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HARDWARE OF THE CTF3 BEAM POSITION MEASUREMENT SYSTEM

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Abstract

The paper describes the Beam Position Measurement hardware developed for the drive beam linac of the CLIC Test Facility 3 (CTF3). The system, capable of measuring both, the beam position and absolute current, is a part of an R&D facility and should therefore be flexible to work in unforeseen conditions. For that reason, its operation can be changed gradually from completely automatic, controlled by software, to full autonomous analogue mode, with an oscilloscope as the observation tool. During its testing and calibration, the system can be optionally independent of external signals. The paper describes the functionality of the system as a whole and of its particular modules. The interface between the modules and the system software is also outlined.

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1. Introduction

The paper describes the Beam Position Measurement hardware developed for the drive beam linac of the CLIC Test Facility 3 (CTF3) [1]. The system, capable of measuring both, the beam position and absolute current, is a part of an R&D facility and should therefore be flexible to work in unforeseen conditions. For that reason, its operation can be changed gradually from completely automatic, controlled by software, to full autonomous analogue mode, with an oscilloscope as the observation tool. During its testing and calibration, the system can be optionally independent of external signals. The paper describes the functionality of the system as a whole and of its particular modules. The interface between the modules and the system software is also outlined.

2. System structure

The block diagram of the system, reduced to three channels, is shown in **Fig. 1** and the diagram of one channel with one pick-up is shown in **Fig. 2**. Further figures, namely **Fig. 3**, **4**, **5**, **6**, and **7**, present functional parts of the system. Each part is described separately.

The part of the system concerning beam analogue signals of one channel is shown in **Fig. 3**. The Inductive Pick-Up (**IPU**) [2] senses the azimuthal distribution of the beam image current. Its construction is similar to a wall current monitor, but the pick-up inner wall is divided into electrodes and each of which forms the primary winding of a toroidal transformer. The beam image current component flowing along each electrode is transformed to a secondary winding, connected to a pick-up output. Four pick-up output signals drive an active hybrid circuit being part of the Head Electronics (**HE**) module [3], located close to the pick-up. The active hybrid produces two difference (**Δ**) signals proportional to the beam horizontal and vertical positions, and one sum (**Σ**) signal, proportional to the beam current. The bandwidth of these signals, ranging from below 1 kHz to beyond 150 MHz, exceeds five decades. Even if the IPUs and HE are the only components of the system that work, one can still use an oscilloscope connected to the Δ and Σ signal cables to estimate the beam position from the signal amplitudes.

The Δ and Σ signals from the HE are sent to the equipment room, where they are split into three outputs by the Distribution Amplifier, hosted in a NIM crate. One output of each channel is bandlimited by an antialias low-pass filter and this output is connected to one channel of a digitizer. The second output is reserved for full bandwidth oscilloscope observations and the third is a spare one.

The 8-channel 12-bit 100 MHz digitizers SIS 3300 [4], occupying a VME crate, convert analogue pick-up signals into digital words with the clock rate of 96 MHz (the 5th harmonic of the 19.2 MHz RF frequency), delivered by the Digitizer Clock module, shown in **Fig. 4** together with other modules involved in signal acquisition and control. The digitizers are controlled through the VME bus by the Digital Stub Controller (**DSC**), running a real time program. The program executes operator commands sent from a workstation application program, prepares the digitizer acquisitions, transfers the signal samples from the digitizer memory to the DSC memory, processes the samples, calculates the beam position and charge, and finally, makes them available for workstation application programs. The DSC also controls the whole system by means of one VMOD-TTL and one VMOD-DOR digital ports.

The acquisition triggers are produced by the TG8 timing VME unit. They are distributed to each digitizer in the crate by the Trigger Distribution module [5]. The trigger connections from the Trigger Distribution module to the digitizers are made by coaxial cables of the same length to guarantee synchronous acquisitions of all digitizers.

The manual interface to the system is provided by the Main Control Unit (**MCU**), connected to the system by a VMOD-TTL digital I/O port. In manual mode, the operator can set the system state by front panel switches of the MCU. The MCU also interfaces the digital I/O ports to the HE modules as well as the Calibration Current Generator (**CCG**) [6]. The CCG generates current pulses of precise amplitude, simulating the beam current. Paths of analogue calibration signals are shown in **Fig. 5**. The pulses are commuted to the HE of one selected pick-up by built in analogue multiplexer of the CCG and, as a second layer of the distribution, by 16 Channel Analogue Multiplexer. The HE module accommodates another switch (third layer of distribution), allowing connecting the calibration current to the IPU calibration inputs. Each electrode transformer of the IPU has an additional turn to which a fraction of this current is applied to calibrate the sensor for accurate beam position and current measurements.

The system contains also two electrostatic and two button pick-ups. The electrostatic pick-up is connected to the HE through the Buffer Amplifier module [7], as shown in **Fig. 6**, adapting high impedance pick-up outputs to the low impedance of the HE module. The button pick-up, presented in **Fig. 7**, is followed by the Downmixer microwave circuitry, connected to the HE module. Calibration signals are received directly by the Buffer Amplifier of the electrostatic pick-up. The button pick-ups have no calibration. For that it would be needed some 3 GHz signals, very difficult to produce and handle.

3. System operation

During normal operation with the beam signals, an operator controls the system using an application program running on a workstation. The application program communicates by a network link with the real time program running on the DSC. The DSC program controls the digitizers directly over the VME bus and other system modules by the digital I/O cards, connected to the MCU module. The MCU puts into effect the control of the system software.

The TG8 module triggers the digitizer acquisitions synchronously to the beam. The acquisitions stop automatically after the previously set number of data is collected. The acquisitions start before and stop after the beam transitions to digitize also the pick-up signals without the beam. This is needed to detect base lines and residual droops of the signals for further amplitude calculations.

During system calibration or testing without beam, the system operation is very similar, but the acquisition trigger of the TG8 also triggers the CCG, delivering current pulses simulating the beam to one selected pick-up. The acquisitions are run as with the beam but they are longer to accommodate the travel time of the calibration signals from the generator to the pick-up. To test the system current pulses of 1.5 μs are used. For system calibration pulses of 150 μs are used and the acquisitions have to be long enough to cover this period. Longer pulses are used to increase the calibration accuracy. Since only one pick-up is tested or calibrated at the time, more memory is needed just for the corresponding digitizer channels and only this pick-up data needs to be transferred to the DSC memory.

For system testing, development or unusual use, a few special modes of operation have been foreseen with the calibration signals of the CCG. They are described hereafter.

Software controlled CCG signals operation without TG8 timings and without RF frequency

The CCG pulses can be triggered by a hardware trigger, by the DSC software or by an internal trigger of the zero-crossings of the 50 Hz mains. The input of the Trigger Distribution module, normally connected to the TG8, can be connected to the trigger output [(1)] of the CCG for triggering the digitizers synchronously to the CCG pulses. The acquisitions are run as with the beam but they should be longer to accommodate the travel time of the calibration signals from the generator to the pick-up. Longer acquisitions are also beneficial to increasing the observation span of the signals.

The system operator should have a possibility to switch the digitizers from the external clock to its internal clock of 100 MHz. In this case, the RF frequency is not needed to test the system and its operation is independent of Digitizer Clock module.

Manually controlled operation with the CCG pulses

At any time the system control can be switched into manual mode by a front panel switch of the MCU. The switch state is reflected by one bit of the VMOD-TTL input port, which should be read periodically by the real time DSC program to detect that the system is in the manual mode. This is needed only for operator information and the system can work in the manual mode even without the DSC being on.

In the manual mode the gain of the HE amplifiers depends on the position of an MCU front panel switch. Another two switches can be used to direct the current pulses into the pick-up positive and/or negative calibration inputs and the active pick-up is selected from the front panel of the CCG. For the system testing it is recommended to use high gain and to direct the calibration pulses to the pick-up positive calibration input. In this case the pick-up signals are similar to those of the beam providing that the CCG is set to generate the short pulses of 1.5 μs. The CCG has to be switched also into manual mode using its front panel switch, otherwise it is still under software control. The fact that the CCG is in the manual mode can be also detected by reading the VMOD-TTL input port. The pick-up to which the CCG pulses are sent is selected from the front panel of the CCG. The pick-up response to the calibration pulses can be observed on an oscilloscope connected to the distribution amplifier module of the selected pick-up.

The CCG pulses can be triggered by a software trigger (one bit of the VMOD-TTL output register), TG8, zero crossings of the 50 Hz mains, or another arbitrary signal connected to the trigger input of the CCG. The trigger source is selected by a CCG front panel switch.

Operation with arbitrary testing/calibration signals

The input of the built-in CCG analogue multiplexer, normally connected to the pulsed current source, can be connected to any arbitrary signal source, such as a network analyzer. This allows system testing/calibration with other signals, including calibration in the frequency domain.

[(1)] This output is not shown on the diagrams.

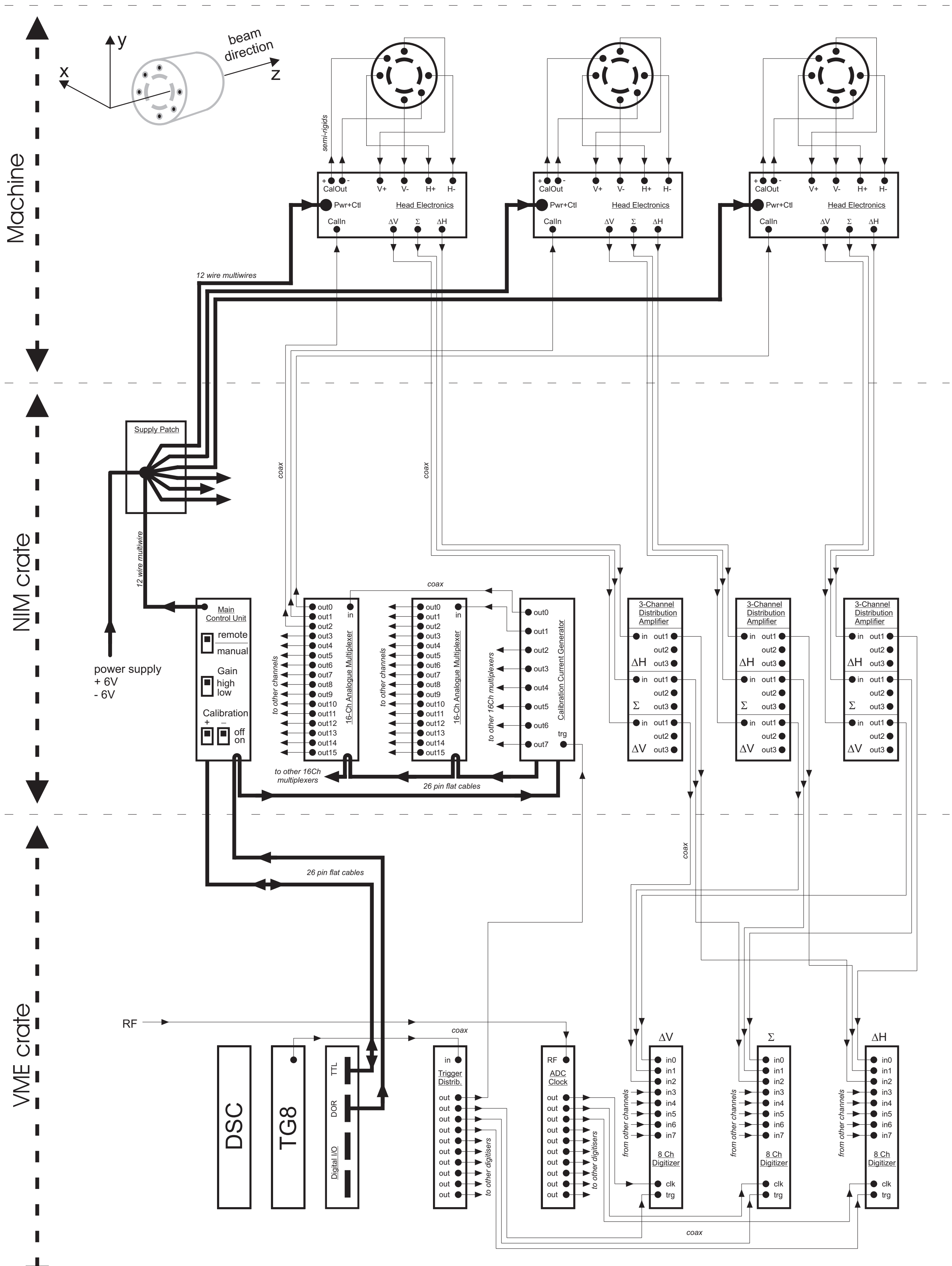

Figure 1. The block diagram of the CTF3 BPM system with three IPUs shown.

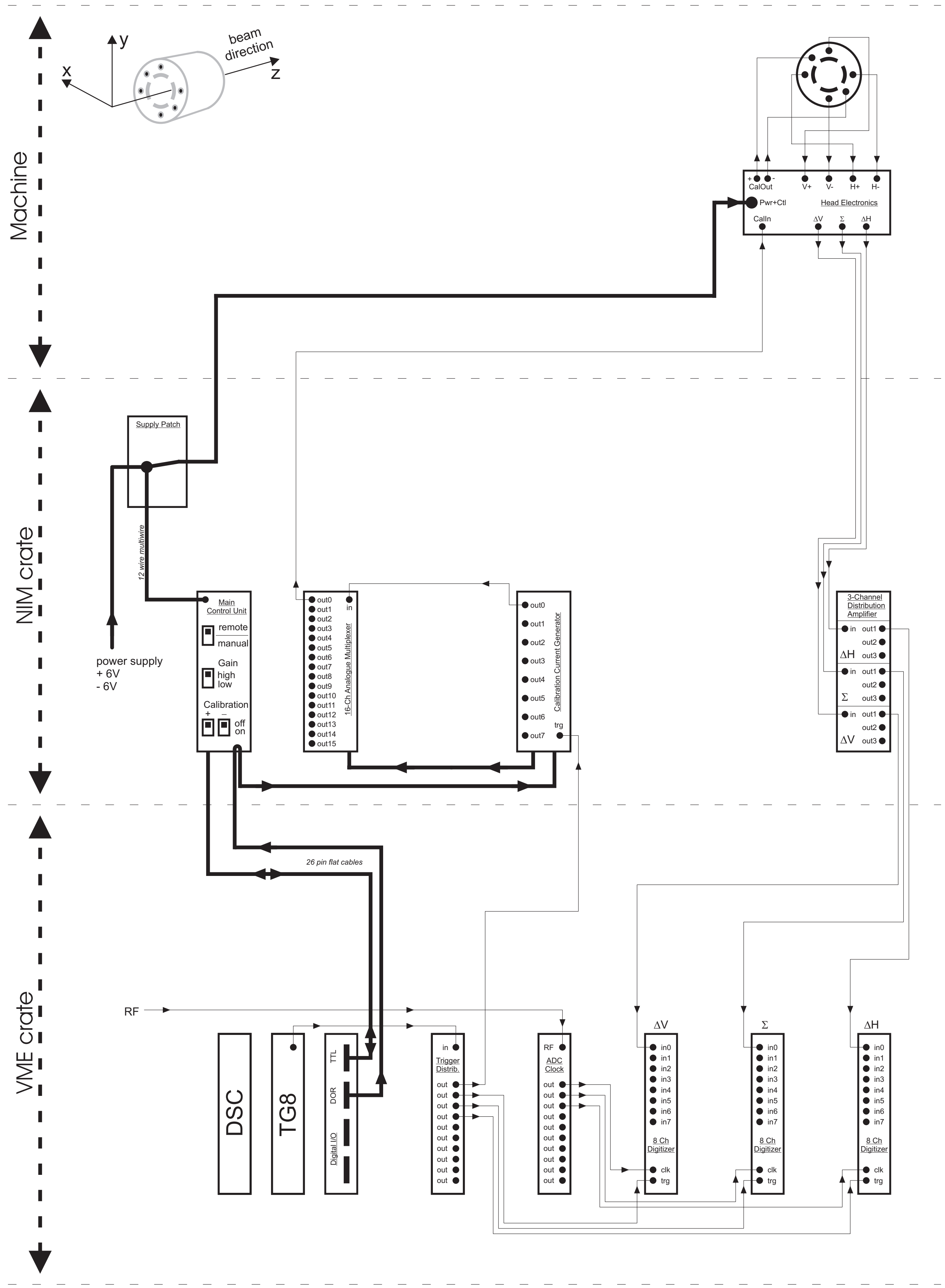

Figure 2. The diagram of one channel of the CTF3 BPM system.

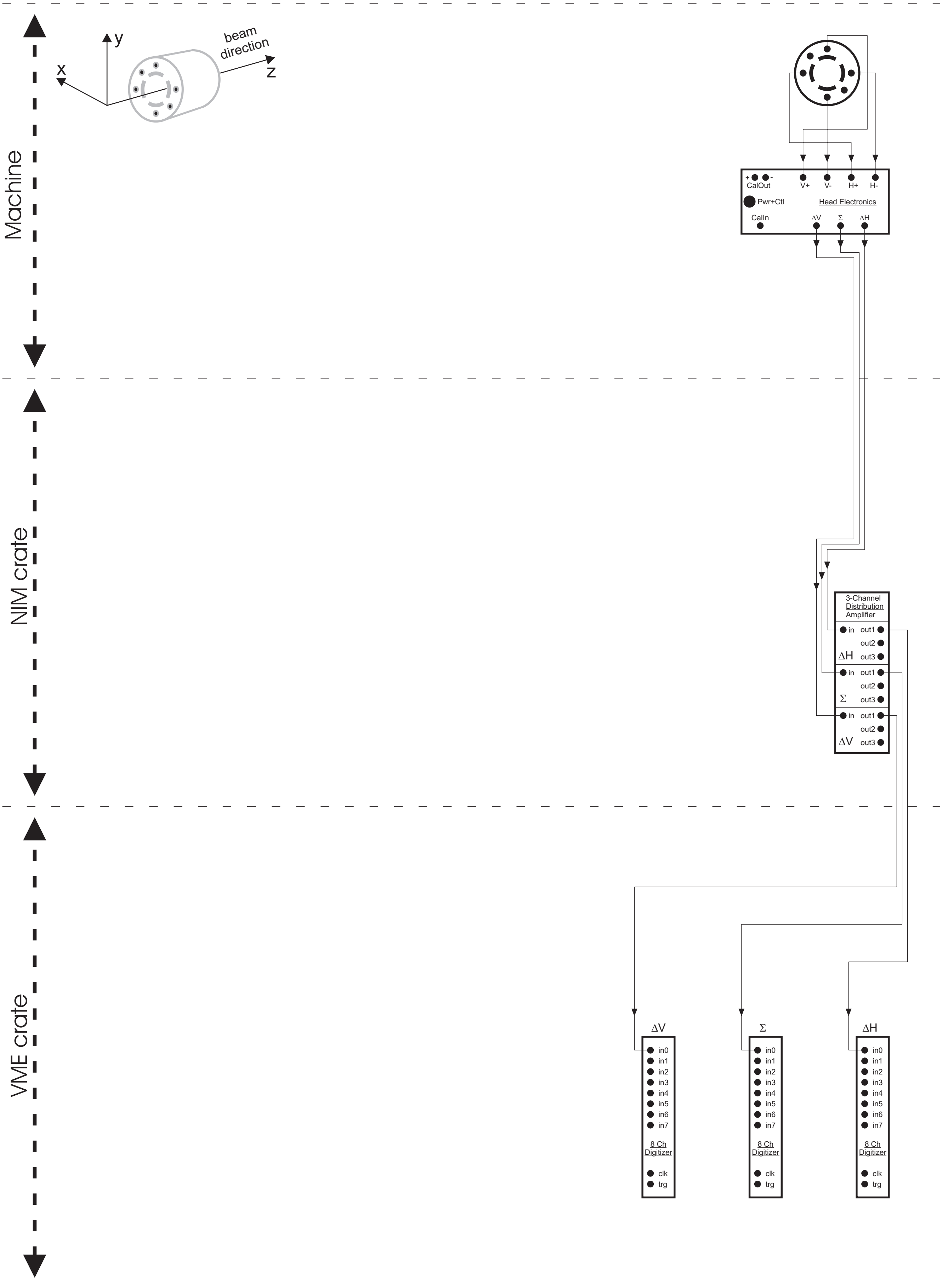

Figure 3. Part concerning the pick-up signals of one system channel.

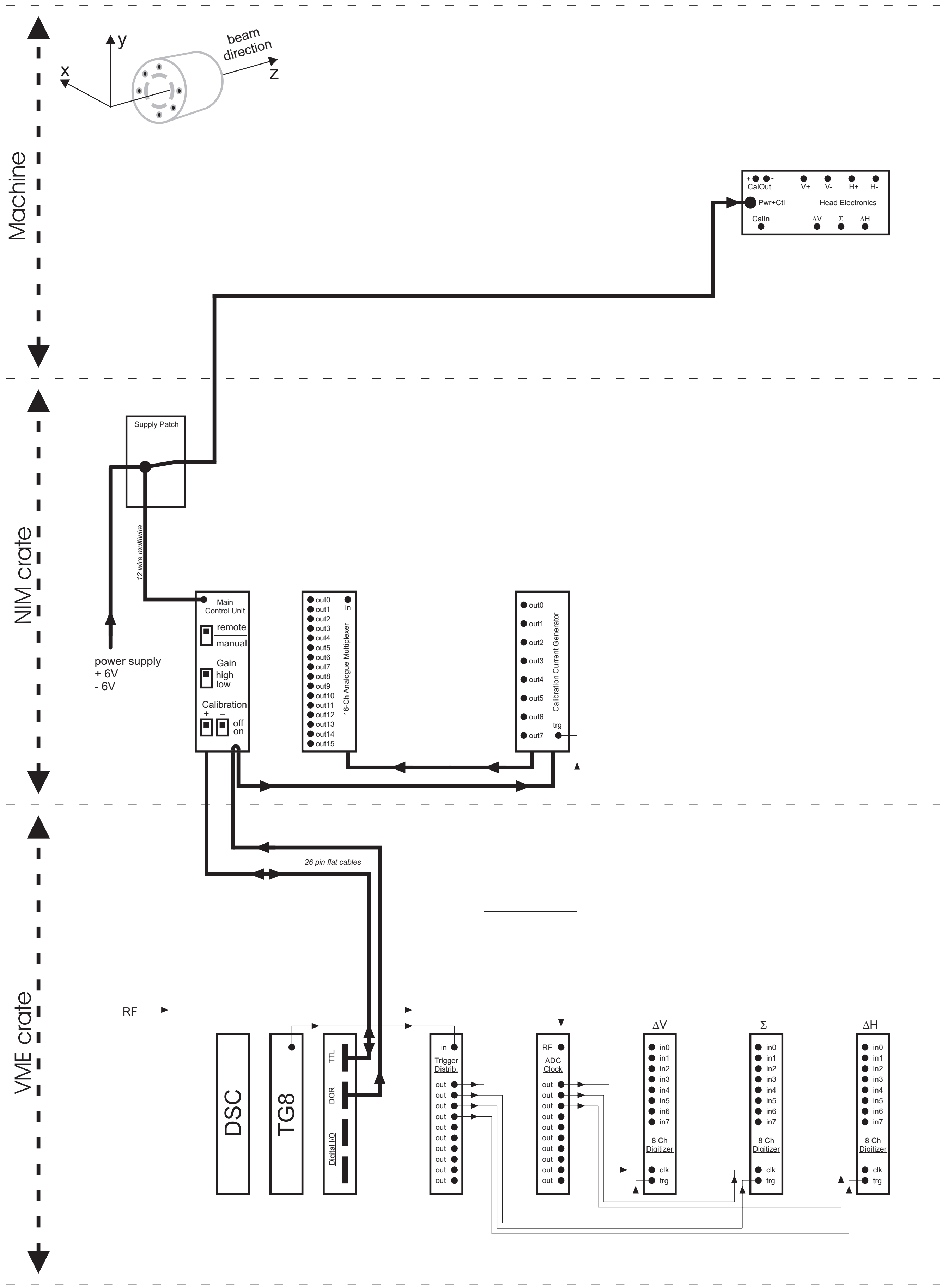

Figure 4. Part concerning the system control and signal acquisitions.

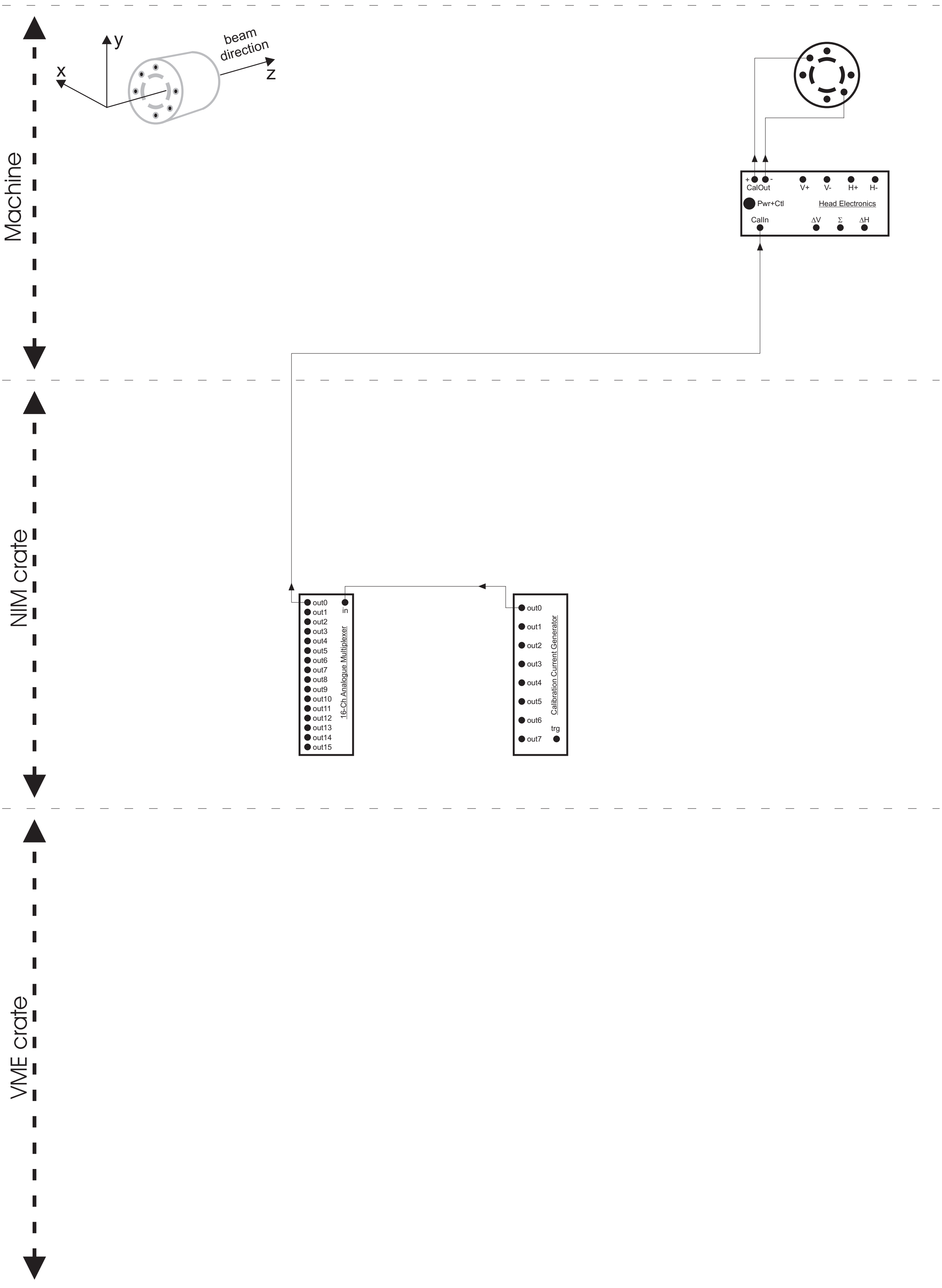

Figure 5. Calibration signal paths for one system channel.

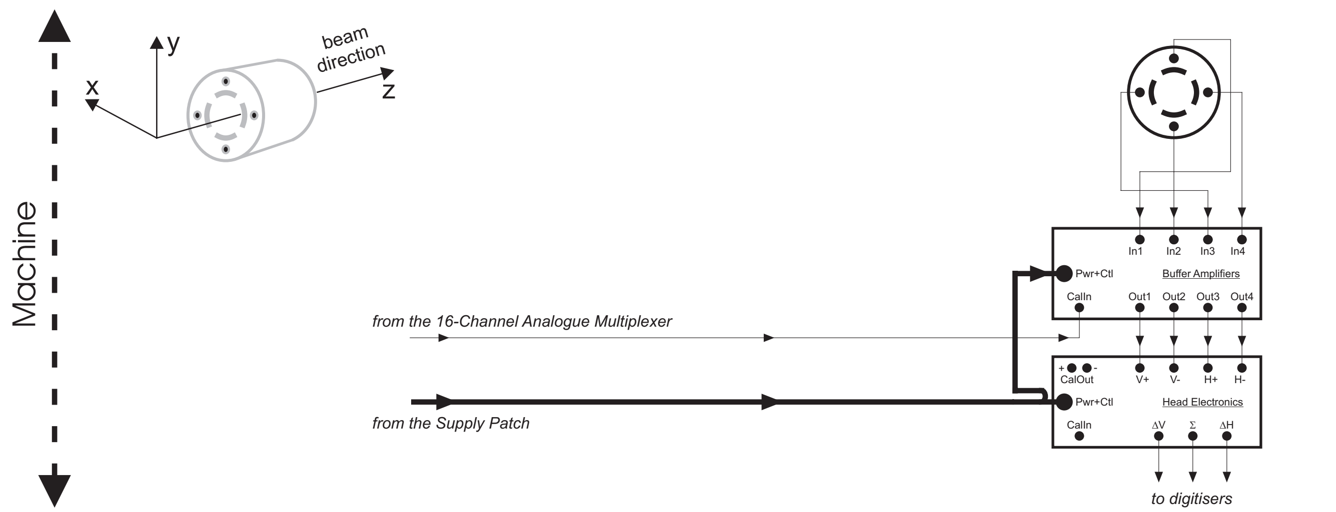

Figure 6. Beginning of a system channel with an electrostatic pick-up (there are two in the system). Additional Analogue Multiplexer module is inserted between the pick-up electrode outputs and the Head Electronics module.

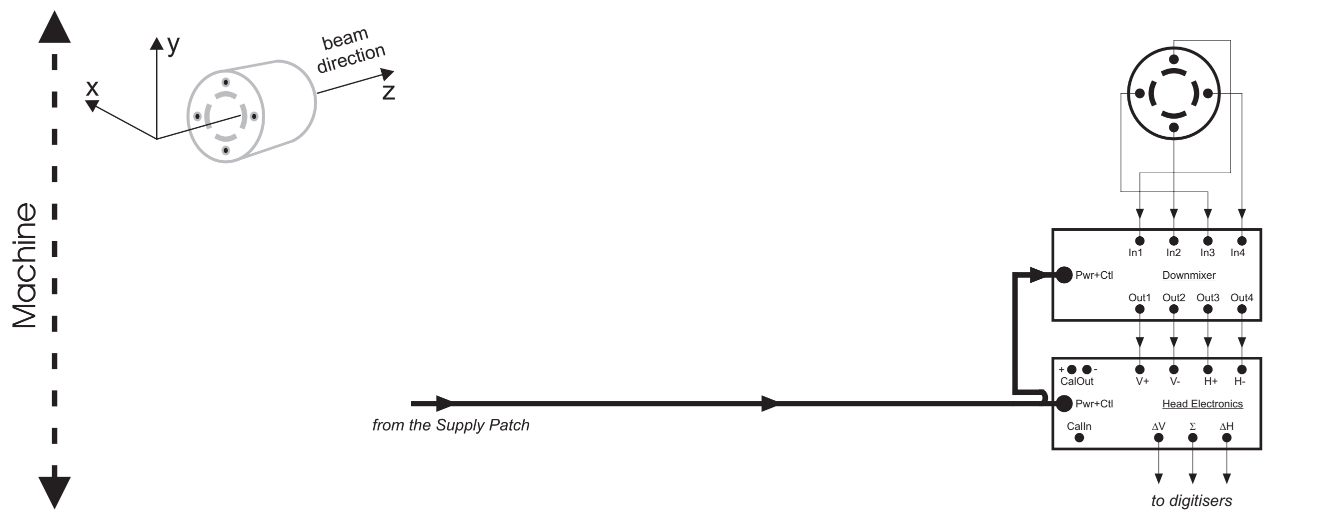

Figure 7. Beginning of a system channel with a button pick-up (there are two in the system). Additional Downmixer microwave circuitry, here shown as one block, is inserted between the pick-up electrode outputs and the Head Electronics module.

4. Coordinate system and signal polarities

The coordinate system chosen is shown on the block diagrams. The longitudinal beam axis z points downstream, to the particle movement direction, the y vertical axis is oriented upwards, the horizontal x axis points to the left as looking downstream (in z positive) direction. This convention is valid also for the CTF3 rings. All pick-up electrode signals are of negative polarity for an electron beam, and as a result, Σ signals are also negative. All Δ signals are negative for positive beam displacements, as to have the Σ to Δ ratio corresponding to the displacement sign. This implies that the horizontal Δ signal (ΔH) is a difference of the left and right electrode signals as looking downstream, and vertical Δ signal (ΔV) is a difference of the top and bottom electrode signals. The corresponding connections between the pick-ups and HE are shown on the diagrams. Relations between the beam displacement, the displacement measured, electrode and HE signals are summarized in **Table 1**.

Table 1. The signal polarities for the beam in different quarters of the coordinate system. Abbreviations: L, R, T, B – left, right, top and bottom electrode signals respectively.

Beam displacement	Measured displacement	Electrode signals				HE output signals		
		L	R	T	B	**Σ** G_{Σ}(L+R+T+B)	**ΔH** G_{Δ}(L – R)	**ΔV** G_{Δ}(T – B)
none	zero	¯⊔¯	¯⊔¯	¯⊔¯	¯⊔¯	¯⊔¯	—	—
left	H positive	¯⨆¯	¯⌣¯	¯⊔¯	¯⊔¯	¯⊔¯	¯⊔¯	—
right	H negative	¯⌣¯	¯⨆¯	¯⊔¯	¯⊔¯	¯⊔¯	_⊓_	—
upward	V positive	¯⊔¯	¯⊔¯	¯⨆¯	¯⌣¯	¯⊔¯	—	¯⊔¯
downward	V negative	¯⊔¯	¯⊔¯	¯⌣¯	¯⨆¯	¯⊔¯	—	_⊓_

The CCG calibration pulses are of positive polarity. The IPU electrode transformers are wound in such a way that these pulses produce negative signals at the IPU outputs, thus the Σ signals are negative for both, beam and calibration signals.

The IPUs have two calibration signal inputs. The left and top electrodes are connected to one input, called Cal+, and the right and bottom electrodes to the second input, called Cal-. When applying the calibration signal to the Cal+ input (Cal+ mode), response signals of negative polarity appear on the left and top pick-up outputs. Similarly, applying the calibration signal to the Cal- input (Cal- mode), response signals of negative polarity appear on the right and bottom pick-up outputs. To test the common mode rejection of a pick-up and of its HE module, the calibration signals can be applied simultaneously to both, Cal+ and Cal- inputs (Cal0 mode). In this case, it is simulated a beam in the pick-up centre.

The calibration modes, corresponding hypothetical beam positions, polarities of the IPU electrode signals and of the HE output signals are summarized in **Table 2**.

Table 2. Calibration signals and corresponding simulated beam positions.

Calibration mode	Simulated displacement	Electrode hypothetical signals				HE output signals		
		L	R	T	B	**Σ** G_{Σ}(L+R+T+B)	**ΔH** G_{Δ}(L – R)	**ΔV** G_{Δ}(T – B)
Cal+	H positive V positive	¯⨆¯	—	¯⨆¯	—	¯⊔¯	¯⊔¯	¯⊔¯
Cal-	H negative V negative	—	¯⨆¯	—	¯⨆¯	¯⊔¯	_⊓_	_⊓_
Cal0	H zero V zero	¯⊔¯	¯⊔¯	¯⊔¯	¯⊔¯	¯⊔¯	—	—

For the electrostatic pick-up the CCG calibration pulses of positive polarity are inverted by an external transformer and they are sent to the pick-up electrodes over the cables connecting the pick-up to the Buffer Amplifiers module, from the module side. Tables 1 and 2 apply also to the electrostatic pick-up.

5. System special modules

5.1. Head Electronics (HE) [3]

- The module produces Σ and Δ signals from four pick-up electrodes (the inductive pick-up has 8 electrodes, but they are combined in pairs, here considered as single electrodes).
- It amplifies Σ and Δ signals from the mV range, too small to be sent over some 100 m long cables going to the equipment room, to the input level of the digitizers (range ±2 V). The pick-up signals are sent to the HE module by very good quality semi-rigid coaxial cables, about 2 m long.
- The amplifiers have two remotely controlled gains, differing exactly by a factor of 10. This allows good adaptation to the digitizer input span as the beam intensity changes. High gain is foreseen for beam currents up to 0.7 A and low gain for currents from 0.7 A to 7 A [(1)].

[(1)] The HE modules for electrostatic and button pick-ups have modified gains to work with beam currents up to 10A (different values for some components).

- It makes correction for low frequency components of Δ signals, by amplifying them more than components of higher frequencies [1]. This allows lowering the low cut-off frequency of the pick-up signals by a decade, to below 1 kHz. The Σ signal channel has no correction, since its low-cut off frequency is below 300 Hz.
- It contains two relays switching the calibration input signal to the pick-up positive calibration input (Cal+ mode), the negative calibration input (Cal- mode) or both (Cal0 mode). This allows to have only one calibration signal coaxial cable going to the machine.

Inputs

- 4 pick-up electrode signals, SMA connectors
- calibration signal input, SMA connector
- power supply ±6V and controls, connector: male Burndy 12 pin

Outputs

- Σ, ΔH, ΔV signals, SMA connectors
- 2 calibration signal outputs (connected to the pick-up calibration inputs), SMA connectors

Type: a special module put into Al box 180 × 120 × 60 mm, author: M. Gasior

5.2. 3-Channel Distribution Amplifiers

- The module distributes each of the Σ and Δ signals to three outputs.
- All channels have gain of 1.
- One output for each channel has low-pass filter meant as antialias filter for the digitizers.

Inputs

- 3 inputs for Σ, ΔH, ΔV signals, BNC connectors

Outputs

- 3 times 3 outputs, Lemo connectors

Type: NIM, author: J. Tan

5.3. Main Control Unit (MCU)

- The module puts into effect remote control for the whole system. It is connected to the digital port modules: one VMOD-TTL and one VMOD-DOR.
- It distributes the control signals to the HE and CCG modules.
- The MCU is normally in a remote mode, allowing full remote control of the system by the DSC real time software, i.e. all options mentioned hereafter can be set remotely. One can also switch the module and whole system into a manual mode, in which the system can be operated without any external signals. In this case the CCG produces test or calibration pulses sent to the calibration inputs of a pick-up. See the section concerning CCG for further details.
- In the manual mode, the gain of the HE amplifiers can be high or low, depending the position of a front panel switch *GAIN*.
- In manual mode, the system can be put into following states by the MCU front panel switches *CAL+* and *CAL-*:
  - Operation with the beam: both switches in the off position. The calibration signal, even when generated by the CCG, is not connected to any pick-up and the pick-ups are sensitive only to the beam passes.
  - Calibration of the positive beam displacement: switch *CAL+* on, and *CAL-* off. The calibration current is sent to the positive calibration input of the pick-up selected from the CCG front panel. It is as the beam was passing in the left upper corner of the pick-up aperture, as looking downstream. The Δ signals have the same polarity [2] as Σ signal and their amplitudes are about two times larger.
  - Calibration of the negative beam displacement: switch *CAL+* off and *CAL-* on. The calibration current is sent to the negative calibration input of the selected pick-up. It is as the beam was passing in the right bottom corner of the pick-up aperture. The Δ signals have opposite polarity as the Σ signal and their amplitudes are about two times larger.
  - Calibration zero: both switches in the on position. The calibration current is sent to both positive and negative calibration inputs of the selected pick-up. This simulates a beam passing through pick-up centre.

[1] The HE modules for electrostatic and button pick-ups have no correction (some components not soldered to the module PCB).

[2] For all IPUs the Σ signal is negative for both, the electron beam and the calibration signals. For a beam of positive charges the Σ polarity would be positive.

In this case the Δ signals have zero amplitudes, exact to a residual fraction of the Σ signal related to the finite common mode rejection.

Digital I/O signals

- 26 pin flat cable connected to the VMOD-TTL module used as one 8-bit input (port A) and one 8-bit output port (port B).
- 26 pin flat cable connected to the VMOD-DOR module used as one 16-bit output. This cable is daisy chained to the CCG.

Power supply and control signals

- Power supply ±6 V, controls to the Head Electronics: Cal+, Cal-, Gain, connector male Burndy 12 pin. A 12-wire cable with all these signals goes to the supply patch, to drive control signals of the HE modules. All HE modules are controlled in parallel.

Type: NIM, author: M. Gasior

5.4. Calibration Current Generator (CCG) [6]

- Even though the system is called "position measurement system" it is also able to give a precise measurement of the beam absolute current. The CCG is a crucial part of this feature.
- There is only one such a generator for the whole system and it is connected to only one channel at a time. This allows to produce and maintain one precise module and to calibrate each channel with exactly the same current value.
- Each IPU electrode passes through its transformer ring, transforming the beam current (primary winding) to the secondary winding, connected to a pick-up output. On this transformer there is one additional turn, which is used to inject the calibration current, simulating the beam. As seen from the pick-up output, there is virtually no difference between the calibration and beam currents. This allows to simulate the beam current with very good precision, and in consequence, to calibrate the system for precise absolute measurement of the beam current. In the calibration process, a current from a precise current source is sent through calibration turns of the pick-up, and the output Σ and Δ signal are measured to determine the transfer ratio of the pick-up Σ amplitude to the calibration current value. Since inductive pick-ups are sensitive to currents (not to voltages), and current is used for calibration, the current value injected into calibration turns is independent of parasitic resistances (cables, connectors, relays) and very good calibration accuracy can be achieved. Current pulses of the CCG are also used for testing the whole system pick-up by pick-up without the beam.
- The module can produce current pulses of 300 mA amplitude, exact to 0.1%. The pulses are sent to a calibration input of one selected pick-up. This allows to test and calibrate the whole system channel by channel, in manual mode without the beam and digitizers working, no timing, no clocks nor control signals are needed. The only external things needed are power supply voltages and an oscilloscope connected to a distribution amplifier [(1)] (every amplifier has one output reserved for that).
- The current pulse duration can be set to 1.5 µs, used to simulate the beam, or 150 µs, used to calibrate the system. Both values can be chosen by the software as well as from the module front panel. A longer pulse is needed to measure the droop of the Δ and Σ signals and for stabilizing the current in long coaxial cables going to a pick-up in the machine.
- The module can be in one of the four modes:
  - *REMOTE*: The module is fully controlled by software and all features mentioned hereafter are available, except *CALIBRATION* mode, which can be turned on only from the module front panel.
  - *MANUAL+EXTTRG* (manual with an external trigger): The module is controlled from its front panel and the current pulses are synchronized to the trigger pulses coming to the front panel *TRG* input. During normal operation the *TRG* input of the CCG is connected to one of the outputs of the Trigger Distribution module, distributing the TG8 triggers, and the CCG current pulses are synchronized to the TG8 acquisition triggers.
  - *MANUAL_IT* (manual with the internal trigger): The module is controlled from its front panel and the current pulses are synchronized to zero-crossings of the 50 Hz mains. The module has also a trigger output (not shown on the block diagrams). This output can be connected to the input of the Trigger Distribution module to synchronize digitizer acquisitions to the CCG pulses.
  - *CALIBRATION*: This mode is dedicated for amplitude calibration of the generator current pulses. The pulses are converted to voltage by a precise resistor and this voltage is subtracted from a reference voltage by a resistive bridge. The difference can be adjusted to zero with accuracy much better than 0.1% (0.3 mA) by oscilloscope observations. The 0.1% overall accuracy is set by long term stability of a CCG reference.

[(1)] The distribution amplifier is not needed if one connects the oscilloscope directly to the Σ and Δ signal patch, grouping all cables coming from the machine.

- The CCG module has its own, relay based, analogue multiplexer with one input (normally connected to the current pulse generator) and eight outputs (limit from the CCG front panel size). Since the CCG pulses are sent to each pick-up individually, there are not enough channels for all system pick-ups. For that reason, each multiplexer output can be connected to the input of the Analogue Multiplexer module, to have another layer of signal distribution. See Analogue Multiplexer section for further details. The active CCG multiplexer output and the output of the Analogue Multiplexer output (i.e. the index of a pick-up), to which the current pulses are sent, is selected by the software or, in the manual mode, by two CCG front panel hexadecimal code wheels. One of them selects the active CCG output and the second the active output of the Analogue Multiplexer module.
- The module can be directly controlled by a VMOD-DOR module, without the intermediate MCU.
- To limit the power dissipation in the module and in the pick-ups, the CCG pulses have to be spaced at least by 5 ms. Software as well as hardware triggers coming too often are ignored.
- The current pulses are blocked for 10 ms after each change of the active pick-up. This is to avoid switching relays when they carry the pulse current in order to extend the relay lifetime.

Input

- trigger input, accepted levels: TTL, NIM, ECL, PECL, jumper selectable positive or negative slope, Lemo connector

Outputs

- 8 multiplexed current pulse outputs, Lemo connectors
- trigger output, TTL level of jumper selectable polarity, Lemo connector
- calibration *PULSE* out (output pulse monitoring), 1.5 V on 50 Ω, SMA connector
- calibration *ZERO* out (for adjusting to zero the difference between the pulse amplitude and the reference voltage), output impedance 10 kΩ, SMA connector

Digital I/O signals

- 26 pin flat cable connected to the VMOD-DOR module (normally through daisy chained MCU)

Type: NIM, author: M. Gasior

5.5. Analogue Multiplexer (AMUX)

- It is a slave module of the CCG. It commutes a single input to one of its sixteen outputs. It is based on relays, since it has to deal with current of 300 mA, giving on a load of 50 Ω voltage of 15 V.
- One CCG, having 8 outputs, can have 8 slave Analogue Multiplexer modules, so the system can handle up to $8 \cdot 16 = 128$ pick-ups.
- The module is controlled remotely through CCG or manually by a CCG front panel switches.
- Digital control from one CCG can be daisy chained to 8 Analogue Multiplexer modules.
- The module can be also controlled via VMOD-DOR digital I/O module, without the intermediate CCG. In this case it can be used as a standalone module for multiplexing arbitrary signals.
- The Analogue Multiplexer is based on coaxial RF miniature relays, resulting in good signal quality.

Input

- multiplexer input, Lemo connector

Outputs

- 16 multiplexer outputs, Lemo connectors

Digital I/O signals

- 26 pin flat cable connected to a CCG module

Type: NIM, author: M. Gasior

5.6. Trigger Distribution [5]

- The module distributes one TG8 trigger to 16 outputs, connected to digitizer modules.
- It adapts the $\overline{\text{TTL}}$ level of the TG8 to NIM level of the digitizer trigger.
- It uses only power supply voltages from the VME bus. VME module format has been chosen only to simplify the cabling of the system (the module should be close to the digitizers, preferably in the same crate).
- It has been developed as a universal module suitable also for other purposes. It can be used as analogue distribution amplifiers in configuration one input – sixteen outputs, or four independent channels with one

input and four outputs. The module contains also logic level translators, which may be connected to the amplifiers according to needs. Implemented are the following translations:

- TTL to NIM and NIM to TTL,
- TTL to PECL and PECL to TTL,
- TTL to ECL and ECL to TTL.

The abovementioned levels can be also inverted on the TTL side.

The module contains also a place and connectors on the module PCB to mount a mezzanine board to implement other unforeseen features. The module PCB is suitable for both standards, VME and NIM.

Input

- input of the distributed signal, Lemo connector

Outputs

- 16 outputs, Lemo connectors

Type: VME, author: M. Gasior

5.7. Buffer Amplifiers of the Electrostatic Pick-Ups [7]

- The module, shown in **Fig. 6**, adapts high-impedance electrode outputs of the electrostatic pick-up to low impedance of the HE.
- For the electrostatic pick-ups the HE modules have different gains than those for IPUs and the Δ channels have no frequency characteristics correction.
- The module receives directly the calibration signal, omitting the HE module.

Inputs

- 4 pick-up electrode signals, SMA connectors
- calibration input, SMA connector
- power supply ±6V, +5V, and controls, connector: male Burndy 5 pin

Outputs

- 4 buffered signals, SMA connectors

Type: a special Al box, author: L. Søby

5.8. Downmixer of the Button Pick-Ups

- The module, shown in **Fig. 7**, mixes down button pick-up electrode signals from 3GHz range.
- For the button pick-up the HE module has modified gains and the Δ channels have no correction of frequency characteristics.
- The button pick-ups have no calibration for which some 3 GHz signals would be needed, very difficult to produce and handle.

Inputs

- 4 pick-up electrode signals, SMA connectors
- power supply ±6V, +24V, and controls, connector: male Burndy 12 pin

Outputs

- 4 downmixed signals, SMA connectors

Type: microwave plumbery, author: L. Søby

6. Interface to the system software

The system is controlled by means of one VMOD-TTL (digital input and output) and one VMOD-DOR (digital output) cards. The bit distribution of the ports and their functionality, listed in **Table 3** and **Table 4**, defines the interface to the system software. A header file defining masks for bit manipulations on the digital ports is shown in **Listing 1**.

When the MCU is in the manual mode, the bits A0-A2 of the VMOD-TTL port A, configured as an input, reflect the positions of the MCU front panel switches. In the remote mode, the bits are copies of the bits B0-B2 of the VMOD-TTL port B, configured as an output. This allows testing the MCU and its connection to the

VMOD-TTL card by changing the bits and testing if they correspond to each other. Bit A3 read as 1 means that the MCU is in the manual mode. Similarly, bit A7 read as 1 indicates a manual mode of the CCG module.

In the remote mode, the VMOD-DOR bits D6-D0 point to the pick-up, to which the CCG pulses are sent. Bits D6-D4 point to the active Analogue Multiplexer module, since one CCG module can have up to eight slave Analogue Multiplexers, and bits D3-D0 point to one of the sixteen outputs of the active Analogue Multiplexer module. Bit D7 is used to select the pulse length of either 1.5 µs, foreseen for system testing, or 150 µs, dedicated to the system calibration. Bit D8 is used to trigger the CCG by software, bit D9 to select either software or hardware trigger for the CCG module, and bit D10 to switch the CCG module to the internal trigger of 50 Hz.

7. Specialist mode of the main application program

The system operator application program should have a specialist mode dedicated to hardware testing and calibration. In this mode a hardware specialist should be able to:

- See the states of all VMOD-TTL and VMOD-DOR bits.
- Manipulate all VMOD-TTL and VMOD-DOR output bits.
- Change the digitizer acquisition length up to filling the whole memory of one digitizer channel by one acquisition (128 K samples, corresponding to some 1.4 ms with the clock of 96 MHz).
- Store in an ASCII format all acquisition samples of the channel corresponding to the pick-up, to which the CCG pulses are sent.
- Switch the digitizers to theirs internal 100 MHz clocks. Slower rates would also be welcome.
- Visualize in numerical and graphical formats results of the base line restitution, signal droop calculations and signal integration boundaries.

During normal operation the application program should display a warning when the MCU or CCG module is switched to a manual mode.

8. Acknowledgments

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9. References

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[3] *Head Electronics for IPU-CTF3*, EDMS documentation, reference EDA-00108, the schematic diagram at https://edms.cern.ch/file/369892/2/EDA-00108-sch-V2.pdf.

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[6] *Calibration Current Generator*, EDMS documentation, reference J38082, the schematic diagram at https://edms.cern.ch/file/360449/1/J38082.pdf.

[7] *CTF3 Electrostatic Head Amplifier*, EDMS documentation, reference EDA-00019, the schematic diagram at https://edms.cern.ch/file/364830/1/EDA-00019.pdf.

Table 3. Bit assignment of the VMOD-TTL digital input/output ports. Its port A is supposed to work as an input and port B as an output. Port C is not used.

Port / bit	Signal name	Function
A0 (LSB)	A_HE_GAIN_IN	read as 0 (1) – the gain of the HE amplifiers is low (high), valid in MAN and REM modes
A1	A_CAL_POS_IN	read as 0 (1) – HE Cal+ relay is on (off), valid in both MAN and REM modes
A2	A_CAL_NEG_IN	read as 0 (1) – HE Cal- relay is on (off), valid in both MAN and REM modes
A3	A_MCU_MAN	read as 0 (1) – the MCU module is in the remote (manual) mode
A7	A_CCG_MAN	read as 0 (1) – the CCG module is in the remote (manual) mode
B0 (LSB)	B_HE_GAIN_OUT	set to 0 (1) – the gain of the HE amplifiers is low (high), valid only in REM mode
B1	B_CAL_POS_OUT	set to 0 (1) – HE Cal+ relay is on (off), valid only in REM mode
B2	B_CAL_NEG_OUT	set to 0 (1) – HE Cal- relay is on (off), valid only in REM mode
A4-A6, B3-B7		not used

Table 4. Bit assignment of the VMOD-DOR output digital port. Port bit values are important only in the remote mode. In the manual mode the signal states are controlled from the MCU and CCG front panels.

Bit	Signal name	Function
D0–D6	PI0 – PI6	index of the pick-up to which the CCG pulses are sent, bits PI0-PI3 set the active output of an analogue multiplexer module and bits PI4-PI6 set the active module
D7	CCG_LGTH	set to 0 (1) – the CCG pulse length is 1.5 µs (150 µs)
D8	CCG_TRG_SW	software CCG trigger bit, transition 0→1 triggers the CCG if CCG_TRG_SEL = 0
D9	CCG_TRG_SEL	CCG trigger source selection, set to 0 (1) – the CCG waits for a software (hardware) trigger
D10	CCG_TRG_INT	the CCG internal trigger enable, when set to 1 the CCG runs with its built-in trigger of zero-crossings of the 50 Hz mains
D11-D15		not used

Listing 1. A proposal of the header file with bit masks for the VMOD-TTL and VMOD-DOR ports.

```
/***************************************************************************
   file: bpm_io_ports.h

   Abbreviations used:
        HE - Head Electronics, MCU - Main Control Module,
        CCG - Calibration Current Generator, AMUX - Analogue Multiplexer

****************************************************************************/

/* Bit distribution of the VMOD-TTL port A configured as an input.
   The bit values are important in both MANUAL and REMOTE modes of the MCU.
   Bits not mentioned hereafter are not used.
*/
#define A_HE_GAIN    0x01    /* 0 (1) - the gain of the HE amplifiers is low (high) */
#define A_CAL_POS    0x02    /* 0 (1) - the HE CAL+ relay is on (off) */
#define A_CAL_NEG    0x04    /* 0 (1) - the HE CAL- relay is on (off) */
#define A_MCU_MAN    0x08    /* 0 (1) - the MCU module is in the REOMTE (MANULAL) mode */
#define A_CCG_MAN    0x80    /* 0 (1) - the MCU module in the REOMTE (MANULAL) mode */

/* Bit distribution of the VMOD-TTL port B configured as an output.
   The bit values are important ONLY when the MCU is in the REMOTE mode.
   Bits not mentioned hereafter are not used.
*/
#define B_HE_GAIN    0x01     /* 0 (1) - sets the gain of the HE amplifiers low (high) */
#define B_CAL_POS    0x02     /* 0 (1) - sets the HE CAL+ relay on (off) */
#define B_CAL_NEG    0x04     /* 0 (1) - sets the HE CAL- relay on (off) */

/* Bit distribution of the VMOD-DOR.
   Bits 0-6 are used to address the pick-up to which the CCG pulses are sent.
   Bits 0-3 are used to select one output of an AMUX module and
   bits 4-6 are used to select the active AMUX module.
   Other bits used are specified hereafter.
*/
#define CCG_LGTH     0x0080   /* 0 (1) - sets the CCG pulse length to 1.5 us (150 us) */
#define CCG_TRG_SW   0x0100   /* transition 0->1 triggers the CCG if CCG_TRG_SEL==0 */
#define CCG_TRG_SEL  0x0200   /* 0 (1) - selects software (hardware) trigger */
#define CCG_TRG_INT  0x0400   /* 0 (1) - selects external (internal 50 Hz) trigger */

/* END of bpm_io_ports.h */
```