MCOR 12

Technical Manual

16 channel precision corrector magnet driver

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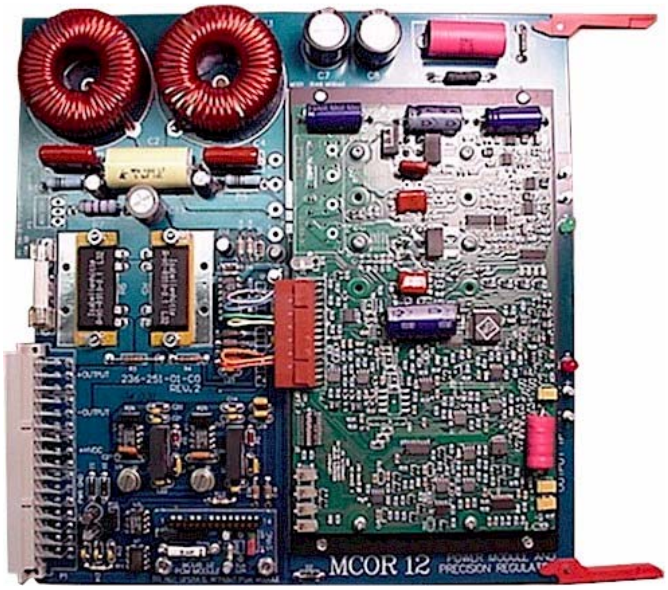
TABLE OF CONTENTS

1.0 SPECIFICATIONS:

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DC Mains Input Range		20		50	V
Output Polarity			bipolar		
Nominal Output Current Range		0		12	A
Maximum Fault Current				15	A
Output Compliance Voltage			DC mains X 90%		V
Power Dissipation of Module at full current				20 (30A8)	W
Load Capacitance range (for stable operation)		0		50	uF
Output short circuit duration:					
	Line to line		continuous		sec
	Line to ground		continuous (driver shuts down)		sec
Transfer Ratio:			1.00V=2.00A		
	Error (at 25° C ambient, 12A)			0.1	%
	Vs. temperature (10 to 25° C)		15		ppm/° C
	Vs. temperature (25 to 50° C)		7		ppm/° C
	Vs. time				ppm/mo.
	PSRR (DC-60Hz, 1V change)		84		dB
	Nonlinearity		0.025		%
Initial Offset:			480		uA
RMS Output Current Noise (w/ 6mH+5 ohm load):					
	DC-200 kHz (0A)		0.01		% of F.S.
	DC-200 kHz (12A)		0.01		% of F.S.
RMS Injected Noise (into HVDC busbar):					
	DC-200 kHz		20		mV
RMS Common-Mode Noise (output to GND):					
	DC-200 kHz		120		mV
Small Signal Bandwidth (w/ 6mH+5 ohm load):					
	3 dB, 0.5 % FS signal			1.5	kHz
Slew Rate 0 to 5 A, 70 VDC mains				2.5	A/ms
Setting Time 1%, for a 5A step			12		mS
Operating Temperature Range (for spec'd accuracy)		15		65	° C

2.0 THEORY OF OPERATION

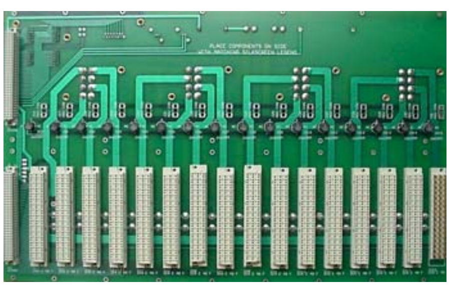
2.1 Overview. The MCOR 12 is a 16-channel, precision magnet driver, capable of providing bi-polar output currents in the range from –12A to +12A. The output current can be adjusted smoothly through zero. A single, unregulated bulk power supply provides the main DC power for the entire crate. The MCOR 12 employs a modular architecture, so that any individual channel is serviceable without disturbing the operation of adjacent channels in the same crate. This feature significantly improves the overall availability of the accelerator, since in most cases the beam lattice can tolerate the loss of a single corrector and continue to operate, but could not handle the loss of an entire crate of correctors during the repair effort.



Each MCOR crate has 17 slots. The slot on far left provides two 96-pin VME connectors for the control system interface card. The remaining slots (slots 0 thru 15) have single 48-pin connectors, and accommodate the individual power regulation modules. The control card communicates with the outside world thru connectors J1 (ExtIntlk), J2 (CrateOK), J3 (DAC), J4 (SAM), and J9 (Bitbus) on the rear backplane of the crate. The control card may be either analog or digitally based, depending on the requirements of the installation. Each power module provides the control card with an independently derived monitor signal, to verify that all correctors are operating within the specified tolerance.

A single hinged front cover provides access to the 16 power modules, which slide into standard card rails. All cards and power modules are accessible from the front of the crate. Two locking extractor handles hold each module in place. The carte is completely air-cooled, using standard rack mounted fans and plenums that draw in cool air from the aisle through a filter, the push the air up through the carte and into the rack, keeping the rack interface at positive pressure.

2.2 Crate and Backplane. The MCOR 12 crate is standard 6U by 220-mm Eurocard subrack, available off- the-shelf from Schroff. A 4-layer printed-circuit backplane provides all of the power and signal connectivity between the power modules, the control card and the outside world. Figure 2.1 show a simplified block diagram of the crate. A single unipolar bulk power supply provides the main DC power to the crate through the 180A Powerpole connector on the rear panel. This connector is attached internally to a pair of PC mount busbars that distribute the bulk DC power across the backplane. The +5, +15 and –15 utility voltages are distributed via standard copper traces to the individual modules through the backplane. A standard 48-pin, type “E” DIN connector provides the signal and power connections from the backplane to each power module. The interface card connects to the backplane using a VME format for connector arrangement, positioning, and module width. No internal chassis wiring is necessary, except for the pigtail connectors on the internal utility power supply. All other external connections, including the outputs to the magnets and the control system cables, are accomplished through PC mounted connectors on the backplane, thus allowing the assembly work to be performed by standard board fabrication plants. A computerized test bench is used for testing and certifying the finished crates and power modules.



- The MCOR Backplane provides all of the power and signal connectivity between the power modules (**MCOR12** -/+12A,40V) (**MCOR30-/+**30A,70V), the control card and the outside world.

- The Backplane allows mixing of the MCOR12 and MCOR30 modules in the crate.

2.3 Power Modules. Each power module provides a precision regulated output drive current of -12A to +12A, in response to the analog command signal from the interface card. The transfer function of input command voltage to output current is determined by resistor values on the power module’s programming card (See 2.3.1). The power module produces two independent measurements of its output current; one closes the local regulation loop, and the other returns an independent monitoring signal to the interface card. The power module also sends back its fault status, and accepts external sync, fault reset, and inhibit signals. The following events will cause the power modules protection circuitry (U2) to activate, shutting down the servo amp and indicating a fault condition:

DC bulk supply undervoltage	<20V
DC bulk supply overvoltage	>50V
Excessive output current	>15A for several seconds
Excessive module temperature	
A missing programming card	
A hard short on either output to ground	
An active inhibit command from the control card	

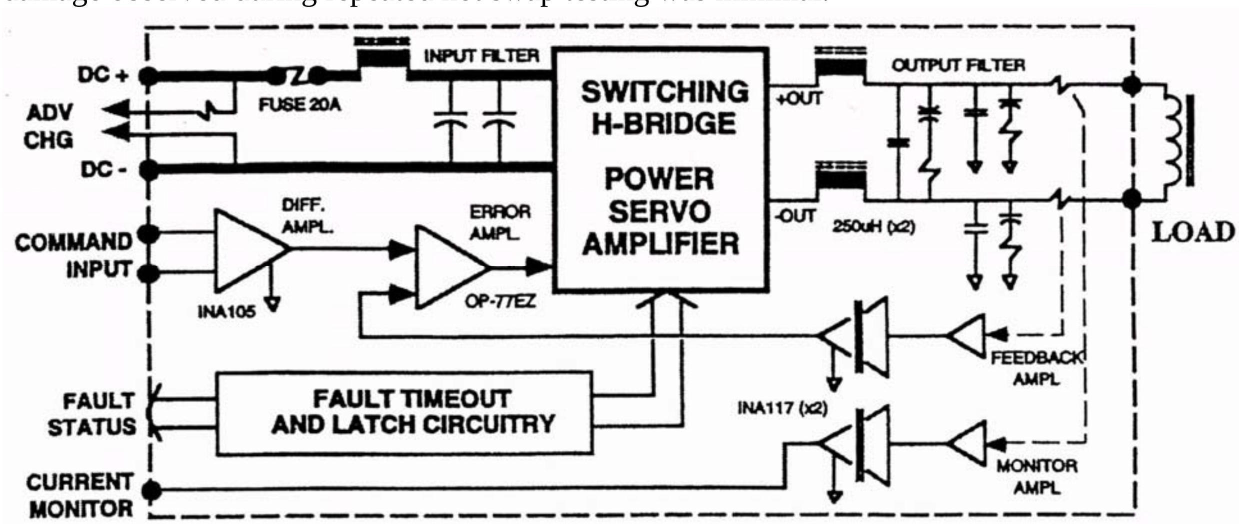
An internal latch in the protection circuitry shuts down the servo amplifier if any of these fault conditions persists for more than a few seconds.

The AMC 30A8 servo amplifier on the power module produces unfiltered, bi-polar DC pulses from its H-bridge output stage, requiring the use of an output filter bank before delivering current to the corrector magnet. The filter design employed is a variation of the classical Praeg filter, arranged symmetrically around the power ground point. The functional diagram of the power module is shown in Figure 2.1. The power resistor R7, R8 and R9 provide damping to minimize the loop response peaking at the filter's resonant frequency. The filter is set to be critically damped, and attenuates both the differential and common- mode components of the output ripple. Following the filter stage are two precision 4-terminal Manganin shunt resistors (R5, R6), one in each output leg. These 10 milliohm shunts (Isabellenhutte A-H1 series) have an absolute tolerance of 0.1%, and a floating pre-amplifier stage (U4, U5), and then referred to ground by a precision differential amplifier (U8, U9). One shunt signal is fed back to the error amplifier, while the other is sent back to the interface card as a redundant current monitor signal.

The analog command signal is receives by the unity gain differential amplifier (U1), whose purpose is to prevent input ground loops, and to reject common- mode noise. This precision differential amplifier contains laser-trimmed gain setting resistors, and provides a typical gain tolerance of 0.01% and a gain stability of 1 ppm/ °C. The processed command signal is then compared against the current feedback signal by the error amplifier stage (U3), which uses an Op77EP as the gain element. A single pole-zero network (C101, R103) provides the feedback loop frequency compensation. The resultant error signal is applied to the input of the on-board 30A8 servo amplifier module, which operates as voltage amplifier with a gain of approximately 6, and a rolloff frequency of about 2.5 kHz.

The 30A8 servo amplifier is a commercial unit, manufactured by Advanced Motion Controls for applications in robotics and process control. This model was chosen for its compact size, ruggedness, PC mount capability, and internal fault protection system, which provides protection against thermal overload, overvoltage and output short circuits (to either rail). At the time of this writing, the 30A8 module is service on MCOR power modules (approx. 860 units) have demonstrated an aggregate MTBF of over 1,000,000 hours.

The bulk DC input to the power module is equipped with a LC decoupling filter network (L3, C7, C8), and a meltdown protection fuse (F1). An "advance connector" (P3) was originally included in the design to soften the inrush currents during "hot swap" operation, by pre-charging the filter capacitor through a current limiting resistor (R1A, R1B) before the main connector block makes contact. However, this scheme was never implemented, as actual connector block damage observed during repeated hot swap testing was minimal.



2.1 Power Module Block Diagram.

2.3.1 Programming (PGM) Card. The PEP II rings and extraction lines require over 860 corrector magnets, made up of nearly a dozen different magnet geometries. Each magnet design has a unique inductance and frequency characteristic, and in addition each corrector installation has a unique cable plant resistance and maximum current rating.

In order to provide “custom-tailored” service to each corrector magnet, yet retain a high degree of modularity and consistency in the driver design, each MCOR 12 power module accommodates a small programming (PGM) card. This card contains a set of passive components that match several important characteristics of power module to its corrector magnet, including:

- IVA (output current vs. SAM voltage) determined by R101
  R=300,000/ full-scale output current

- DVI (DAC voltage vs. output current) determined by R102
  R=300,000/ full-scale output current

- Tuning compensation values – C101 (pole), R103 (zero)

- IMMO (maximum output current limit) determined by R104
  R=3,000 ohm for 7.5 max output
  R=20,000 ohm for 12A max output
  R=OPEN CKT for 15A max output

- Internal or external sync selection

It is important to note that all MCOR 12 power modules are identical and interchangeable. Every power module is capable of any full-scale current rating, as dictated by the plug-in PGM card that "piggybacks" on the power module. The PGM card is the only item that changes from slot to slot, giving the power module a tailored response to its corrector magnet. Each PGM card is labeled with the building, rack level and slot to which it belongs. When a power module is replaced, the programming card is removed from the old power module and installed on the new one, preserving the tailored response for that corrector magnet.

3.0 CONTROL

The MCOR corrector chassis must interface with two fundamentally different types of control systems presently in use on the machine: DAC/SAM and Bitbus. In order to accommodate these control schemes, as well as any future concoctions, the MCOR crate architecture places the total control system interface on a single VME-standard card. This control card occupies the left-most slot of the crate. A block diagram showing each type of control card is shown in the figure below.