Motor Selection Register and the Interval Counter and then waits for 127 msec in order to let the selected motor relay properly switch. Finally it sets the RUN bit, which enables the motor driver chip to start.

The motor is halted by pressing the Start/Stop button again (Local Mode), issuing the VME stop command (Remote Mode) or sending the stop code (Radio Mode). Further stop conditions are the Interval Counter reaching zero in Interval Mode and the two error flags OVT and NOMOT.

Position Counter

The two Hall sensor signals coming from the active motor, are interpreted by a dedicated chip (HP HCTL2020), which decodes the information and provides a clock pulse PCLK and a direction flag PCUP. By means of a small state machine, this information is transformed to the position sign and the up/down flag of a 15 bit BCD counter (range: -7999..+7999), as shown in the following diagram:

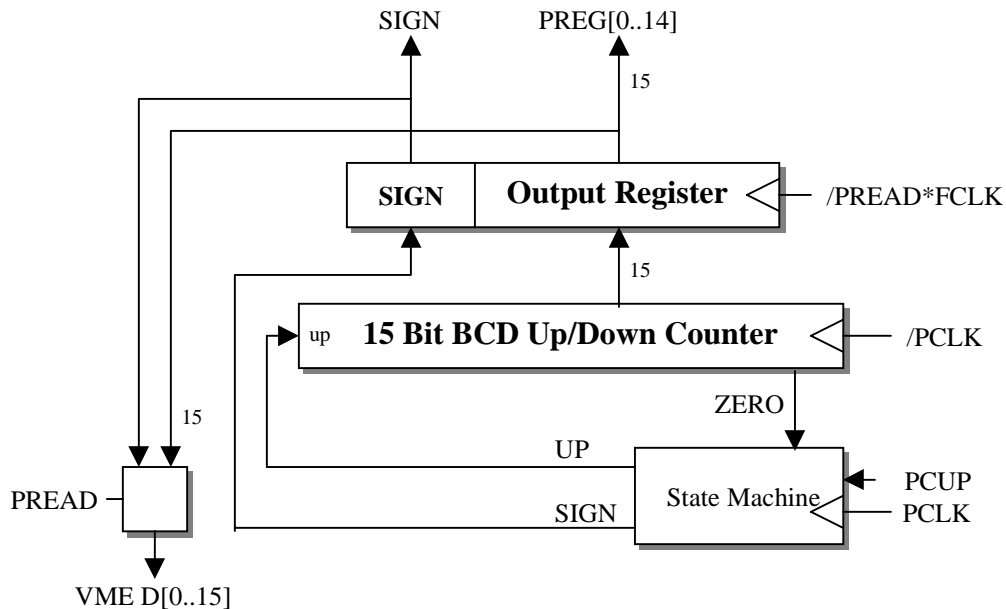


Fig. 8: Position Counter Logic

The Output Register, which is updated by a fast clock FCLK of 1 MHz, drives the Position Display at the front panel and can be read via VME in Remote Mode. During the read cycle the Output Register update is inhibited.

Taking into account an actuator thread pitch of 0.75 mm per revolution, the Position Counter range results in a mechanical stroke of -27.26 .. +27.26 mm.

Interval Counter

The Interval Counter enables to let a motor run a predefined number of steps. The maximum number is 999. The logic configuration is shown in the following diagram:

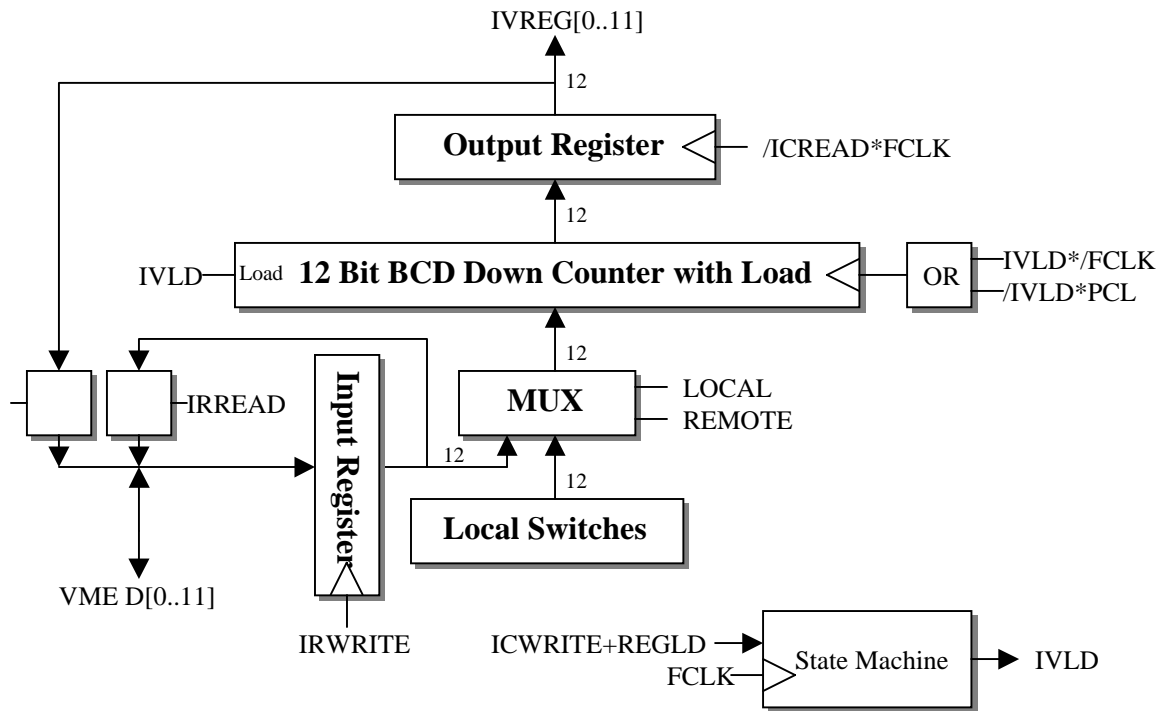


Fig. 9: Interval Counter Logic

In Local Mode the required number of steps is selected by a three digit push button switch at the front panel. The actual state of the switches is loaded into the three digit BCD down counter by pressing the Interval Set button and again (for easy repetition) during the motor start cycle (s. above).

In Remote Mode the Interval Counter is loaded from an Input Register by means of a dedicated VME command (ICWRITE) and also during the start procedure. The Input Register can be set-up by the VME command IRWRITE and can be read back for verification.

In Radio mode the Interval Counter is not used.

The Output Register, which is updated by a fast clock FCLK of 1 MHz, drives the Interval Display at the front panel and can be read via VME in Remote Mode. During the read cycle the Output Register update is inhibited.

The Interval Display is active only in the Interval Mode.

Motor Driver

The active motor is driven by a bridge circuitry, which has been implemented by means of a dedicated chip (SGS-Thomson L6203) with DMOS power transistors, which provide up to 4 A total rms current and a maximum peak current of 5 A. A constant supply voltage of 15 V is used, and the speed variation (s. above) is done by pulse width modulation at a frequency of 1 kHz.

III. Manual Motor Control

In Local Mode motor control can be done manually at the front panel of the Branch Control Board.

Selection of a motor is done by the *BRANCH / MOTOR* Select Switches. (Branch #0..F hex ,

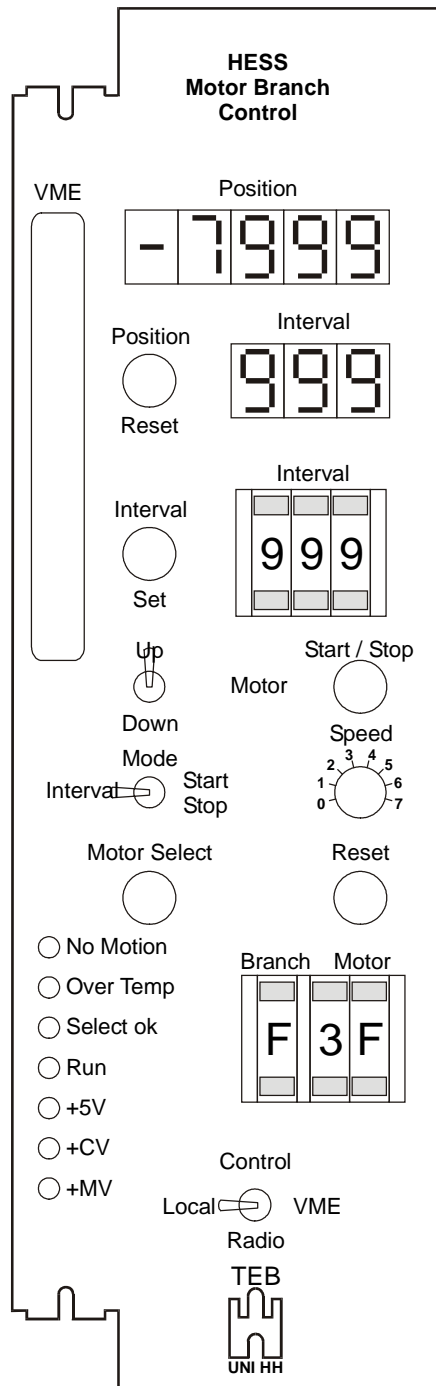


Fig. 10: Front Panel

The lower three green LED's are monitoring the power supplies for the logic (+5V), the Control Voltage CV for switching the motor relays and the Motor Voltage MV for driving the motor.

Motor #00..3F hex) With the *MOTOR SELECT* button one can activate the selection and verify it by observing the LED indicators at the Branch Driver Boards. Another check is provided by the green *SELECT OK* LED, which indicates, that a motor really has been connected successfully. If one does not want to make these checks in advance, he does need to press the *Motor Select* Button, because the *BRANCH / MOTOR* Select Switches are evaluated once again before motor start.

The Run Mode is selected by the *Mode* switch. In *Start/Stop* Mode the motor movement is started by activating the *Start/Stop* Button and halted by pressing it again. In *Interval* Mode an additional stop condition is, that the motor has covered a certain distance, which can be preselected by the *INTERVAL* Switches (max. 999), loaded into the counter by the *INTERVAL SET* button. A new interval with the same count can be simply started by pressing the start button again.

Motor speed can be chosen by an eight position rotary switch *SPEED*. In Interval Mode motor speed slows down to half the actual speed for the last 64 pulses. If the Interval Counter is down to zero, the voltage is switched off and both motor terminals are electrically connected for a brake effect.

Direction of motor movement is set by the *UP DOWN* Switch.

The *Position* Counter (range -7999 to +7999) counts the pulses up and down depending on the direction. At any position this counter can be reset to zero. So the reading is always a relative information.

Since there are no limit-switches foreseen, the Hall Signal pulses are used to detect whether the motor is still running. In all modes the motor power is switched of, if there is no motion. This condition is flagged by the red *NO MOTION* LED.

Another failure, which stops the motor, is an over temperature condition of the H-bridge circuit, which controls the motor power. In both error conditions the system has to be *RESET* by the red button. In principal the Reset function stops a motor, disconnects it from the power and clears the error conditions.

IV. Computer Control via VME

A dedicated VME board has been designed, which provides a link between a common VME crate and the Branch Control Board **BCB**. It allows to access all registers and functions on that board in order to be able to completely set up, operate and monitor the mirror control by computer software.

a) Block Diagram

Fig.11 shows a block diagram of the VME interface board. The four least significant address bits **IAD4..IAD1** together with three control bits are directly sent to **BCB**, because the address decoding is done on that board.

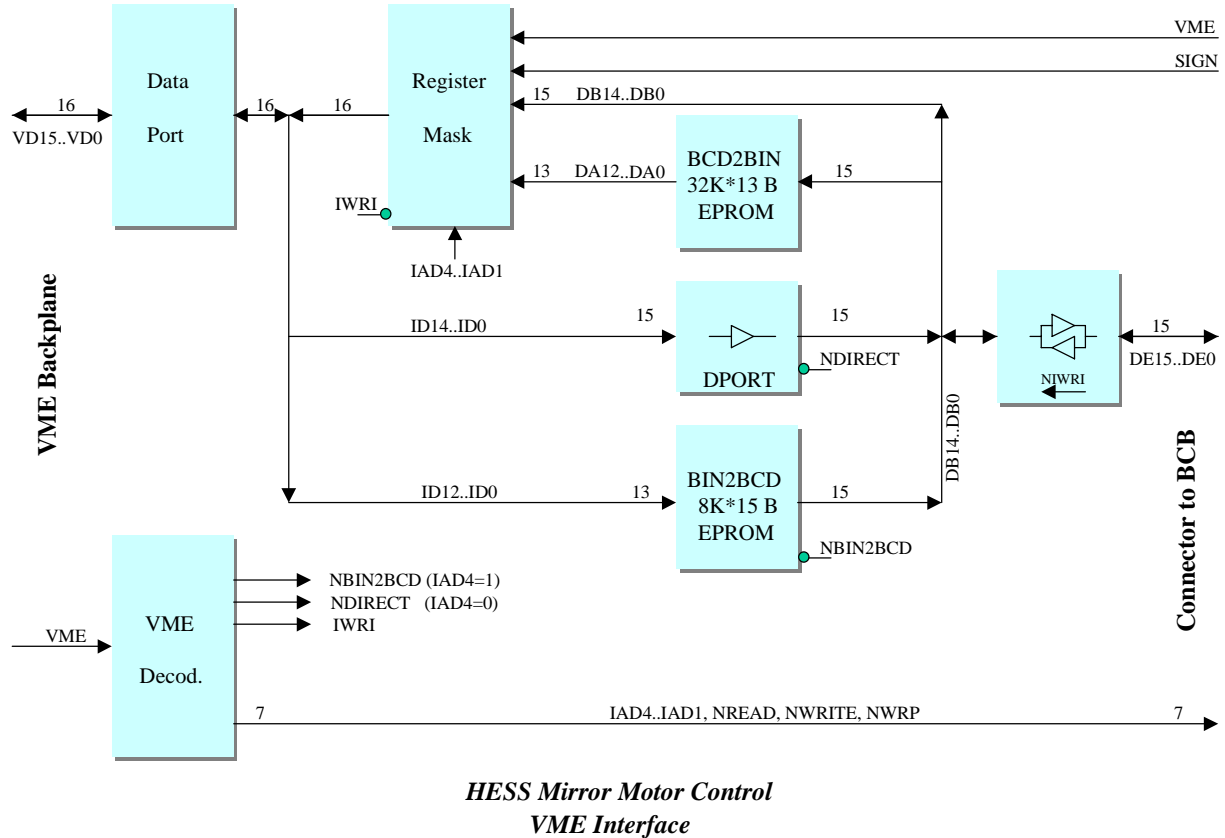


Fig.11: Block Diagram of the VME Board

Data written to the Interval Register are converted from binary to BCD format, because on **BCB** the Interval Counter and the Position Counter are implemented as BCD Counters. Consequently data, which are read from these counters and from the Interval Register, are reconverted from BCD to binary code.

Data transfer to all other registers (**IAD4=0**) is done without any data conversion.

The Register Mask acts as multiplexer between the two possible data paths and masks all unused register bits.

Additionally it contains a Test Register, which stores the data bits **DA12..DA0** for a write access with **IAD4=0** and the data bits **DB14..DB0** for a write cycle with **IAD4=1**. So it allows for a stand-alone test of the board.:

Verification of the BCD to Bin conversion can be done by writing with **IAD4=0** BCD data, which after passing the port **DPORT** are converted and stored in the Test Register in binary code.

On the other hand the BIN to BCD conversion can be tested by writing with **IAD4=1** binary data, which are converted by the **BIN2BCD** EPROM and written to the Test Register.

The most significant Data Bit is reserved for the flag **VME**, which is set to 1 only, if the interface board is connected to the Mirror Controller and if the mode switch on **BCB** is set to VME.

b) VME Instructions

The VME Interface of the board supports **Short Supervisory Access** and **Short Non Privileged Access** (Address Modifier \$29 and \$2D). The address lines are not completely decoded. The four most significant bits **A15..A12** are occupied by the Board Address BAD, which can be selected by means of a 4 bit hexadecimal rotary switch. The least significant 4 bits **A4..A1** are forming the address space of the board. The remaining bits **A11..A5** are not recognised. The following table provides a list of all instructions implemented. The second column gives the instruction address (hexadecimal notation), which has to be added to the Base Address of the board.

The Base Address can be calculated from the Board Address BAD by means of the following formula:

$$\text{Base (Byte Address)} = \text{BAD} * \$1000$$

The complete instruction (byte) address then is given by:

$$\text{Instruct. Address} = \text{Base Address} + \text{Ad},$$

where **Ad** is given by the following table:

Instruction	Ad	A11..A5	A4	A3	A2	A1	Acc
General Clear	0	x	0	0	0	0	write
Read Status Register	0	x	0	0	0	0	read
Write Command Register	2	x	0	0	0	1	write
Read Command Register	2	x	0	0	0	1	read
Write Motor Selection Register	4	x	0	0	1	0	write
Read Motor Selection Register	4	x	0	0	1	0	read
Write Speed Register	6	x	0	0	1	1	write
Read Speed Register	6	x	0	0	1	1	read
Start Motor	8	x	0	1	0	0	write
Stop Motor	A	x	0	1	0	1	write
Clear Error Flags	C	x	0	1	1	0	write
Reset Position Counter	10	x	1	0	0	0	write
Read Position Counter	10	x	1	0	0	0	read
Write Interval Register	12	x	1	0	0	1	write
Read Interval Register	12	x	1	0	0	1	read
Write Interval Counter	14	x	1	0	1	0	write
Read Interval Counter	14	x	1	0	1	0	read
Read Test Register	18	x	1	1	0	0	read

The instructions are shortly described in the following:

General Clear

This instruction resets the State Machine on the board to a defined Ground State. It clears the Command Register, the Motor Selection Register, the Speed Register and the Status Bits **MON**, **SEL**, **OVT** and **NOM**.

Read Status Register

VME	0	0	0	0	0	0	0	0	0	MV	CV	NOM	OVT	SEL	MON
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

- MON:** 0: Motor is off
1: Motor is on
- SEL:** 0: No Motor is selected
1: One Motor is selected
- OVT:** 0: No 'Over Temperature' condition during the last Motor operation
1: The Motor has been stopped because of 'Over Temperature'
- NOM:** 0: The Motor is moving after Start
1: After Start the Motor is not moving
- CV:** 0: Control Voltage is o.k.
1: Control Voltage Failure.
- MV:** 0: Motor Voltage is o.k.
1: Motor Voltage Failure.
- VME:** 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Write Command Register

x	x	x	x	x	x	x	x	x	x	x	x	x	x	DIR	PSM
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

- PSM:** 0: Set the Control Unit into Start/Stop Mode
1: Set the Control Unit into Preset Mode
- DIR:** 0: Set Direction positive (Position Counter will be incremented)
1: Set Direction negative (Position Counter will be decremented)

The Command Register is cleared by the 'General Clear' instruction.

Read Command Register

VME	0	0	0	0	0	0	0	0	0	0	0	0	0	DIR	PSM
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

- PSM:** 0: The Control Unit is in Start/Stop Mode
1: The Control Unit is in Preset Mode
- DIR:** 0: Direction is positive (Position Counter will be incremented)
1: Direction is negative (Position Counter will be decremented)
- VME:** 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Write Motor Selection Register

x	x	x	x	x	x	BR3	BR2	BR1	BR0	M5	M4	M3	M2	M1	M0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

- M5..M0:** 6 bit Motor Number on a Control Branch
- BR3..BR0:** 4 bit Branch Number

Read Motor Selection Register

VME	SEL	0	0	0	0	BR3	BR2	BR1	BR0	M5	M4	M3	M2	M1	M0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

M5..M0: 6 bit Motor Number on a Control Branch

BR3..BR0: 4 bit Branch Number

SEL: 0: No Motor is selected
1: One Motor is selected

VME: 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Write Speed Register

x	x	x	x	x	x	x	x	x	x	CR2	CR1	CR0	SP2	SP1	SP0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

SP2..SP0: 3 bit Identifier of Motor Rotation Speed
0: slowest speed
7: fastest speed

CR2..CR0: 3 bit Identifier of Motor Creep Speed
0: slowest speed
7: fastest speed

Read Speed Register

VME	0	0	0	0	0	0	0	0	0	CR2	CR1	CR0	SP2	SP1	SP0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

SP2..SP0: 3 bit Identifier of Motor Rotation Speed

CR2..CR0: 3 bit Identifier of Motor Creep Speed

VME: 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Start Motor

That instruction starts the motor, which is selected by the Motor Selection Register.

In Start/Stop Mode, the motor is running, until it is stopped by the 'Stop Motor' command.

In Preset Mode, the motor is running, until the Interval Counter is counted to zero or the 'Stop Motor' Command is issued.

Stop Motor

That instruction stops the motor immediately in both operation modes.

Clear Error Flags

That instruction resets the Error Flags **OVT** and **NOM**.

Reset Position Counter

That instruction sets the Position Counter to zero.

Read Position Counter

VME	SGN	0	P12	P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	P0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

P12..P0: 13 bit position information

SGN: 0: Sign is positive
1: Sign is negative

VME: 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Write Interval Register

0	0	0	0	0	0	IR9	IR8	IR7	IR6	IR5	IR4	IR3	IR2	IR1	IR0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

IR9..IR0: 10 bit preset value (range: 1..999) for interval movement in Preset Mode. It is written to the Interval Counter either by the VME Command 'Write Interval Counter' or automatically by the VME Command 'Start Motor'. The direction has to be set by the Command Register.

Read Interval Register

VME	0	0	0	0	0	IR9	IR8	IR7	IR6	IR5	IR4	IR3	IR2	IR1	IR0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

IR9..IR0: 10 bit preset value for interval movement in Preset Mode.

VME: 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Write Interval Counter

The 10 bit preset value, stored in the Interval Register, is written to the Interval Counter.

Read Interval Counter

VME	0	0	0	0	0	IC9	IC8	IC7	IC6	IC5	IC4	IC3	IC2	IC1	IC0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

IC9..IC0: Current Status of the Interval Counter.

VME: 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Read Test Register

VME	T14	T13	T12	T11	T10	T9	T8	T7	T6	T5	T4	T3	T2	T1	T0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

T14..T0: Test Register Bits.

VME: 0: The Motor Control Unit is not switched to VME mode or
the VME Board is not connected to the Control Unit.
1: The VME board has access to the Motor Control Unit

Any Write Access with **A4=0** writes the data of Bus **DA12..DA0** (see block diagram) to the Test Register.

Any Write Access with **A4=1** writes the data of Bus **DB14..DB0** (see block diagram) to the Test Register.