

Instruction Manual

PMX

High Voltage Power Supply

MODEL :
SERIAL# :
DATE :

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IMPORTANT SAFETY PRECAUTIONS

SAFETY

THIS POWER SUPPLY GENERATES VOLTAGES THAT ARE DANGEROUS AND MAY BE FATAL.
OBSERVE EXTREME CAUTION WHEN WORKING WITH THIS EQUIPMENT.

High voltage power supplies must always be grounded.

Do not touch connections unless the equipment is off and the Capacitance of both the load and power supply is discharged.

Allow five minutes for discharge of internal capacitance of the power supply.

Do not ground yourself or work under wet or damp conditions.

SERVICING SAFETY

Maintenance may require removing the instrument cover with the power on.

Servicing should be done by qualified personnel aware of the electrical hazards.

WARNING note in the text call attention to hazards in operation of these units that could lead to possible injury or death.

CAUTION notes in the text indicate procedures to be followed to avoid possible damage to equipment.

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This information contained in this publication is derived in part from proprietary and patent data. This information has been prepared for the express purpose of assisting operating and maintenance personnel in the efficient use of the model described herein, and publication of this information does not convey any right to reproduce it or to use it for any purpose other than in connection with installation, operation, and maintenance of the equipment described.

WICHTIGE SICHERHEITSHINWEISE

SICHERHEIT

DIESES HOCHSPANNUNGSNETZTEIL ERZEUGT LEBENSGEFÄHRLICHE HOCHSPANNUNG.
SEIN SIE SEHR VORSICHTIG BEI DER ARBEIT MIT DIESEM GERÄT.

Das Hochspannungsnetzteil muß immer geerdet sein.

Berühren Sie die Stecker des Netzteiles nur, wenn das Gerät ausgeschaltet ist und die elektrischen Kapazitäten des Netzteiles und der angeschlossenen Last entladen sind.

Die internen Kapazitäten des Hochspannungsnetzteiles benötigen ca. 5 Minuten, um sich zu entladen.

Erden Sie sich nicht, und arbeiten Sie nicht in feuchter oder nasser Umgebung.

SERVICESICHERHEIT

Notwendige Reparaturen können es erforderlich machen, den Gehäusedeckel während des Betriebes zu entfernen.

Reparaturen dürfen nur von qualifiziertem, eingewiesenem Personal ausgeführt werden.

“WARNING” im folgenden Text weist auf gefährliche Operationen hin, die zu Verletzungen oder zum Tod führen können.

“CAUTION” im folgenden Text weist auf Prozeduren hin, die genauestens befolgt werden müssen, um eventuelle Beschädigungen des Gerätes zu vermeiden.

PRECAUTIONS IMPORTANTES POUR VOTRE SECURITE

CONSIGNES DE SÉCURITÉ

CETTE ALIMENTATION GÉNÈRE DES TENSIONS QUI SONT DANGEUREUSES ET PEUVENT ÊTRE FATALES.
SOYEZ EXTRÊMEMENT VIGILANTS LORSQUE VOUS UTILISEZ CET ÉQUIPEMENT.

Les alimentations haute tension doivent toujours être mises à la masse.

Ne touchez pas les connectiques sans que l'équipement soit éteint et que la capacité à la fois de la charge et de l'alimentation soient déchargées.

Prévoyez 5 minutes pour la décharge de la capacité interne de l'alimentation.

Ne vous mettez pas à la masse, ou ne travaillez pas sous conditions mouillées ou humides.

CONSIGNES DE SÉCURITÉ EN CAS DE REPARATION

La maintenance peut nécessiter l'enlèvement du couvercle lorsque l'alimentation est encore allumée.

Les réparations doivent être effectuées par une personne qualifiée et connaissant les risques électriques.

Dans le manuel, les notes marquées « **WARNING** » attire l'attention sur les risques lors de la manipulation de ces équipements, qui peuvent entraîner de possibles blessures voire la mort.

Dans le manuel, les notes marquées « **CAUTION** » indiquent les procédures qui doivent être suivies afin d'éviter d'éventuels dommages sur l'équipement.

IMPORTANTI PRECAUZIONI DI SICUREZZA

SICUREZZA

QUESTO ALIMENTATORE GENERA TENSIONI CHE SONO PERICOLOSE E POTREBBERO ESSERE MORTALI.
PONI ESTREMA CAUTELA QUANDO OPERI CON QUESTO APPARECCHIO.

- Gli alimentatori ad alta tensione devono sempre essere collegati ad un impianto di terra.
- Non toccare le connessioni a meno che l'apparecchio sia stato spento e la capacità interna del carico e dell'alimentatore stesso siano scariche.
- Attendere cinque minuti per permettere la scarica della capacità interna dell'alimentatore ad alta tensione.
- Non mettere a terra il proprio corpo oppure operare in ambienti bagnati o saturi d'umidità.

SICUREZZA NELLA MANUTENZIONE.

- Manutenzione potrebbe essere richiesta, rimuovendo la copertura con apparecchio acceso.
- La manutenzione deve essere svolta da personale qualificato, coscio dei rischi elettrici.
- Attenzione alle **AVVERTENZE** contenute nel manuale, che richiamano all'attenzione ai rischi quando si opera con tali unità e che potrebbero causare possibili ferite o morte.
- Le note di **CAUTELA** contenute nel manuale, indicano le procedure da seguire per evitare possibili danni all'apparecchio.

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CHAPTER 1 INTRODUCTION

1.1 PMX DESCRIPTION

Spellman's PMX redefines the standard for high performance Mammography X-Ray generators including FFDM and DBT. It features 2 and 3 point exposure modes as well as smart AEC with pre exposure.

The 50kV @ 5kW (peak) high voltage output coupled with a dual focal spot, DC current source filament power supply provides stable and accurate X-Ray tube emission currents. The solid encapsulated high voltage output section eliminates oil concerns while reducing effects of environmental humidity and contamination.

PMX's flexible interfacing and controlling capabilities as well as powerful application features represent a radically new advanced approach to mammography X-Ray generators.



1.1.1 Power Supply Requirements

Single Phase

Line Voltage	200Vac-240Vac, +/-10%, 1 Phase, 35 Amps
Line Frequency	50/60 Hz.
In Rush Current	50 Amps, Maximum
Standby Current	1 Amp

WARNING: *The PMX generator can provide power that can damage the X-Ray tube. The user is responsible for limiting the maximum exposure values to within the ratings of the X-Ray tube. Spellman is not liable for any damage to the X-Ray tube by the misuse of the PMX X-Ray generator.*

The following table defines the power line requirements for the generators.

NOTE: *THE FOLLOWING TABLE CONTAINS RECOMMENDED VALUES FOR THE WIRE SIZES BETWEEN THE MAINS DISCONNECT AND THE GENERATOR. THE ACTUAL VALUES USED AT AN INSTALLATION ARE DEPENDENT ON THE QUALITY OF THE INPUT LINE (VOLTAGE LEVEL) THE CURRENT REQUIREMENTS AND THE LENGTH OF THE CABLE RUN AND MUST BE CONFIRMED BY THE INSTALLER.*

ALL THE RATINGS LISTED CONSIDER THE GENERATOR REQUIREMENTS ONLY. THE INSTALLER MUST MAKE THE NECESSARY COMPENSATION FOR ADDITIONAL LOAD REQUIREMENTS

A POOR QUALITY INPUT LINE MAY RESULT IN THE INSTALLER HAVING TO DERATE THE GENERATOR'S MAXIMUM POWER

Mains Voltage	Minimum Recommended Mains Disconnect to Generator 15 ft./5 m max)	Generator In Rush Line Current	Minimum Recommended Generator Service Rating	Minimum Recommended Ground Wire Size	Apparent Mains Resistance
220 Vac	#10 (6 mm ²)	50 A	35 A	#10 (6 mm ²)	0.06 Ω

- External EMC Filter (required to meet CE/EMC specifications) – Not provided with the generator. Customer is responsible for providing the external filter as needed; Schaffner FN2070-08-36A type EMI filter or equivalent one recommended.
- Mains Contactor - Not provided within the generator. Customer is responsible for mains safety disconnection.

1.1.2 Environment Requirements

Operating Environment

Operating Temperature	10 to 40 °C (50 to 104 °F).
Relative Humidity	20 to 85%, non-condensing.
Atmospheric pressure range	500 to 1060 hPa (375 to 795 mm Hg).
<u>TRANSPORT AND STORAGE</u>	
Ambient temperature range	-40 to 85 °C (-40 to 185 °F).
Relative humidity	5 to 95%, non-condensing.
Atmospheric pressure range	500 to 1060 hPa (375 to 795 mm Hg).

1.2 THEORY OF OPERATION

1.2.1 Function Overview

The PMX X-Ray generator utilizes sophisticated power conversion technology. A variety of analog, digital and switching power conversion techniques are used throughout.

The PMX generator is basically an AC to DC power converter. Within the generator, conversions of AC to DC, then to high frequency AC, then to high voltage DC take place. By reviewing further the sub-assemblies, a basic understanding of the process can be gained.

1.2.2 Line Rectification and Filtering

Basic AC line rectification provides the DC buss voltage for the high voltage inverter, Anode rotor drive, and the filament supply.

The input line voltage can vary from 180V up to 264V within the series.

The line voltage is connected directly to the EMI filter. The EMI filter reduces conducted HF noise on the AC mains. The output of the EMI filter is connected to an off line auxiliary power inverter circuit that provides 24V power for generating other auxiliary supply DC voltages.

1.2.3 Inverter

The inverter is a "half-bridge" topology. Current mode control is used for driving the inverter. An IGBT power module employed. The IGBT provides high frequency switching to control the

primary current flow to the high voltage transformer.

Circuits on the Power PCB board provide the gate control of the IGBT switches. The system control board generates gate drive control signals. The circuits on the Power PCB provide the required gate voltages and offsets.

1.2.4 High Voltage Transformer

The output of the High Frequency Quasi-resonant Inverter is connected to the primary of the High Voltage Transformer. The High Voltage Transformer is a step up type. Typical secondary output voltage is in the range of 12.5kV depending upon output voltage ratings.

1.2.5 High Voltage Assembly

The High Voltage Assembly will vary depending upon the model ordered. The circuitry typically consists of an arrangement of half wave voltage doubler.

A high bandwidth resistive/capacitive divider provides voltage feedback for regulation and monitoring. A sense resistor connected at the low voltage end of the High Voltage Multiplier circuit provides current feedback for regulation and monitoring.

1.2.6 System Control PWB

Auxiliary DC voltages are generated in the low voltage power supply section of the System Control PWB.

LEDs provide status diagnostics needed for recognizing the operation/shutdown mode of the generator.

A precision +10Vdc reference is generated on the control PCB for programming kV, mA and other references.

Control of the generator utilizes sophisticated analog and digital circuitry resulting in fast and accurate control, protection and communication interfacing.

This generator is based on advanced quasi-resonant PWM control. Analog signals are digitized in A/D converter and processed within FPGA and DSP circuits to provide maximum accuracy and reliability.

All feedback signals are sent to the user interface through digital and D/A circuits where switching is possible between feedback and program signals. This allows the user to preset the desired output before energizing high voltage.

All program voltages are typically ramped up to set level by the digital ramp generator.

FPGA and accompanying A-D and D-A converters and drivers provide system Fault

Control Indication. User interface is processed on this PWB as well, providing isolated relay coils, opto couplers and open collector contacts.

1.2.7 Filament Power Supply

The filament inverter provides the power to drive the filament winding of the X-Ray tube. The filament inverter is a high frequency, series resonant inverter. The inverter provides high frequency ac current to the primary of the filament isolation transformer. The filament isolation transformer secondary is connected to a full wave rectifier and capacitor filter creating a DC filament. Relay K4 connects the filament output to TB3 terminals 1 or 3 for small or large filament respectively as required by the operator. The filament circuitry also provides a variety of control, diagnostic and protection functions.

See Figure 1.2 for a simplified diagram of the X-Ray tube connection and current sensing circuits. The filament circuitry also provides a variety of control, diagnostic and protection functions.

If any abnormal condition appears, monitoring circuitry will shut down the unit indicating the fault.

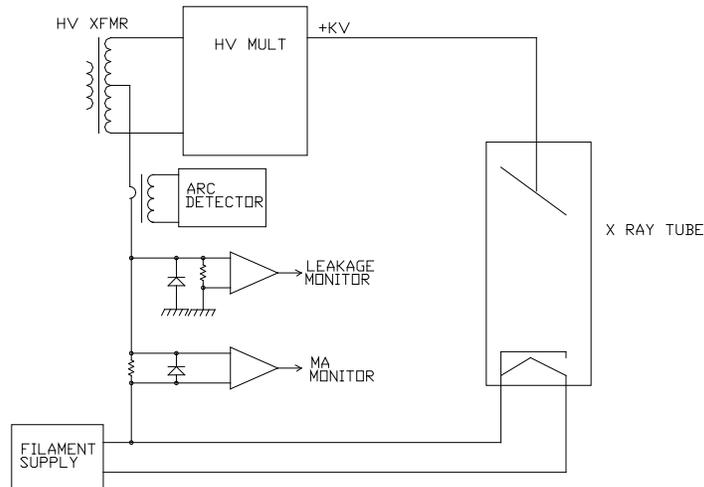


Figure 1.2 Simplified schematic of X-Ray tube connection

1.2.8 High Speed Starter

The rotating anode is powered and controlled by the action of a split-phase type of induction motor circuits in the PMX generator. The rotating anode has considerable mass to dissipate the heat generated by the beam current, and subsequently requires some time to accelerate to its normal operating speed. To reduce this time, the "high speed starter" circuit in the PMX applies a series of "boost" steps consisting of different frequencies and increased voltage during the boost cycle to

increase the acceleration of the anode rotation to operating speed within several seconds. Following the boost cycle, the applied voltage is reduced to proper voltage to maintain rotation. There are two operating modes for the anode rotor: low speed (60Hz stator voltage), and high speed (180Hz stator voltage). These are selected by the operator depending on the requirements of the application.

The PMX is equipped with safety interlocks for user personnel and equipment protection. An open interlock circuit inhibits operation of the PMX generator.

1.3 SAFETY

1.3.1 Safety and Warning Symbols

WARNING: THIS X-Ray UNIT MAY BE DANGEROUS TO OPERATOR UNLESS SAFE EXPOSURE FACTORS AND OPERATING INSTRUCTIONS ARE OBSERVED.

The following advisory symbols are used on the safety warning labels, and/or on circuit boards.

	High voltage symbol used to indicate the presence of high voltage.
	Warning symbol used to indicate a potential hazard to operators, service personnel or to the equipment.

	IEC 60417-5017	Earth (ground)
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CHAPTER 2

INSTALLATION

2.1 INTRODUCTION

This chapter contains instructions for unpacking, positioning, and cabling the PMX generator, allowing for initial power-up and exposures.

2.2 UNPACKING

WARNING: THE GENERATOR WEIGHS APPROXIMATELY 23 POUNDS (10.5KG).

1. Inspect the package exterior for evidence of damage due to handling in transit. Notify the carrier and Spellman immediately if damage is evident. Do not destroy or remove any of the packing material used in a damaged shipment.
2. Remove the cardboard outer packaging. See the cautionary note below before removing the packaging.

CAUTION: OPEN THE CARDBOARD PACKAGING CAREFULLY. SHARP TOOLS MAY DAMAGE THE CONTENTS.

3. Set aside the cardboard packaging.
4. After unpacking, inspect for visible damage.
5. Keep the shipping containers. In case of shipping damage, place the unit(s) back in its shipping pack and notify the carrier and the Customer Support Department as indicated in this manual.

2.3 OVERALL CONNECTIONS

NOTE: THIS IS BASIC CONNECTION ILLUSTRATION FOR TESTING. MORE COMPLEX AND DEDICATED CIRCUITRY IS NEEDED IN THE FINAL APPLICATION.

All cables should be routed away from high voltage areas, and dressed and secured neatly in place. Cables should be cut to the correct length if possible as excess cabling may contribute to EMI/RFI problems. For those cables that cannot be cut to the correct length (HV cables and console cables for example), try to minimize the area inside any loops of excess cable, as these loops are in effect an antenna.

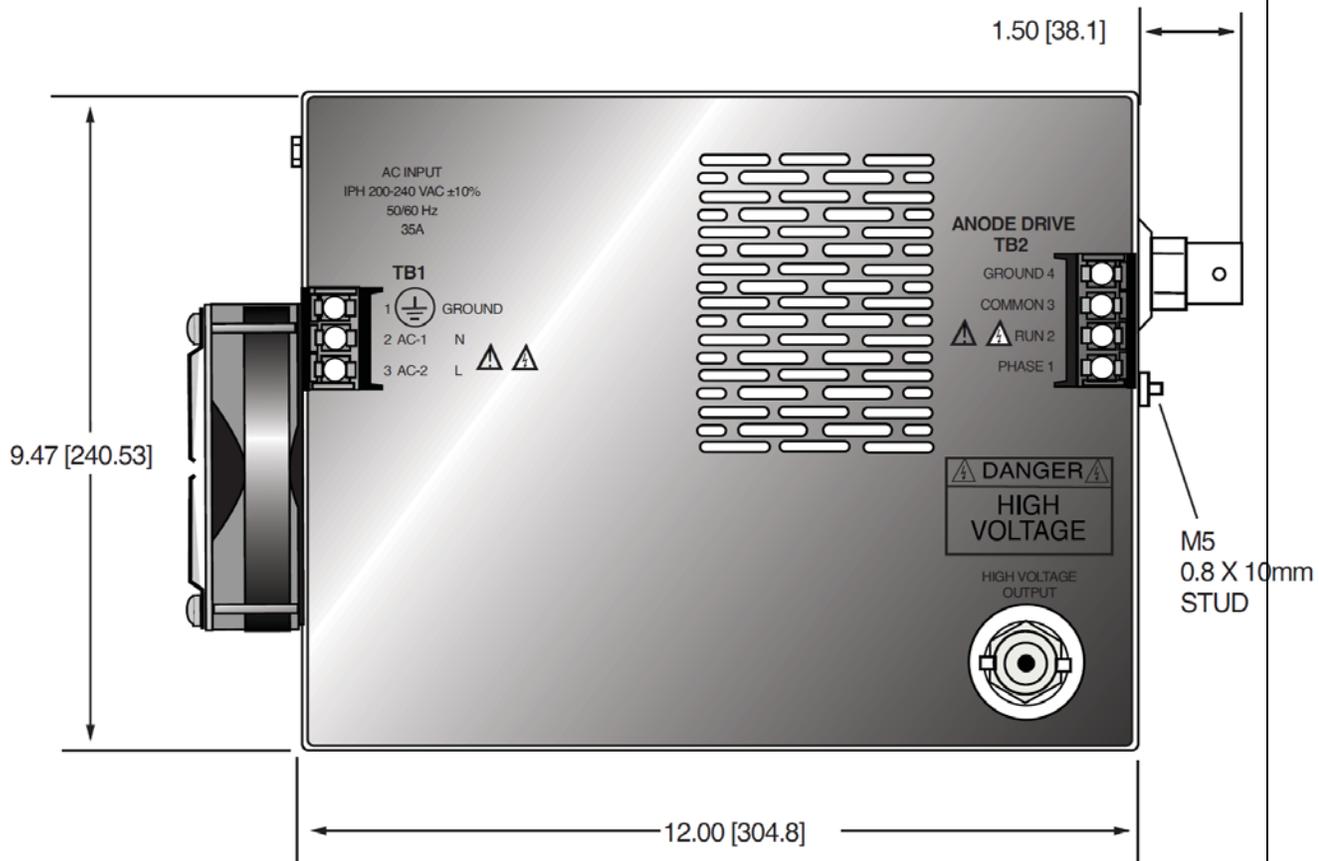
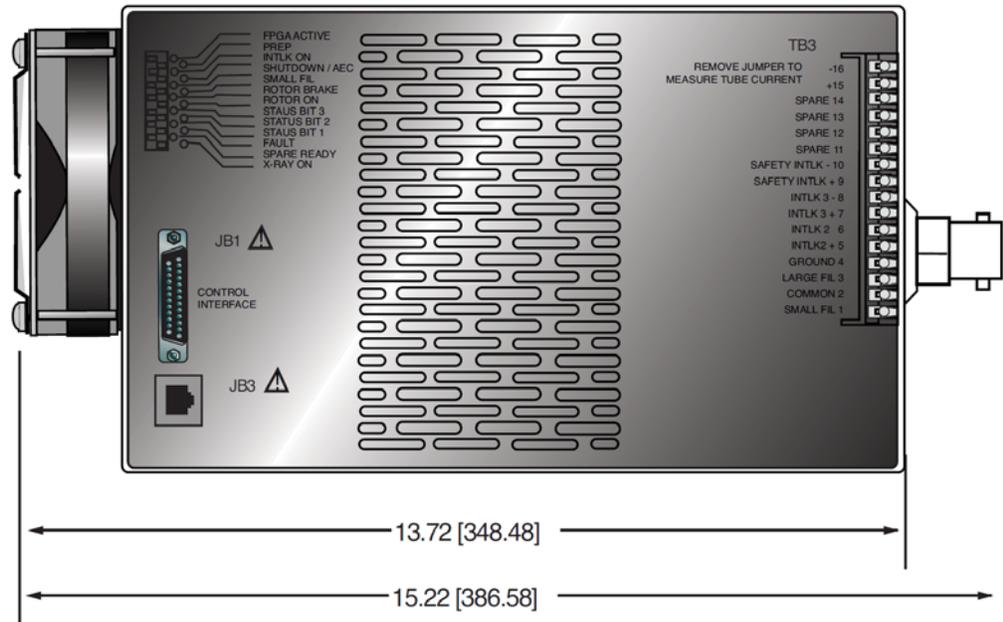


Figure 2-1: PMX I/O and indicator locations

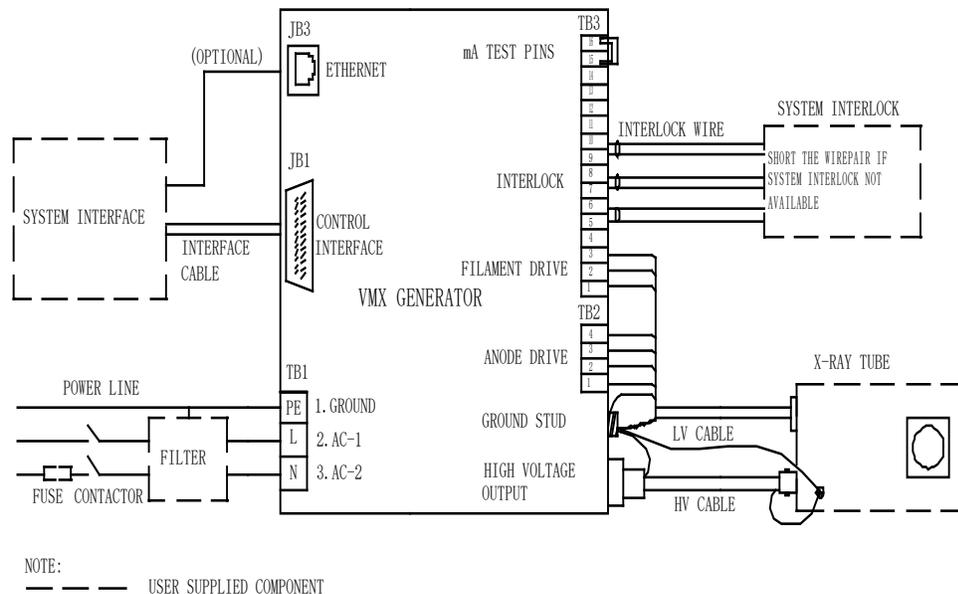


Figure 2-2: Overall connection

2.4 POWER LINE MAINS

WARNING: MAIN CONTACTOR IS NOT PROVIDED WITHIN THE GENERATOR, CUSTOMER IS RESPONSIBLE FOR MAINS SAFETY DISCONNECTION.

The PMX supply does not contain power line current limiting or fuses. It is strongly recommended that the user provide fuses or circuit breaker protection on the input power lines to limit fault current that may occur due to component failure, or operator error. Fuses or circuit breakers with current rating of 35 Amps are recommended

Refer to Chapter 1 for generator power and generator power line requirements.

1. Check the input voltage rating on the nameplate of the supply and make certain that this is the rating of the power source to be connected.

2. Units operate on 200V-240VAC, +/- 10%, 50/60Hz, single phase 35A.
3. A three-wire terminal block (TB1) is provided for connecting to the AC supply (refer to Figure 2-2).
4. **DO NOT SWITCH ON MAINS POWER AT THIS TIME.**

2.5 Cable connection illustration

2.5.1 HV Cable Connection

The X-Ray tube should be mounted in its normal fixture i.e. tube stand or other device.

1. Verify that the HV cable terminations are clean and in good condition.
2. Be sure that the rubber expansion ring is located at the bottom of the HV cable plug.

3. Connect HV cable to the CA3 type high voltage output terminal at rear of the unit.
4. Connect the other side of HV cable to the corresponding HV terminal on tube housing.
5. Connect the cable shield wire accompanying HV cable to the PMX ground stud and tube housing separately.

2.5.2 Stator Cable Connection

Refer to Table 2-1 for the X-Ray tube stator connections.

1. Tube low voltage cable is a hybrid one with filament and stator drive wire bundled together. Tube side should be standard terminal style, while generator side is unterminated. Customer should terminate the wire with suitable terminal.
2. Connect wires from the X-Ray tube housing low voltage connector stator pins to PMX terminal block TB2 terminals 1 (stator PHASE), 2 (stator RUN), 3 (stator COM), and 4 (GROUND).
3. Connect tube thermal switch wires to TB3-5 and TB3-6 if present. If not, short the two pins. Normally, there are no such separate wires for MAMMO tubes; it is always integrated into the three phase line. Refer to tube housing data sheet for specific information.

2.5.3 Filament Driver Cable Connection

1. Filament driver cable has three wires and bundled together with stator wires within same cable. Customer should terminate the wire with suitable terminals and leave enough length to reach the terminal TB3.
2. Connect wires from the X-Ray tube housing low voltage connector filament pins to PMX terminal block TB3 terminals 1 (FIL Small), 2 (FIL COM), and 3 (FIL Large).

Pin #	Definition	Description
TB3-1	SMALL FIL	To tube small filament.
TB3-2	COMMON	To tube filament common.
TB3-3	LARGE FIL	To tube large filament.

Table 2-2. Pin layout of filament driver connector.

2.6 MULTI INTERFACE CABLE CONNECTIONS

The PMX has multi interface connections include digital I/O, serial communication, and interlock. Operator must verify and connect every signal properly though some of them are optional, before initiating power-up and basic test.

The interlock, serial communication and exposure buttons interface shall be made

available via a multi signal cable. Refer to *-* for a schematic of isolation and signal direction.

2.6.1 Pin Layout of the Multi interface

The multi signal interface shall have a female 25 pin D-Sub (JB1) on the PMX. Twisted pairs shall be used where applicable. The pin layout is given in Table 2-3.

Pin #	Definition	Description
JB1-1	GND	Generator signal ground for reference of interface circuits
JB1-2	(+) 5VDC Out	5 volts DC from generator for use in powering interface circuitry such as optocouplers. 100mA maximum.
JB1-3	RS232 Tx Out	RS232 Transmit (out) from generator
JB1-4	RS232 Rx In	RS232 Receive (in) to generator
JB1-5	PREP	User Signal (Contact Closure) to alert the generator that exposure sequence will begin. Once this signal is active, exposure parameters are locked in and cannot be changed. The generator enables the starter to boost the rotor. Contact connection to pin 24. Closed = PREP.
JB1-6	READY	Generator Signal to user to indicate the rotor runs to speed and the generator is ready for X-Ray exposure. Transistor output. Low/Active=Ready
JB1-7	ROTOR SHUTDOWN	User Signal to generator to brake the rotor drive off. Low brakes Rotor. (Open will not restart rotor until a new PREP cycle is started). Reference to GND.
JB1-8	EXPOSURE	User Signal (Contact Closure) to generator to generate X-Rays. Filament is boosted, and High Voltage is generated after the boost time. (Approximately 1 second). Contact connection to pin 24. Closed=Exposure.

JB1-9	X-Ray ON 75% Status	Transistor output to indicate X-Ray ON status. (Reference to GND). High/Active=X-Ray ON Status Synchronize with 75% kV setting point.
JB1-10	X-Ray ON Status	Transistor output to indicate HV ON status. (Reference to GND). High/Active=HV ON Status. Synchronize with HV start-up.
JB1-11	N/C	Not Used
JB1-12	X-Ray SHUTDOWN/AEC	User Signal to generator to rapidly turn HV OFF and ON during Exposure. (AEC). Reference to GND. LOW Shuts down HV.
JB1-13	RS232 ISO Ground	Isolated ground from the isolated RS232 transceiver I.C.
JB1-14	HVG FAULT Status	Generator signal indicating generator fault. Open collector transistor output. Low/Active=Fault
JB1-15	Status Bit 1	3 bit status lines for up to 6 status messages. See separate matrix (Table 2-4) describing functionality. Open Collector transistor output. Low/Active=Message.
JB1-16	Status Bit 2	
JB1-17	Status Bit 3	
JB1-18	N/C	N/C
JB1-19	N/C	N/C
JB1-20	kV Monitor	Signal from generator. 0-10V=0-50kV. Zout=1K ohm
JB1-21	Emission Monitor	Signal from generator. 0-10V=0-200mA. Zout=1K ohm
JB1-22	Filament Current Monitor	Signal from generator. 0-10V=0-6A. Zout=1K ohm
JB1-23	Program/Monitor Return	Ground for reference of program and monitor signals
JB1-24	+24VDC Out	For connection to PREP and EXPOSURE control relay coils.
JB1-25	SHIELD/GND	For connection of interface cable shield to generator chassis ground.

Table 2-3 Pin layout of multi signal connector

Refer to chapter 3 for detailed requirements and function descriptions.

2.7 Interlock Connections

Interlock connections are provided for a variety of safety functions such as room door interlock, separate thermal switch interlock, tube flow switch interlock. The unit will not operate unless the interlocks are closed.

Opening the interlock circuit will cause the unit to shut off.

Three safety interlocks are located in TB3 for system interlock purpose. Short the terminals if not used.

The pin definition shows below:

Pin #	Definition	Description
TB3-5	Interlock 2 +	Used if tube has separate thermostat switch. Open=over temp. (Short terminals if not used).
TB3-6	Interlock 2 -	
TB3-7	Interlock 3 +	Used if tube has cooling circulator flow switch. Open=no flow. (Short terminals if not used).
TB3-8	Interlock 3 -	
TB3-9	Safety Interlock+	User signal (Contact Closure) for safety interlocks such as door interlocks. Open turns HV OFF, or inhibits HV from being generated.
TB3-10	Safety Interlock-	

2.8 Tube Current Monitor Connection

Tube current test pins are provided for monitoring the actual tube current (mA) if needed. Normally, a jumper is installed to short the two pins (refer to Figure 2-2).

Remove the jumper and install the current meter in series to monitor the actual tube current.

Two test pins are located in TB3 (TB3-15, TB3-16). **Short the two pins if not used.**

The pin definition shows below:

Pin #	Definition	Description
TB3-15	Tube current +	Tube current flows out from this pin.
TB3-16	Tube current -	Tube current flows into this pin.

2.9 GROUND CONNECTION

NOTE: THE INSTALLER SHOULD ENSURE THAT ALL CABLE CONNECTIONS TO THE GENERATOR ARE SECURE, AND ALL CABLES EXTERNAL TO THE GENERATOR ARE ADEQUATELY PROTECTED AGAINST ACCIDENTAL DISCONNECTION.

2.9.1 X-Ray Tube Housing Ground

A separate ground wire (10 AWG, 6mm²) must be connected from the X-Ray tube housing to the ground stud on the rear of the PMX chassis. These ground locations may have other ground wires already connected;

ensure that these existing ground wires are not disconnected when making the X-Ray tube ground connection.

Failure to make this ground connection may result in intermittent operation and/or exposure errors or even worse IGBT failure.

2.9.2 Chassis Ground

The chassis of the PMX generator must be grounded to the local earth ground and also to the tube housing ground. See Figure 2-2 for typical operating setup. A three-wire terminal block is provided for connecting to the AC supply.

2.10 FINAL CHECKS

The room interface connections may now be completed. Before power on, user needs to check the items as below finally.

- When finished all wiring, check that all connections are tight and secure.
- Double check the breaker, EMC filter, fuses, etc. User is responsible for on the main input power lines.
- Check that all cables are dressed neatly outside the cabinet, and secured as necessary.
- Check the ground connection again.

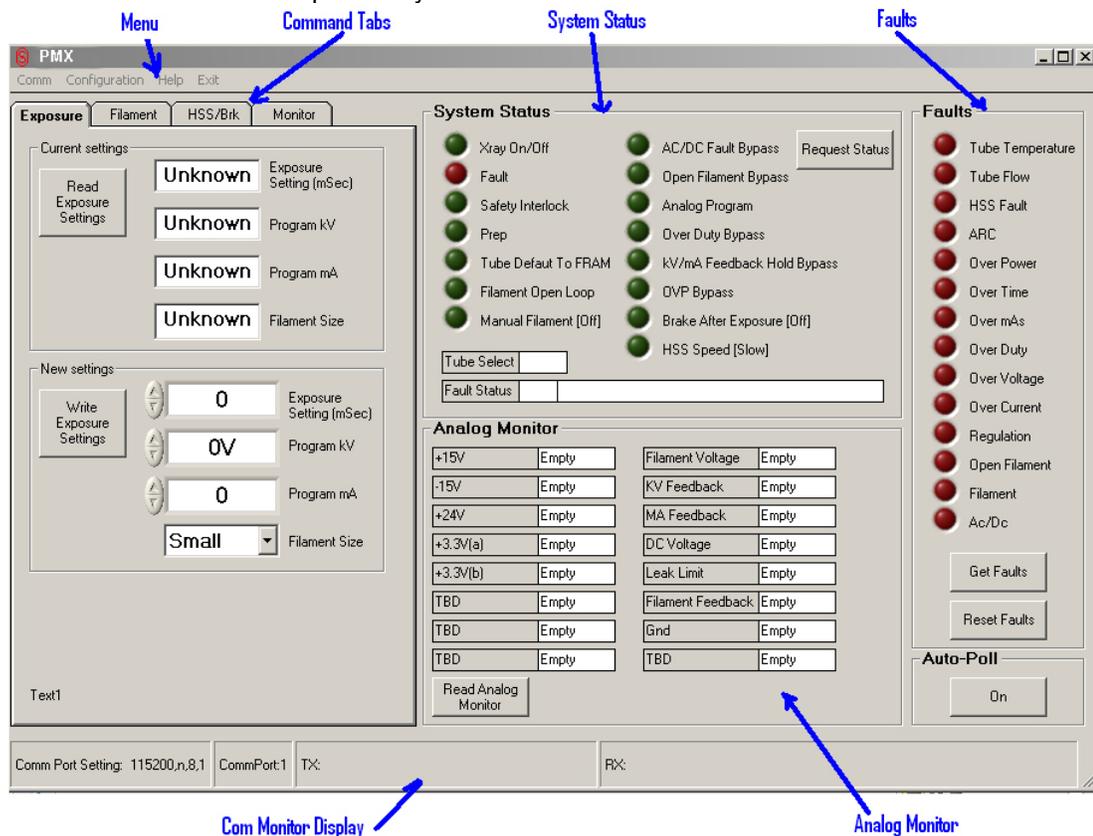
NOTE: THE INSTALLER SHOULD ENSURE THAT ALL CABLE CONNECTIONS TO THE GENERATOR ARE SECURE, AND ALL CABLES EXTERNAL TO THE GENERATOR ARE ADEQUATELY PROTECTED AGAINST ACCIDENTAL DISCONNECTION.

2.11 GUI SOFTWARE

The optional GUI utility software allows for data communication between the generator and an external computer. This provides a “virtual console” with which user can release all the command defined in the protocol and verifies all the functions independently before

integrating the generator into their ultimate system.

The GUI consists of the Analog Monitor Section, the System Status Section, the Fault Section, the Command Tab Section, the Com Monitor Display, and the Menu.



The Command Tab section, along with the Monitor / Status / Fault sections provide access to the various commands defined in the PMX Protocol Spec. The Analog Monitor, System Status, and Fault sections are always visible and can be accessed at any time. The Command Tab section provides access to other commands grouped together by

function. Clicking on the tabs at the top of the Command Tab section selects a particular group of commands. Only one group (tab) can be selected at any one time.

See separate document for the detailed GUI instruction.

CHAPTER 3 INTERFACING

3.1 introduction

This chapter describes the interfacing of the PMX generator to the customer system control side, especially with the serial communication,

exposure control switch. Also, exposure mode is introduced with the timing sequence described as well.

3.2 MULTI INTERFACE

NOTE: THE INSTALLER MUST PROVIDE THE NECESSARY INTERFACING CABLES FOR WIRING TO THE GENERATOR INPUTS AND OUTPUTS DESCRIBED IN THIS SECTION.

WARNING: LINE VOLTAGE IS PRESENT INSIDE THE GENERATOR AT ALL TIMES THAT THE MAIN DISCONNECT IS SWITCHED ON. FOR SAFETY, THE MAIN DISCONNECT SHOULD BE SWITCHED OFF AND LOCKED OUT WHILE CONNECTING ROOM EQUIPMENT.

3.2.1 Connector Style and Pin Layout

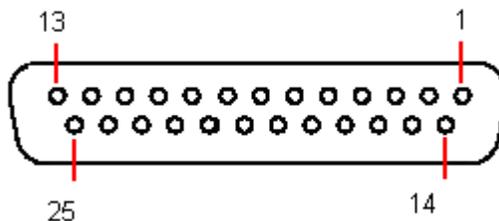


Figure 3-1 multi signal interface connector

Pin #	Definition	Description
JB1-1	GND	Generator signal ground for reference of interface circuits
JB1-2	+5VDC Out	5 volts DC from generator for use in powering interface circuitry such as opto couplers. 100mA maximum.
JB1-3	RS232 Tx Out	RS232 Transmit (out) from generator
JB1-4	RS232 Rx In	RS232 Receive (in) to generator
JB1-5	PREP	User Signal (Contact Closure) to alert the generator that exposure sequence will begin. Once this signal is active, exposure parameters are locked in and cannot be changed. The generator enables the starter to boost the rotor. Contact connection to pin 24. Closed = PREP.

JB1-6	READY	Generator Signal to user to indicate the rotor runs to speed and the generator is ready for X-Ray exposure. Transistor output. Low/Active=Ready
JB1-7	ROTOR SHUTDOWN	User Signal to generator to brake the rotor drive off. Low brakes Rotor. (Open will not restart rotor until a new PREP cycle is started). Reference to GND.
JB1-8	EXPOSURE	User Signal (Contact Closure) to generator to generate X-Rays. Filament is boosted, and High Voltage is generated after the boost time. (Approximately 1 second). Contact connection to pin 24. Closed=Exposure.
JB1-9	X-Ray ON 75% Status	Transistor output to indicate X-Ray ON status. (Reference to GND). High/Active=X-Ray ON Status Synchronize with 75% kV setting point.
JB1-10	X-Ray ON Status	Transistor output to indicate HV ON status. (Reference to GND). High/Active=HV ON Status. Synchronize with HV start-up.
JB1-11	N/C	Not Used
JB1-12	X-Ray SHUTDOWN/AEC	User Signal to generator to rapidly turn HV OFF and ON during Exposure. (AEC). Reference to GND. LOW Shuts down HV.
JB1-13	RS232 ISO Ground	Isolated ground from the isolated RS232 transceiver I.C.
JB1-14	HVG FAULT Status	Generator signal indicating generator fault. Open collector transistor output. Low/Active=Fault
JB1-15	Status Bit 1	3 bit status lines for up to 6 status messages. See separate matrix (Table 2-4) describing functionality. Open Collector transistor output. Low/Active=Message.
JB1-16	Status Bit 2	
JB1-17	Status Bit 3	
JB1-18	N/C	N/C
JB1-19	N/C	N/C
JB1-20	kV Monitor	Signal from generator. 0-10V=0-50kV. Zout=1K ohm
JB1-21	Emission Monitor	Signal from generator. 0-10V=0-200mA. Zout=1K ohm
JB1-22	Filament Current Monitor	Signal from generator. 0-10V=0-6A. Zout=1K ohm
JB1-23	Program/Monitor return	Ground for reference of program and monitor signals.
JB1-24	+24Vdc Out	For connection to PREP and EXPOSURE control relay coils.
JB1-25	SHIELD/GND	For connection of interface cable shield to generator chassis ground

Table 3-2 Pin layout of multi signal interface

3.2.2 Serial Communication Interface

The serial communication is part of the Multi Signal Interface (JB1).

The RS232 communication interface has been isolated inside the HVG with specific IC.

The pin definition shows below:

Pin #	Definition	Description
JB1-3	RS232 Tx	RS232 Transmit (out) from generator
JB1-4	RS232 Rx	RS232 Receive (in) to generator
JB1-13	RS232 ISO Ground	Isolated ground from the isolated RS232 transceiver I.C.

User should connect the RS232 cable properly with system side such as PC. Twisted wires are preferable to enhance the EMC performance.

GUI software can be used temporarily to test the PMX provided installed on the user PC. (Refer to separate document for detailed information of GUI). But user need to develop their own ultimate software based on open protocol (Refer to separate document) and design system control board to integrated PMX into their system with proper method (Refer to 2.6.1 NOTE the isolation requirement).

controlled by a momentary normally open contact. If remote control is required, the remote interface dummy plug must be removed and replaced with the appropriate remote circuits. See Figure 3-2 for recommended interface circuits.

In order to eliminate signal bounce caused by mechanical contact, an electronic switch such as opto coupler device is recommended for these signals.

3.2.3 Digital I/O Control Interface

Remote digital control of the PREP, ROTOR SHUTDOWN, EXPOSURE, X-Ray SHUTDOWN, are available on the 25-pin I/O connector for maintenance. All of these controls except PREP and EXPOSURE are toggle on/off type signals. PREP and EXPOSURE are

Warning: Max current that the +24Vdc supply can provide is 100mA.

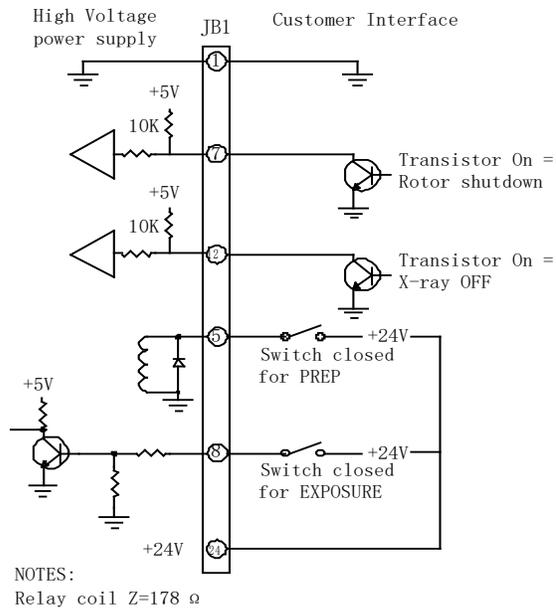


Figure 3-2 Digital I/O Control Interface

3.2.4 Remote Status Interface

Remote status signals for KV MIN tube current limit, tube power limit, overvoltage, and filament

Current limit, over temperature, and power supply fault is provided.

These signals are open collector type. (Normally off), and are intended to drive the diode of an opto-coupler.

Figure 3-3 for recommended interface circuits.

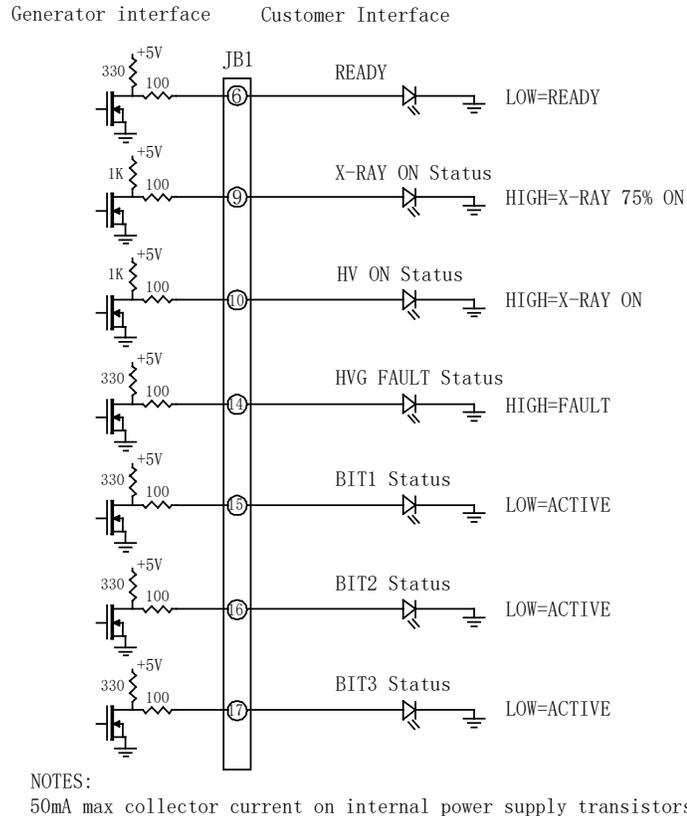


Figure 3-3 Remote status interface

If a fault occurs, the power supply will shut down and a 3 bit binary code will be generated at the user interface connector JB1. To reset, use the reset function on remote user interface.

The fault information is provided with three bit code. Below is the information list. More than one fault is defined with one code combination. Use can get specific fault information by serial command.

BIT1	BIT2	BIT3	MESSAGE
high	high	high	No Messages
low	high	high	Tube Temp/Flow Fault/HSS Fault
high	low	high	Arc Detected/Shutdown
high	high	low	Over Load: Power/MAS/Time/Duty
low	low	high	Over Voltage/Over Current/Regulation error
low	low	low	Open Filament/Filament Fault

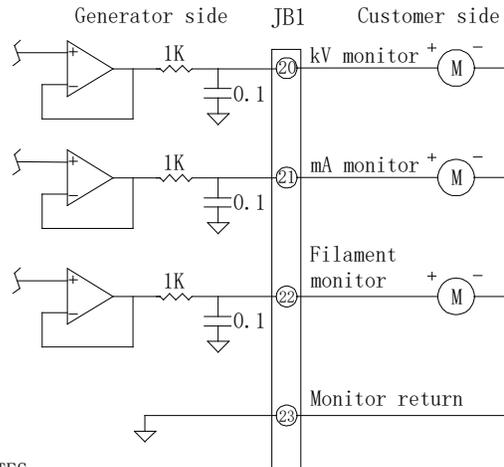
Table 3-3 status messages matrix

3.2.5 Remote Monitoring Interface

Test points are made available at the 25-pin I/O connector from monitoring tube voltage, tube current and tube filament current. The test

points are always positive regardless of the output polarity, where 0 to 10V = 0-100% of output. Accuracy is within $\pm 0.5\%$. All test points have output impedance of 1Kohm.

Figure 3-4 for wiring diagram and specifications for remote monitor interface.



NOTES:

- 1) Metering circuit should be high Z type (>10Meg) for accurate measurement.
- 2) All signals 0-10Vdc = 0-100 % of specified maximum outputs .

Figure 3-4 Remote monitoring interface

3.3 ETHERNET INTERFACE

Ethernet is an optional serial communication interface with separate standard RJ45 style connector. JB3 is terminal number.

RJ45 pin definition shows below:

Pin #	Definition	Description
JB3-1	TX+ White/Orange	10/100 Base-T Ethernet Interface
JB3-2	TX- Orange	
JB3-3	RX+ White/Green	
JB3-4	POE V+ blue	
JB3-5	POE V+ blue/white	
JB3-6	RX- Green	
JB3-7	POE V- brown/white	
JB3-8	POE V- brown	

CHAPTER 4 CONFIGURATION, CALIBRATION AND OPERATION

4.1 INTRODUCTION

This chapter describes the procedure for configuring the tube type, configuring user

allowed dual speed starter data and operating filament auto-calibration.

WARNING: USE EXTREME CARE IN MEASURING HIGH VOLTAGES. ACCIDENTAL CONTACT MAY CAUSE SERIOUS INJURY OR DEATH.

MAINS VOLTAGE WILL BE PRESENT INSIDE THE GENERATOR CHASSIS, EVEN WITH THE POWER SWITCHED OFF. THIS VOLTAGE IS EXTREMELY DANGEROUS, USE EXTREME CAUTION.

THE DC BUS CAPACITORS, LOCATED ON THE DC BUS ASSEMBLY, PRESENT A HAZARD FOR A MINIMUM OF 5 MINUTES AFTER THE GENERATOR HAS BEEN SWITCHED OFF. CHECK THAT THESE CAPACITORS ARE DISCHARGED BEFORE TOUCHING ANY PARTS IN THE GENERATOR.

WARNING: THE PROCEDURES IN THIS CHAPTER REQUIRE THE PRODUCTION OF X-Rays. TAKE ALL APPROPRIATE SAFETY PRECAUTIONS TO PROTECT PERSONNEL FROM X-Ray RADIATION.

WARNING: ALWAYS ENSURE THAT THE EQUIPMENT UNDER TEST AND ALL ASSOCIATED TEST EQUIPMENT IS PROPERLY GROUNDED

ENSURE THAT THE HIGH VOLTAGE CABLES ARE INTACT / UNDAMAGED AND PROPERLY CONNECTED BEFORE ATTEMPTING EXPOSURES

ENSURE THAT THE PMX IS PROPERLY INSTALLED AS PER CHAPTER 2 AND CHAPTER 3 BEFORE OPERATING WHAT THIS CHAPTER DESCRIBES.

4.2 TUBE PREHEAT TABLE CONFIGURATION

The PMX contains up to 2 tube types power limitation and filament value tables. Consult Spellman representatives when ordering for

available tube tables pre-installed or tube type field configuration possibility.

Reloading the default preheat tables in the PMX unit requires use of the DIP switches. The DIP switches are located near the edge of the board, to the right of the connector. The DIP switch identifiers are stenciled on the PC Board just above the switches, and the individual switches are numbered at the bottom of the DIP switch. The figure below illustrates the DIP switch placement.

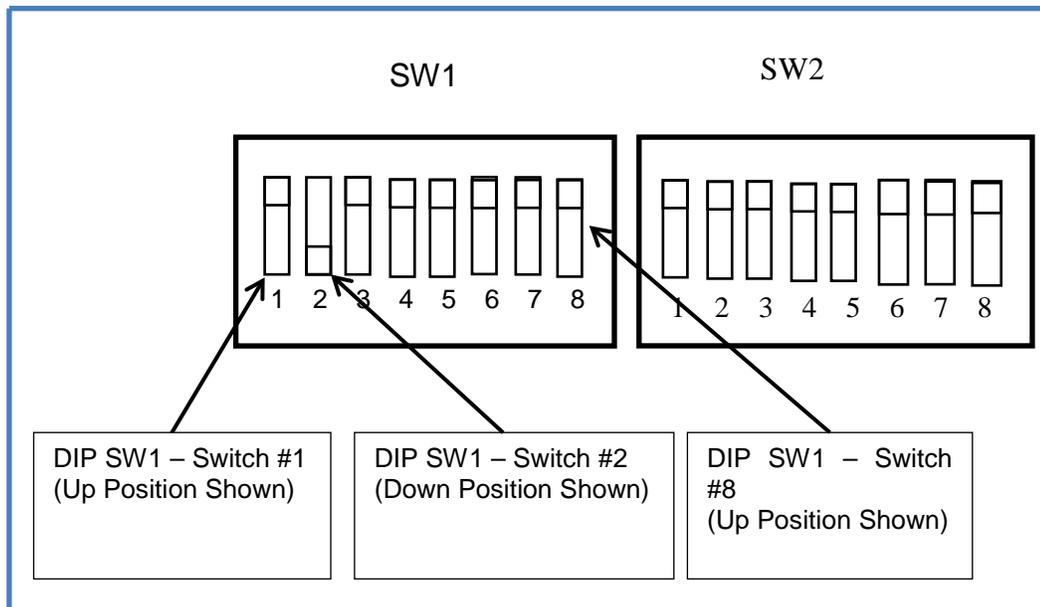


Figure 4-1: DIP Switches for Configuration

Switch 8 on DIP SW 1 controls the loading of the default Tube Table in to FRAM. When the unit is powered up with this switch in the down position the selected tube default data is loaded in to FRAM, overwriting any current data, including learned preheat values. This switch only causes table update when it is in the down position at power up. Setting the switch to the down position after power up does not change the tube table.

Switch 1 and Switch 2 on DIP SW 1 select which tube table will be loaded in to FRAM and become the active Tube. The setting of these switches only matters when Switch 8 is in the Down position at power up. Changing the Switch 1 and/or Switch 2 does not change or reload the tube table if the unit is powered up with Switch 8 in the up position.

Table 1 -Tube Table Selection Matrix			
Tube Selected	Tube number	Switch #1 Position	Switch #2 position
(IAE)XM1016T	0	Up	Up
(Varian) M113T	3	Down	Up
Invalid Setting (do not use)		Down	Down

Follow the below steps to select the desired table from the pre-installed tube table:

Step	Action
1.	Power down the system, if it is not already powered down. Switch #8 on DIP Switch 1 should be in the up position as show above. This is the normal working position.
2.	Set Switch #8 on Dip Switch 1 to the down position, this is with the switch set toward the center of the board (opposite to the above illustration). Also set switch #1 and switch #2 on DIP SW1 to the desired tube table as specified in Table 1 above.

3.	Turn on the power to the PMX unit, and wait for 10 seconds. This will reload the selected default table in to the FRAM.
4.	After the 10 seconds has elapsed, turn the power off, and return Switch 8 to the Up position. The tables have been reloaded and the system is ready to use. Make sure to leave Switch 8 in the Up position.

4.3 FILAMENT AUTO-CALIBRATION

The calibration function automatically establishes calibration curves relating filament current to tube current (mA) at three or four kV settings, depending on generator type. This allows the generator to predict the filament temperature (filament current) that will be required for any mA value over the full kV operating range.

It is recommended that the X-Ray tube be seasoned before attempting auto calibration, particularly if the tube has not been used for

some time. Refer to tube datasheet for seasoning operation.

There are two different modes for user selection to calibrate filament. User can calibrate the large filament and small filament separately or calibrate both large filament and small filament at one time. Sending "Set Calibration Mode" command (command number 28) with different argument will enter different calibration mode (Refer to protocol specification document for details).

Use these steps to perform the X-Ray tube auto calibration function:

Step	Action
1.	<p>Entering calibration mode</p> <p>Sending a "Set Calibration Mode" command (command number 28) with an argument of 1 or 2 or 3 with Prep and Exposure control in the OFF state. Generator will enter calibration mode but in 'pause' state as the Prep and Exposure is inactive.</p>
2.	<p>Enable Prep and Exposure to start calibration</p> <p>Calibration will be starting if both Prep and Exposure are activated. Once the sequence has started the generator will automatically cycle through the exposure settings as long as the Prep and Exposure control are ON until it either finishes calibration or there is an exposure fault.</p> <p>An exposure fault will cause the calibration routine to abort, and the unit to exit calibration mode. If the user removes Prep and / or Exposure control during the sequence, the calibration routine will enter a "Paused" state. It will not exit calibration mode, but it will stop doing exposures and wait until Prep and Exposure control are both returned to the ON state. If the user returns Prep and Exposure control ON, the PMX will continue the calibration. Usually it will continue from where it was when the sequence was paused, but depending on what it was doing when the calibration sequence was interrupted it may go back and repeat a previous step.</p> <p>The user may cancel calibration at any time by first setting Prep and / or exposure control off, and then sending a "Set Calibration Mode" Command with an argument of 0. Sending this command resets the calibration sequence. The next time calibration is started it will go back to the beginning. Once calibration is started previous values for preheat will be overwritten. Stopping calibration in the middle will result in some points being calibrated and others not being calibrated. This may result in poor or inconsistent preheat adjustment.</p> <p>If user chooses to calibrate large and small filaments separately, only the chosen filament will be affected. For example if small filament is calibrated and you attempt to</p>

	calibrate the large filament, but the calibration fails, it does not affect the small filament calibration. In this case you would have to rerun the large filament calibration, but not the small filament calibration.
--	--

3.	Exiting calibration mode When calibration process is finished, Prep and Exposure should be released, and then sending a "Set Calibration Mode" Command with an argument of 0 will let the PMX exit calibration mode.
----	--

4.4 OPERATING X-RAY EXPOSURES

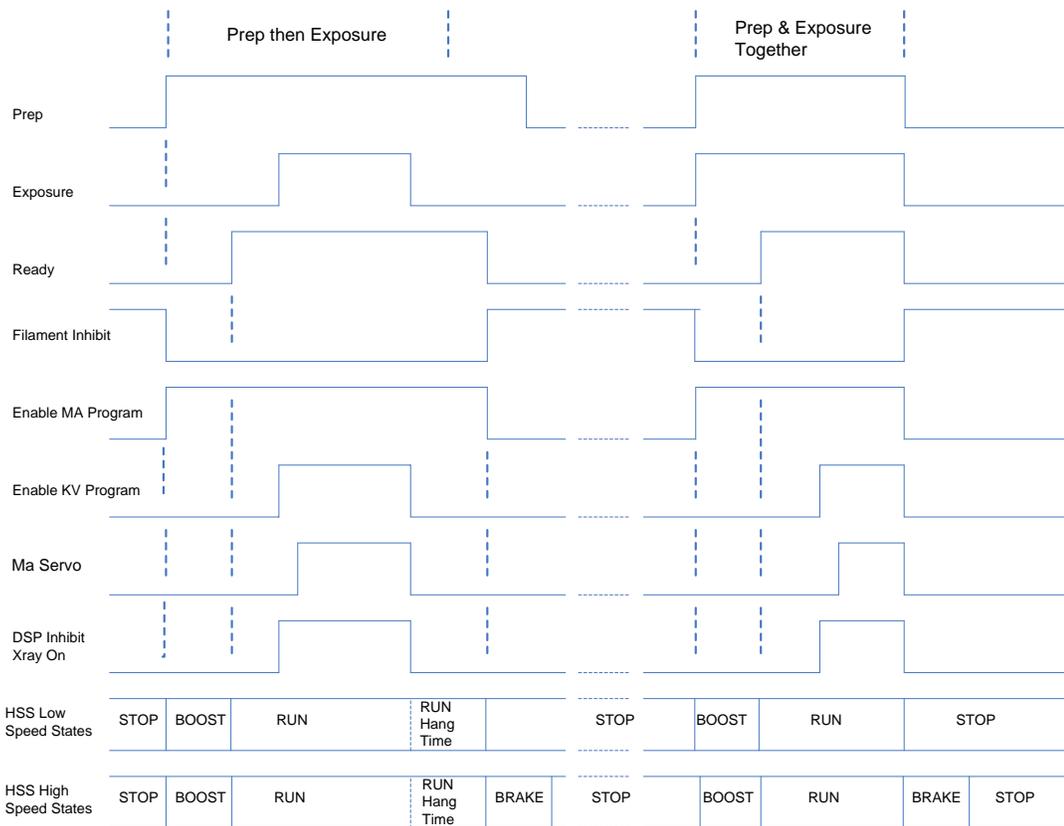
4.4.1 Normal Exposure

WARNING: AFTER TURN OFF, DO NOT UNPLUG THE OUPUT CABLE UNTIL THE INTERNAL CAPACITANCE IS DISCHARGED (APPROXIMATELY 3 MINUTES).

Use these steps to initiate a normal exposure:

Step	operation	Action
2.	Presetting	Using the computer interface, select ROTOR SPEED, and SMALL or LARGE FILAMENT. Set KV (initial setting of 20kV is suggested), mA (10mA suggested), and EXPOSURE time (0.5 seconds suggested).
2.	PREP	After presetting desired levels, initiate a PREP command. This will cause the X-Ray tube anode rotor to start, and apply filament pre-heat current to the tube per value stored in the PMX internal memory.
3.	READY	After approximately 2 seconds, a READY status signal will be returned to the computer indicating that the anode rotor is up to speed, and the tube is ready to generate X-Rays. The READY signal will remain for 30 seconds and automatically reset.
4.	EXPOSURE	When READY status is returned from the power supply, an exposure can then be initiated. When exposure is initiated, HV is applied to the X-Ray tube and the power supply loop control automatically adjusts the filament current to provide the mA tube current that was previously pre-set for the duration of the exposure time. Following an exposure, the HV will return to 0 volts until the next PREP/EXPOSURE cycle.

Below is timing sequence for a typical normal exposure.

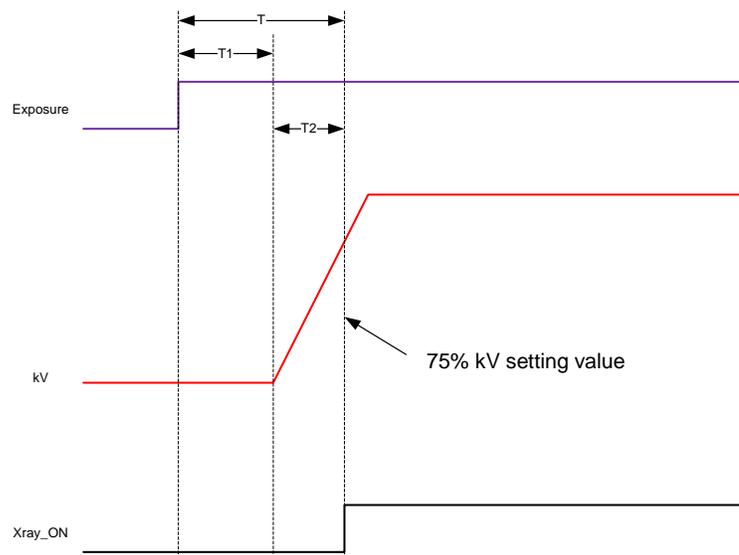


There are still other signals reflecting timing relations with exposure sequence, which are provided for synchronizing purpose for user system application.

X-Ray On 75% Status:

Open collector output signal. High level is active; indicate that the kV reach to 75% setting value, and the exposure time begin to accumulate.

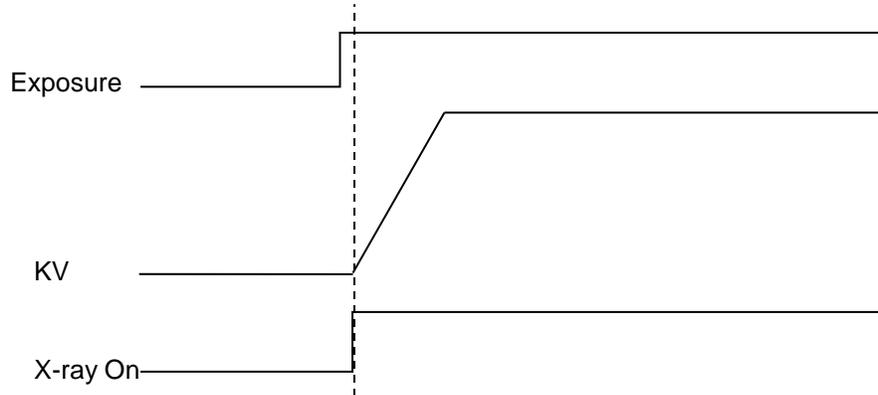
See below the timing:



X-Ray On Status:

Open collector output signal. High level is active; indicate that the HV output is beginning.

See below the timing:



4.4.2 AEC Exposure

In AEC Mode the external AEC control input, also called “X-Ray SHUTDOWN/AEC”, is allowed to gate the high voltage on and off. In order to generate X-Rays Prep, Exposure Control and AEC must all be in the “ON” state, which is High (Logic 1). In addition the unit must be in the ready state. When running in AEC mode the exposure control timer only runs when the AEC signal is high. The exposure sequence terminates when any of the following are true:

1. Prep goes inactive (low)
2. Exposure control goes inactive (low)
3. The exposure timer times out. (Timer is set as part of exposure command)
4. The 30 second Prep time is exceeded.

When in AEC Mode it is assumed that the AEC signal will be in the off state when the exposure sequence terminates. If the AEC signal is ON, an under-time fault will occur. The rotor continues to run when the X-Ray is shut off by the AEC signal. An example of AEC timing is show below for the case of Prep & Exposure together + HSS slow speed. Also note, in AEC mode Break after Exposure is automatically disabled, and will not occur even if it is set. In addition the Break after exposure hang time will be 30 seconds, regardless of the current setting.

See below the Timing.

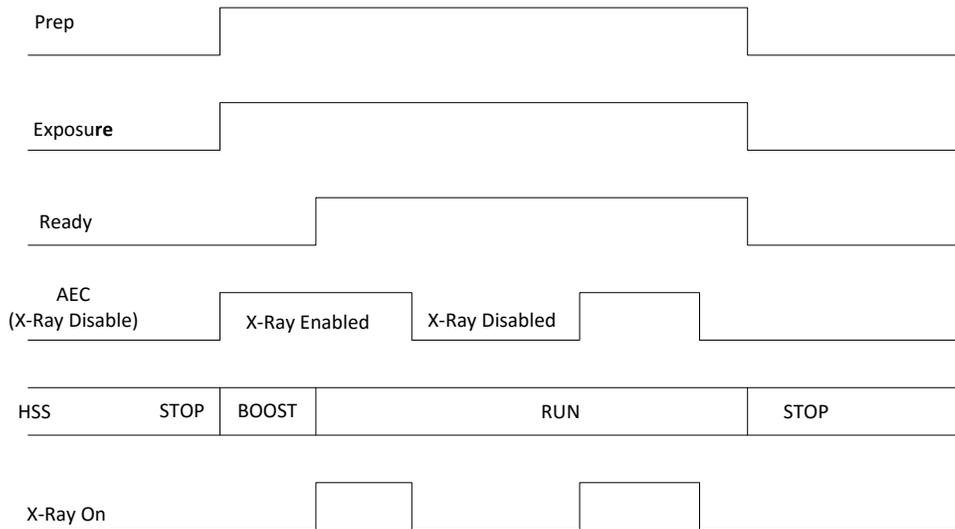


Fig 16 - AEC Timing

4.4.3 Smart AEC Exposure

The main character of this mode is that pre-exposure is followed by the main exposure at different parameter settings defined by the system.

This mode has the ability to change parameters during an “exposure sequence”. Exposure sequence is defined a number of Exposures whereby the System gates the generator ON and OFF by the AEC Shutdown signal input. The end of each individual exposure would be normally terminated by seconds or mAs programming.

In Smart AEC Mode (S-MAC) the exposure is split into two parts. Both parts of the exposure are required to use the same filament and HSS speed, but the kV / mA / exposure time are allowed to change between the first part of the exposure and the second part. The Prep, Exposure Control, X-Ray On (status), and AEC signals, along with the serial command port are all involved with Smart AEC mode. The sequence of events for doing a Smart AEC exposure is as follows:

1. The host sends the required commands to set up the exposure. These are HSS Speed, Filament, kV, mA, and exposure time for 3 point mode, or Filament, kV and mAs for 2 point mode. (Note that in smart AEC, 2 point mode HSS Speed is automatically set to Fast).
2. The host sets Prep “On”. The unit will go into the Boost / Preheat phase on the filament. (See Note 1).
3. The host sets exposure control ON and AEC control ON to enable X-Rays. AEC may be set ON before or simultaneous with exposure control ON.
4. The unit will turn High voltage ON. High voltage will remain ON until the programmed exposure time has elapsed. The host should monitor the X-Ray On status.
5. After the X-Ray On status transitions from ON to OFF the Host should set the AEC control to the X-Ray disabled state (Low). The host must also leave the exposure control ON during this time.
6. The host must now send the settings for the 2nd part of the exposure over the serial interface. Any combination of kV, mA, exposure time if in 3-point mode, or kV and mAs if in 2-point mode may be changed. HSS Speed and Filament may not be changed.

7. The host must wait a minimum of 20 milliseconds after the end of the last command for the PMX unit to process the commands. By the end of the 20 millisecond period the 2nd part of the exposure will be set up and a new value of preheat current applied to the filament. (See Note 2).
8. The host sets the AEC signal High to indicate the 2nd part of the exposure can begin.
9. The PMX unit will turn High voltage ON. High voltage will remain ON until the programmed exposure time has elapsed. The host should monitor the X-Ray On status.
10. When the X-Ray transitions to OFF the exposure sequence is complete. The Host can set Prep and Exposure Control to OFF.

Note 1: The time to ready is 2 seconds. The exposure control signal can be set ON prior to the end of the 2 second time, but the High Voltage will not actually turn ON until the 2 seconds have elapsed from Prep active.

Note 2: Even though the new exposure settings will be programmed and the new preheat set for the 2nd part of the exposure within 20 milliseconds of receiving the last setup command, the filament temperature will not change instantaneously. Turning on the high voltage immediately after the 20 millisecond period ends will not allow enough time for the filament to reach the desired temperature. This may result in large mA variations at the start of the 2nd part of the exposure.

Note 3: In Smart AEC mode, Break after exposure is forced to "OFF", and the Break after exposure hang time set to 30 seconds, regardless of the previously programmed values. (This is the same as in standard AEC mode).

Note 4: There is no specified maximum time between the first part and second part of the exposure. The limiting factor is that the unit can have Prep active for a maximum of 30 seconds, so the entire exposure sequence,

including the 2 second time to ready, can't be longer than 30 seconds.

Note 5: The AEC control signal MUST be in the X-Ray disabled state (low) during the exposure settings update for the 2nd part of the exposure. The state of the AEC control signal does not matter when setting up the 1st part of the exposure because Exposure Control and Prep are low.

Note 6: In Smart AEC Mode, Commands, request last exposure kV monitor and request last exposure mA monitor treat the first and second part of the exposure as separate exposures. For example if the kV monitor is requested after the first part of the exposure has finished, but before the second part has started, the average kV of the first part is reported. If the kV monitor is then requested after the second part of the exposure has finished, the average will be for the second part of the exposure only.

See below the timing sequence:

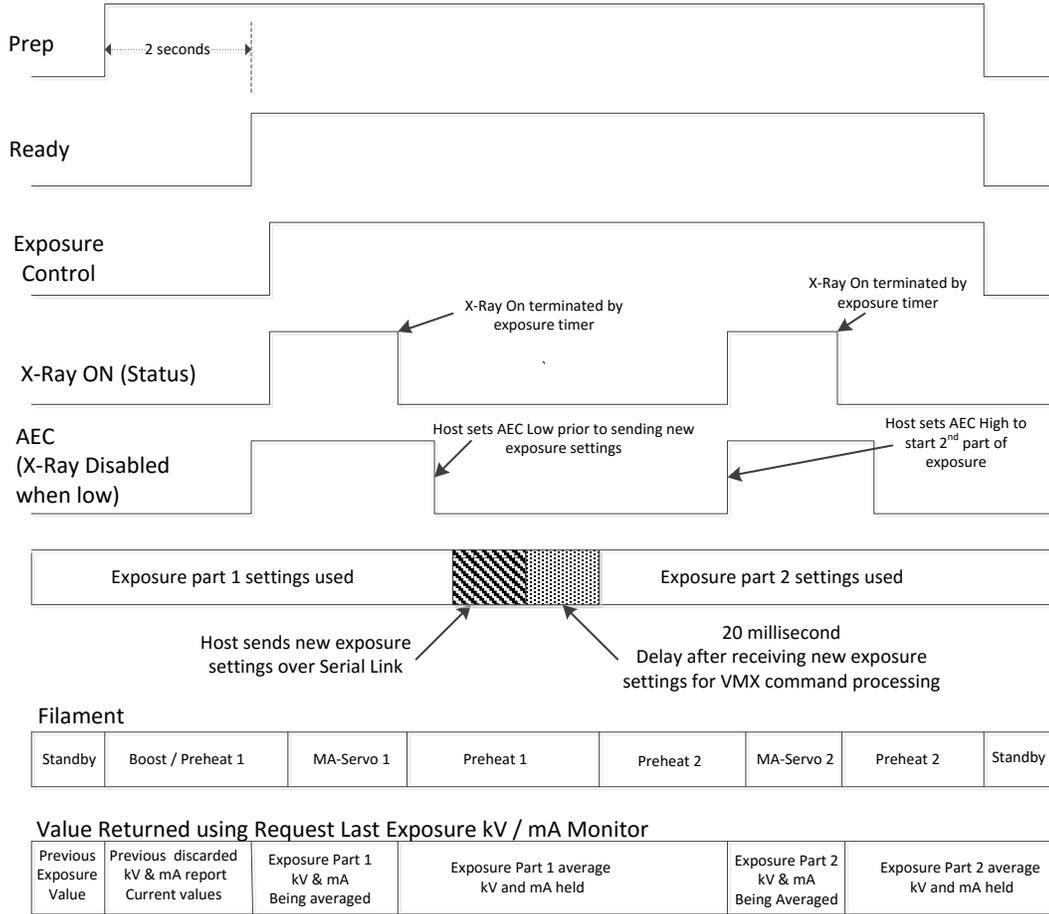


Fig 18 – Smart AEC Mode

Notes:

Setting the AEC signal low before X-Ray On status goes low (X-Ray Off) will cause an under-time fault.

Exposure commands sent at an illegal time such as when AEC is high or X-Ray is ON will be ignored and will return a “State Error” code. Exposure commands used to set up the 2nd part of the exposure must be sent at the time indicated in the diagram.

Aborting the Smart AEC sequence by bringing Prep and/or Exposure control low in after the part 1 exposure is finished but before the part 2 exposure is started will not generate a fault.

It is required to send a new setup between the part 1 exposure and part 2 exposure, even if the new setup is exactly the same as the old. This can be done using the “Set Exposure Settings” command, or Individual set commands such as “Set Exposure kV”, “Set Exposure mA” and “Set Exposure Time” if in 3 point mode, or “Set Exposure kV”, and “Set Exposure mAs” in 2 point mode. It is allowed but not required to send a Set Filament or Set HSS Speed command, provided the setting is the same as in the part 1 exposure.

It is not allowed to change from 2-Point Mode to 3-Point mode or the reverse in the middle of a Smart AEC exposure.

CHAPTER 5

TROUBLE SHOOTING

5.1 INTRODUCTION

Fault or error message will be indicated via system status indicator or serial message during abnormal operation. This Chapter contains tables of those messages and suggests actions to be taken by service personnel to correct any malfunctions that may occur.

5.2 STATUS AND ERROR CODES

5.2.1 Status Messages

LEDs provide status indication of the necessary diagnostics needed for recognizing the operation/shutdown mode of the generator. LEDs display the following information:

System Control Board 460220-001

LED	DEFINITION	COLOR	NORMAL STATE	FUNCTION
DS1	Not used			
DS2	+24V	GREEN	Lit	Indicate +24V power supply is active.
DS3	DSP Alive	RED	Lit	
DS4	STATUS BIT1	YEL	Lit	3 bit status lines for status messages. Refer to chapter 3 the status messages matrix.
DS5	STATUS BIT2	YEL	Lit	
DS6	STATUS BIT3	YEL	Lit	
DS7	READY	YEL	Lit	Indicate the generator is ready for X-Ray exposure.
DS8	SPARE	YEL	Lit	
DS9	FAULT	RED	Lit	Indicate generator fault.
DS10	X-Ray shutdown/AEC	YEL	Lit	Indicate the status of the signal (JB1-12).
DS11	SF	YEL	Lit	Filament selection indicator.
DS12	Rotor on	GREEN	Lit	Starter status indicator.
DS13	HSS fault	RED	Lit	Indicate high speed starter fault.
DS14	Prep	GREEN	Lit	Synchronizing indication of Prep signal.
DS15	Safety Int'lk	GREEN	Lit	Safety interlocks status indication.
DS16	X ray ON	RED	Lit	Synchronizing indication of X-Ray On signal.
DS17	FPGA HEART BEAT	YEL	Lit	Indicate FPGA is working.
DS18	Rotor brake	YEL	Lit	Indicate brake status of starter.

5.2.2 Faults Messages

NAME	Arg. #	DESCRIPTION	ACTION
Interlock 1	1	General Purpose Interlock Input 1 (Originally called Tube Temperature). An open/logic high on the input pin results in a fault condition. A Logic low / Short to GND is the "Good" or non-faulted condition. This was originally intended for connection to a tube temperature switch, but can be used for other purposes.	Check the short connection.
Interlock 2	2	General Purpose Interlock Input 2 (Originally called Tube Flow). An open/logic high on the input pin results in a fault condition. A Logic low / Short to GND is the "Good" or non-faulted condition. This was originally intended for connection to a tube flow switch, but can be used for other purposes.	Check the short connection
HSS Fault	3	High Speed Starter Fault – Any Fault related to operation of the high speed starter.	<ol style="list-style-type: none"> 1. Check the AC line voltage. 2. Check the low voltage cable connections. 3. Ensure that no more than 2 times boost within 1 minute.
ARC	4	ARC Fault – The unit shutdown high voltage because an electric arc occurred.	<ol style="list-style-type: none"> 1. Check HV cable connections. 2. Season X-ray tube. 3. Replace the X-ray tube.
Over Power	5	An attempt was made to turn on the generator with settings that result in a power output of greater than 5kW.	
Over Time	6	This fault is possible only in AEC Mode. It indicates the unit shut-down because of the expiration of the exposure timer, rather than the AEC control signal. (Timeout of exposure timer with AEC active)	Ensure that the cumulative time in one exposure sequence not exceed the exposure timer (ms). In AEC mode, exposure timer acts as back up timer.
Over mAs	7	The mAs of the current exposure has exceeded the set value by 25%. This is calculated by taking the average current and multiplying by exposure time. The unit will fault immediately when this happens, and shut down the high voltage. Note that when in 2 point mode the limit is set to 125% of the value programmed using the "Set mAs" command. In 3 point mode it is calculated by multiplying the set mA value * then set exposure time.	
Over Duty	8	The unit requires 20 seconds in-between exposure cycles. A cycle being defined as entering prep,	Ensure that the exposure operation within the duty cycle limitation.

		<p>exposure control on, high voltage on, high voltage off, exit prep. The unit is also limited to 5 seconds of exposure time in any 2 minute period. If an attempt is made before to turn on high voltage in less the 20 seconds after the last exposure this fault will occur. Also, if the cumulative exposure time over the last 2 minutes exceeds 5 seconds and an attempt is made to turn high voltage on this fault will occur.</p> <p><u>Note: The 20 second limit does not apply to high voltage on / off cycles that are part of a sequence in AEC or AOP mode.</u></p>	
Over Voltage	9	This fault occurs if the output voltage exceeded 60kV for 1 millisecond (or more).	Consult product support.
Over Current	10	If the output current exceeds 213.8 mA for 100 milliseconds (or more) this fault will occur.	Consult product support.
Regulation	11	<p>This fault occurs if the actual kV is exceeded by +/-10% or mA output has exceeded +/- 25% of the set value.</p> <p>Note: There is a delay from high voltage on to when the kV and mA are checked to allow time for the kV and mA to stabilize so false faults are not generated. This time is 30 msec. for kV regulation and 250 msec. for mA regulation.</p>	<ol style="list-style-type: none"> 1. Check the line voltage in good condition. 2. Replace the X-ray tube 3. Consult product support.
Open Filament	12	Tube filament shows open (zero current despite voltage applied to filament) for more than 2 seconds.	<ol style="list-style-type: none"> 1. Check the LV cable connection 2. Measure filament resistance to verify filament condition. 3. Consult product support.
Filament (overcurrent)	13	<p>The filament current has exceeded the set maximum limit of for more than 200 msec.</p> <p>The set limit is 5.2A for all currently supported tubes, but as additional tubes are added, this value may change for the new tubes.</p>	<ol style="list-style-type: none"> 1. Check the preheat value. 2. Change setting value and verify again. 3. Change to another X-ray tube. 4. Consult product support.
Ac/Dc	14	The rectified input voltage to the unit is less than 255V DC for 1 second or more.	Check input line voltage

Under Time	15	In manual or smart AEC mode, the exposure terminated due to the removal of the Prep or exposure control signals prior to the expiration of the exposure Timer. (Exposure was shorter than programmed). Cannot occur in AEC mode.	Verify the control timing in accordance with the function protocol.
Safety Interlock Fault	16	An attempt was made to start an exposure with the safety interlock open. High voltage will not go on.	Check the safety interlock connection.
Setup Fault	17	An attempt was made to start an exposure (turn high voltage on) with an illegal setup programmed into the unit. High voltage will not go on.	Verify the setting value.

Notes:

If high voltage is on when a particular fault occurs the high voltage will immediately be shut off.

Over Time and Under Time faults can only occur at the end of an exposure (immediately after high voltage is turned off). These faults indicate an error in how the control signals were applied as compared to what was expected for

the mode the unit was set up in, rather than a fault in the PMX supply operation.

Over Duty faults can only occur at the transition of exposure control from off to on. That is, right at the start of an exposure. Once an exposure is started it will be allowed to continue even if after it is finished the on time exceeds 5 seconds over the previous 2 minutes.

Table 1 – Guidance and MANUFACTURER’S declaration – ELECTROMAGNETIC EMISSIONS – for all ME EQUIPMENT and ME SYSTEMS

Guidance and manufacturer’s declaration – electromagnetic emissions		
The PMX is intended for use in the electromagnetic environment specified below. The customer or the user of the PMX should assure that it is used in such an environment.		
Emissions test	Compliance	Electromagnetic environment – guidance
RF emissions CISPR 11	Group 1	The PMX is suitable for use in all establishments other than domestic and those directly connected to the public low-voltage power supply network that supplies buildings used for domestic purposes.
RF emissions CISPR 11	Class A	
Harmonic emissions IEC 61000-3-2	Not applicable	
Voltage fluctuations/ flicker emissions IEC 61000-3-3	Not applicable	

Table 2 – Guidance and MANUFACTURER’S declaration – ELECTROMAGNETIC EMISSIONS – for all ME EQUIPMENT and ME SYSTEMS

Guidance and manufacturer’s declaration – electromagnetic immunity			
The PMX is intended for use in the electromagnetic environment specified below. The customer or the user of the PMX should assure that it is used in such an environment.			
Immunity test	IEC 60601 test level	Compliance level	Electromagnetic environment – guidance
Electrostatic discharge (ESD) IEC 61000-4-2	± 6 kV contact ± 8 kV air	± 6 kV contact ± 8 kV air	Floors should be wood, concrete or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30 %.
Electrical fast transient/burst IEC 61000-4-4	± 2 kV for power supply lines ± 1 kV for input/output lines	± 2 kV for power supply lines ± 1 kV for input/output lines	Mains power quality should be that of a typical commercial or hospital environment.
Surge IEC 61000-4-5	± 1 kV line(s) to line(s) ± 2 kV line(s) to earth	± 1 kV line(s) to line(s) ± 2 kV line(s) to earth	Mains power quality should be that of a typical commercial or hospital environment.
Voltage dips, short interruptions and voltage variations on power supply input lines IEC 61000-4-11	<5 % <i>UT</i> (>95 % dip in <i>UT</i>) for 0,5 cycle 40 % <i>UT</i> (60 % dip in <i>UT</i>) for 5 cycles 70 % <i>UT</i> (30 % dip in <i>UT</i>) for 25 cycles <5 % <i>UT</i> (>95 % dip in <i>UT</i>) for 5 s	<5 % <i>UT</i> (>95 % dip in <i>UT</i>) for 0,5 cycle 40 % <i>UT</i> (60 % dip in <i>UT</i>) for 5 cycles 70 % <i>UT</i> (30 % dip in <i>UT</i>) for 25 cycles <5 % <i>UT</i> (>95 % dip in <i>UT</i>) for 5 s	Mains power quality should be that of a typical commercial or hospital environment. If the user of the PMX requires continued operation during power mains interruptions, it is recommended that the PMX be powered from an uninterruptible power supply or a battery.
Power frequency (50/60 Hz) magnetic field IEC 61000-4-8	3 A/m	3 A/m	Power frequency magnetic fields should be at levels characteristic of a typical location in a typical commercial or hospital environment.
NOTE <i>UT</i> is the A.C. mains voltage prior to application of the test level.			

Table 4 – Guidance and MANUFACTURER’S declaration – electromagnetic IMMUNITY – for ME EQUIPMENT and ME SYSTEMS that are not LIFE-SUPPORTING

Guidance and manufacturer’s declaration – electromagnetic immunity			
The PMX is intended for use in the electromagnetic environment specified below. The customer or the user of the PMX should assure that it is used in such an environment.			
Immunity test	IEC 60601 test level	Compliance level	Electromagnetic environment – guidance
Conducted RF IEC 61000-4-6	3 Vrms 150 kHz to 80 MHz	3 Vrms	<p>Portable and mobile RF communications equipment should be used no closer to any part of the PMX, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter.</p> <p>Recommended separation distance</p> $d = 1.17 \sqrt{P}$
Radiated RF IEC 61000-4-3	3 V/m 80 MHz to 2.5 GHz	3 V/m	$d = 1.17 \sqrt{P} \quad 80 \text{ MHz to } 800 \text{ MHz}$ $d = 2.33 \sqrt{P} \quad 800 \text{ MHz to } 2.5 \text{ GHz}$ <p>Where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer and d is the recommended separation distance in meters (m).</p> <p>Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey,^a should be less than the compliance level in each frequency range.^b</p> <p>Interference may occur in the vicinity of equipment marked with the following symbol:</p> 
NOTE 1 At 80 MHz and 800 MHz, the higher frequency range applies.			
NOTE 2 These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people.			
<p>a. Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radios, amateur radio, AM and FM radio broadcast and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location in which the PMX is used exceeds the applicable RF compliance level above, the PMX should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the PMX.</p> <p>b. Over the frequency range 150 kHz to 80 MHz, field strengths should be less than 3 V/m.</p>			

Table 6 – Recommended separation distances between portable and mobile RF communications equipment and the ME EQUIPMENT or ME SYSTEM – for ME EQUIPMENT and ME SYSTEMS that are not LIFE-SUPPORTING

Recommended separation distances between portable and mobile RF communications equipment and the PMX			
The PMX is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The customer or the user of the PMX can help prevent electromagnetic interference by maintaining a minimum distance between portable and mobile RF communications equipment (transmitters) and the PMX as recommended below, according to the maximum output power of the communications equipment.			
Rated maximum output power of transmitter W	Separation distance according to frequency of transmitter m		
	150 kHz to 80 MHz $d = 1.17 \sqrt{P}$	80 MHz to 800 MHz $d = 1.17 \sqrt{P}$	800 MHz to 2,5 GHz $d = 2.33 \sqrt{P}$
0.01	0.117	0.117	0.233
0.1	0.370	0.370	0.737
1	1.17	1.17	2.33
10	3.70	3.70	7.37
100	11.7	11.7	23.3
For transmitters rated at a maximum output power not listed above, the recommended separation distance d in meters (m) can be determined using the equation applicable to the frequency of the transmitter, where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer.			
NOTE 1 At 80 MHz and 800 MHz, the separation distance for the higher frequency range applies.			
NOTE 2 These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people.			

CHAPTER 6

MAINTENANCE

6.1 INTRODUCTION

If a major component (such as the multiplier module or system control board) is replaced, recalibration will be needed. The acceptance test procedure

per Chapter 5 should then be performed prior to placing the generator back into service.

WARNING: ALWAYS SWITCH OFF MAINS POWER TO THE GENERATOR AND WAIT A MINIMUM OF 5 MINUTES FOR CAPACITORS TO DISCHARGE BEFORE BEGINNING ANY MAINTENANCE.

6.2 PERFORMANCE TEST

Only qualified personnel should perform these tests.

High voltage test procedures are described in Spellman Bulletin STP-783, Standard Test Procedures for High Voltage Power Supplies. Copies can be obtained from the Spellman Customer Service Department. Test equipment, including an oscilloscope, a high impedance voltmeter, and a high voltage divider such as the Spellman HVD-100 or HVD-200, is needed for performance tests. All test components must be rated for operating voltage.

6.3 HIGH VOLTAGE DIVIDERS

High voltage dividers for precise measurement of output voltage with accuracy up to 0.1% are available from Spellman. The HVD-100 is used for voltages up to 100kV. The HVD-200 measures up to 200kV. The Spellman divider is designed for use with differential voltmeters or high impedance digital voltmeters. The high input impedance is ideal for measuring high voltage low current sources, which would be overloaded by traditional lower impedance dividers.

CHAPTER 7 REPLACEMENT PARTS

7.1 Replacement Parts

Contact the Spellman Customer Service Department for parts lists for specific models.

Spellman provides parts and subassemblies for its high voltage power supplies but recommends that only qualified personnel perform repairs. High voltage is dangerous; even minor mistakes in repairs can have serious consequences.

When requesting parts, please provide the complete model number and serial number of the power supply in question.

7.2 Correspondence and Ordering Spare Parts

Each Spellman power supply has an identification label on the rear of the chassis that bears its model and serial number.

When requesting engineering or applications information, please state the model and serial number of the power supply. If specific components or circuit sections are involved in the inquiry, it is helpful to indicate the component symbol number(s) shown on the applicable schematic diagram.

When ordering spare parts, please specify the part's description, the part's reference designation or part number, and the model and serial number of the unit.

CHAPTER 8

FACTORY SERVICE

8.1 Warranty Repairs

During the Warranty period, Spellman will repair all units free of charge. The Warranty is void if the unit is worked on by other than Spellman personnel. See the Warranty in the rear of this manual for more information. Follow the return procedures described in Section 8.2. The customer shall pay for shipping to and from Spellman.

8.2 Factory Service Procedures

Spellman has a well-equipped factory repair department. If a unit is returned to the factory for calibration or repair, a detailed description of the specific problem should be attached.

For all units returned for repair, please obtain an authorization to ship from the Customer Service Department, either by phone or mail prior to shipping. When you call, please state the model and serial numbers, which are on the plate on the rear of the power supply, and the purchase order number for the repair. A Return Material Authorization Code Number (RMA Number) is needed for all returns. This RMA Number should be marked clearly on the outside of the shipping container. Packages received without an RMA Number will be returned to the customer. The Customer shall pay for shipping to and from Spellman.

A preliminary estimate for repairs will be given by phone by Customer Service. A purchase order for this amount is requested upon issuance of the RMA Number. A more detailed estimate will be made when the power supply is received at the Spellman Repair Center. In the event that repair work is extensive, Spellman will call to seek additional authorization from your company before completing the repairs.

8.3 Shipping Instructions

All power supplies returned to Spellman must be sent shipping prepaid. Pack the units carefully and securely in a suitable container, preferably in the original container, if available. The power supply should be surrounded by at least four inches of shock absorbing material. Please return all associated materials, i.e. high voltage output cables, interconnection cables, etc., so that we can examine and test the entire system.

All correspondence and phone calls should be directed to:

Spellman High Voltage Electronics Corp.
475 Wireless Boulevard
Hauppauge, New York 11788
TEL: (631) 630-3000 FAX: (631) 435-1620
E-Mail: sales@Spellmanhv.com
www.spellmanhv.com

To obtain information on Spellman's product warranty please visit our website at:

<http://www.spellmanhv.com/en/About/Warranty.aspx>





PMX Power Supply Protocol Definitions 50kV

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1. Serial Communications Interface

Serial communications will use the following protocol:

<STX><CMD><,>ARG><,><CSUM><ETX>

Where:

<STX> = 1 ASCII 0x02 Start of Text character

<CMD> = 2 ASCII characters representing the command ID

<,> = 1 ASCII 0x2C character

<ARG> = Command Argument

<,> = 1 ASCII 0x2C character

<CSUM> = Checksum (see section 1.2 for details)

<ETX> = 1 ASCII 0x03 End of Text character

The serial interface has the following attributes:

- 19.2K baud (Default baud rate, can be changed to 115K baud for reprogramming of the firmware)
- No Parity
- 8 Data Bits
- 1 Stop Bit
- No Hand shaking

1.1 Command Arguments

The format of the numbers for command arguments is a variable length string. To represent the number 42, the string '42', '042', or '0042' can be used. This being the case, commands and responses that carry data are variable in length.

1.2 Check Sums

The checksum is computed as follows:

- Add the <CMD>, <,>, and <ARG> bytes into a 16 bit (or larger) word. The bytes are added as unsigned integers.
- Take the 2's compliment (negate it).
- Truncate the result down to the eight least significant bits.
- Clear the most significant bit (bit 7) of the resultant byte, (bitwise AND with 0x7F).
- Set the next most significant bit (bit 6) of the resultant byte (bitwise OR with 0x40).

Using this method, the checksum is always a number between 0x40 and 0x7F.

The checksum can never be confused with the <STX> or <ETX> control characters, since these have non-overlapping ASCII values. If the DSP detects a checksum error, the received message is ignored and the supply will respond with an error code of 1 (see section 3.4).

2.2. Ethernet Command Format

The Ethernet command format is:

<STX><CMD><,>ARG><,><CSUM><ETX>

Where:

<STX>	= 1 ASCII 0x02 Start of Text character
<CMD>	= 2 ASCII characters representing the command ID
<,>	= 1 ASCII 0x2C character
<ARG>	= Command Argument
<,>	= 1 ASCII 0x2C character
<CSUM>	= Checksum (see section 3.3 for details)
<ETX>	= 1 ASCII 0x03 End of Text character

This is exactly the same format as the RS232 serial commands as defined in section 3. The Ethernet interface acts as a transport for the serial PMX commands. The commands themselves have the exact same format, responses and meanings as with the RS232 serial command. The command formats, responses, and examples as shown in section 4 apply equally to both RS232 and Ethernet communication.

2.3. Ethernet / RS232 use

PMX will accept commands via the RS232 serial link or the Ethernet interface, but only one communication interface can be used at a time. You cannot send commands over RS232 and Ethernet both at the same time. Using both RS232 and Ethernet concurrently is not allowed and trying to do so will cause unreliable communication and erratic operation. Note also that firmware upgrade over the Ethernet interface is not supported. This function is available only over the RS232 interface.

3.0 Serial Commands – RS232 SERIAL Protocol

3.1 Serial Interface Message Format

Serial communications will use the following format:

<STX><CMD><,>ARG><,><CSUM><ETX>

Where:

<STX> = 1 ASCII 0x02 Start of Text character
<CMD> = 2 ASCII characters representing the command ID
<,> = 1 ASCII 0x2C character
<ARG> = Command Argument
<,> = 1 ASCII 0x2C character
<CSUM> = Checksum (see section 3.3 for details)
<ETX> = 1 ASCII 0x03 End of Text character

3.2 Command Arguments

The format of the numbers used for command arguments is a variable length string. To represent the number 42, the string '42', '042', or '0042' can be used. This being the case, commands and responses that carry data are variable in length.

3.3 Checksums

The checksum is computed as follows:

- Add the <CMD>, <,>, and <ARG> bytes into a 16 bit (or larger) word. The bytes are added as unsigned integers.
- Take the 2's compliment (negate it).
- Truncate the result down to the eight least significant bits.
- Clear the most significant bit (bit 7) of the resultant byte, (bitwise AND with 0x7F).
- Set the next most significant bit (bit 6) of the resultant byte (bitwise OR with 0x40).

Using this method, the checksum is always a number between 0x40 and 0x7F. The checksum can never be confused with the <STX> or <ETX> control characters, since these have non-overlapping ASCII values.

The following is sample code, written in Visual Basic, for the generation of checksums:

Public Function ProcessOutputString(outputString As String) As String

```

Dim i As Integer
Dim CSb1 As Integer
Dim CSb2 As Integer
Dim CSb3 As Integer
Dim CSb$
Dim X

X = 0
For i = 1 To (Len(outputString)) 'Starting with the CMD character
X = X + Asc(Mid(outputString, i, 1)) 'adds ascii values together
Next i

CSb1 = 256 - X
CSb2 = 127 And (CSb1) 'Twos Complement
CSb3 = 64 Or (CSb2) 'OR 0x40
CSb$ = Chr(Val("&H" & (Hex(CSb3))))
ProcessOutputString = Chr(2) & outputString & CSb$ & Chr(3)

End Function

```

3.4 Checksum Errors:

If the DSP detects a checksum error, the received message is ignored , and the unit responds with a command byte equal to 1 as shown in the following sequence:

<STX>1,<CSUM><ETX>.

The 1 in the command byte indicates a checksum error has occurred.

3.5 Timeouts:

There exists the possibility that the message from the Host to the unit is distorted so badly that the unit can't process the message at all and no response will be sent. The host should implement a time out of 100 milliseconds from when the message is sent. If the host sends a message and no response is received before this 100ms timeout expires the host should use this an implied NAK and assume the command was not received by the unit.

4.0 Command Overview

Commands are separated into two modes: command and service modes. Command mode is for normal operation and service mode for modifying certain parameters and reading their value. Service mode commands are not meant to be used as part of normal operation. They are intended for system testing and unit servicing.

4.1 Command Mode Commands

Command Mode RS232 Commands			
Command Name	<CMD>	<ARG>	RANGE
Request Analog Monitor Readbacks	19	None	-
Request Status	22	None	-
Reset Faults	31	None	-
Set Exposure Settings	50	1-4 ASCII	See cmd
Get Exposure Settings	51	None	-
Set Exposure Time	72	1 ASCII	20-12000
Set Exposure kV	10	1 ASCII	0-4095
Set Exposure mA	11	1 ASCII	0-4095
Set Exposure Filament	73	1 ASCII	0-1
Set Exposure mAs	74	1 ASCII	1-6000
Request Exposure Time Setpoint	52	None	-
Request Exposure kV Setpoint	14	None	-
Request Exposure mA Setpoint	15	None	-
Request Exposure Filament Setting	53	None	-
Request Exposure mAs Setpoint	54	None	-
Set HSS Speed	59	None	0 or 1
Request Fault Status	68	None	-

Command Mode RS232 Commands			
Request Last Exposure kV monitor	60	None	-
Request Last Exposure mA monitor	61	None	-
Get Last Exposure Length	65	None	-
Set Brake After Exposure	35	1 ASCII	0-1
Set Brake After Exposure Hang Time	36	1 ASCII	0-65535
Get Brake After Exposure Hang Time	37	None	-
Set AEC Mode	57	1 ASCII	0-1
Request AEC Mode	58	None	-
Set 2-Point / 3 –Point Exposure Mode	55	1 ASCII	0-1
Request 2-Point / 3 –Point Exposure Mode	56	None	-
Set Smart AEC Mode	75	1 ASCII	0-1
Request Smart AEC Mode	76	None	-
Request Current Anode Heat Load	77	None	-
Request Auxiliary Status	78	None	-
Request Expanded Fault Status	69	None	-
Request Expanded HSS Status	84	None	-

4.2 Service Mode Commands

Service Mode RS232 Commands			
Command Name	<CMD>	<ARG>	RANGE
Set Baud Rate	07	1 ASCII	2 = 19200, 5 = 115200
Program Filament Limit	12	1-ASCII	0-4095
Request Filament Limit Setpoint	16	None	-
Request Filament Pre-Heat Setpoint	17	None	-
Get Revision	27	None	-
Set Exposure Settings Max Exposure Time	40	1 ASCII	0-10000
Request Max Exposure Time	32	None	-
Set Exposure Settings PreHeat Value	33	1 ASCII	0-4095
Set Ready For Exposure Time	34	1 ASCII	0-4095
Get Ready For Exposure Time	42	None	-
Set Maximum mAs	38	1-4 ASCII	0-600
Get Maximum mAs	39	None	-
Request Filament Current Feedback	62	None	-
Set Calibration Mode	28	1 ASCII	0-1
Request Calibration Status	29	None	-

4.3 Response Overview

The responses to the above commands will follow one of two general formats depending on whether the command was a set command, intended to modify system or exposure setup, or a request command, intended to return system status, current setup or exposure information.

4.3.1 Set Command Response Format

The general format the response to a set command is:
<STX><CMD>,<\$-OR-ERR/WARN>,<CSUM><ETX>

Where:

- <STX> = 1 ASCII 0x02 Start of Text character
- <CMD> = 2 ASCII characters echoing the command ID
- <,> = 1 ASCII comma (0x2C character)
- <\$-OR-ERR/WARN> = If the setting(s) specified by the command are valid this will be the ASCII \$ character. If the setting is invalid or results in an invalid setup for the system a 1 or 2 character code will be returned. See the following section on warnings and errors.
- <,> = 1 ASCII comma 0x2C character
- <CSUM> = Checksum (see section 3.3 for details)
- <ETX> = 1 ASCII 0x03 End of Text character

4.3.2 Request Command Response Format.

The general format for the response to a request command is:
<STX> <CMD>,<ARG1>,{<ARGn>,<CSUM><EXT>

Where:

- <STX> = 1 ASCII 0x02 Start of Text character
- <CMD> = 2 ASCII characters echoing the command ID
- <,> = 1 ASCII comma (0x2C character)
- <ARG> = A data value consisting of a variable number of ASCII characters. The actual meaning is command dependent.
- ,<ARG+n>= Additional ASCII data values separated from the previous value by a comma. Additional values may not be present depending on the command and the number of additional values is command dependent.
- <,> = 1 ASCII comma 0x2C character
- <CSUM> = Checksum (see section 3.3 for details)
- <ETX> = 1 ASCII 0x03 End of Text character

4.3.3 Warnings and Errors

As mentioned in section 4.3.1 set commands are responded to with either a “\$” (dollar sign) character or a 1 or 2 character long ASCII format numeric code that can be an error or a warning.

- A response of a \$ character indicates successful reception and processing of the sent value. The value sent in the command has been accepted and is now the active value that will be used by the system.
- A response of an ASCII encoded number 3 -9 indicates a parameter error. This means one or more of the values sent in the command is invalid, or out of range. The value(s) in the command are ignored and the old values that the system is set for remain in effect. Some of the “Set” commands only set a single value. For these commands an error code of 3 indicates an invalid or out of range parameter. This is the only possible error for these functions. Some functions, such as the “Set Exposure” function use multiple error codes. For these commands the meaning of the error codes is dependent on the particular command. See the individual command for a list of possible error codes and their meaning.
- A response of an ASCII “10” (2 characters) indicates a warning. This is a possible response for commands that modify exposure settings. It indicates that the parameter in the command is in range, but when combined with the other current supply settings results in an invalid set up. The new value has been accepted but the supply is now in an “invalid programming” condition. The high voltage will not turn on if commanded. If the intent of the user is to send additional commands to complete the change of exposure settings this warning can be safely ignored. If the user’s intent is to start an exposure without further changes to the exposure settings however, It indicates a problem. The user must resolve the setup problem before an exposure can begin.

4.4 Detailed Command Structure

4.4.1 Request Analog Monitor Readbacks

Description:

The host requests that the firmware transmit the present values of Analog Monitor Readbacks. All read back values are in the range 0 – 4095. See the scaling summary table after the description of values to convert from scaled value to actual value of voltage or current. Please note that the voltage scaling for the monitor voltages is not the same as their respective set values.

Direction:

Host to supply

Syntax:

<STX><19><,><CSUM><ETX>

Example:

<STX><19><,><CSUM><ETX>

Response:

<STX><19><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><ARG5><,><ARG6><,><ARG7><,><ARG8><,><ARG9><,><ARG10><,><ARG11><,><ARG12><,><ARG13><,><ARG14><,><ARG15><,><ARG16><,> <CSUM><ETX>

Where: (ARG# in ASCII format)

ARG1 = +15V = 0 – 4095 (scaling = 0.0062256 V/Bit)
ARG2 = -15V = 0 – 4095 (0.0043663*ARG – 16.4665)
ARG3 = +24V = 0– 4095 (0.0104762 V/Bit)
ARG4 = +3.3Va = 0 – 4095 (0.00310847 V/Bit)
ARG5 = +3.3Vb = 0– 4095 (0.0011978 V/Bit)
ARG6 = TBD
ARG7 = TBD
ARG8 = TBD
ARG9 = Filament Voltage Monitor = 0-4095 = 0–11.78V
ARG10 = KV Feedback Monitor = 0-4095 = 0-53,476V
ARG11 = MA Feedback Monitor = 0-4095 = 0-213.828mA
ARG12 = DC Voltage Monitor = 0-4095 = 0-346.4V
ARG13 = Leak Limit monitor = 0–4095 = 106.914
ARG14 = Filament Feedback Monitor = 0–4095 = 0-6.415A
ARG15 = GND Monitor = (0.000732V/Bit)
ARG16 = TBD

Description of Monitored Values:

ARG1 = +15V, the output of the regulated 15V supply.
 ARG2 = -15V, the output of the regulated -15V supply.
 ARG3 = +24V, the output of the regulated +24V supply.
 ARG4 = 3.3Va, the output of the regulated 3.3V supply.
 ARG5 = 3.3Vb, monitors same voltage as ARG4 (see note1)
 ARG6-ARG8 are not used currently.
 ARG9 = The monitored Voltage across the Tube Filament.
 ARG10 = The monitored High Voltage output of the supply.
 ARG11 = The monitored output current of the supply.
 ARG12 = The monitored DC input line voltage to the supply.
 ARG13 = The monitored Filament Leak current.
 ARG14 = The monitored current through the filament.
 ARG15 = Ground Voltage Offset (This actually measures the offset error of the A/D converter rather than an actual voltage).

Scaling Summary Table

ARG	Function	Range	Scaling/Bit
1	+15V	0 – 25.5V	0.0062256V / Bit
2	-15V (note1)	-16.466V – 0V	Use Equation: Voltage = Arg*0.0043663 – 16.4665V
3	+24V	0 – 42.9V	0.0104762V / Bit
4	3.3V(a) (note 2)	0 – 12.73V	0.00310847V / Bit
5	3.3V(b) (note 2)	0 – 4.906V	0.0011978V / Bit
9	Filament Voltage	0 – 11.78V	0.0028766V / Bit
10	kV Feedback (note 3)	0 – 53476V	13.059V / Bit
11	mA Feedback (note 3)	0 – 213.828	0.052217mA / Bit
12	DC Voltage	0 – 346.4V	0.084596V / Bit
13	Leak Limit	0 – 106.9mA	0.0261mA / Bit
14	Filament Feedback	0 – 6.415A	0.0015665A / Bit
15	GND Monitor	0 - 3V	0.7326 mV / Bit

Notes:

1. Although mathematically it is possible to get positive voltages up to 1.4V out of the equation the board circuit will prevent

this. Due to resistor tolerances the voltage may not read as exactly zero for an actual voltage of zero.

2. The monitors for 3.3V(a) and 3.3(b) monitor the same voltage. These voltages are used for an A/D calibration routine. To monitor the 3.3V the user may use either one.

3. The kV and mA feedback values when X-Ray is on are held for 2 seconds after the end of an exposure (X-Ray turns off). This is the default mode of operation, but if SW2 – switch 6 is set then the values are not held after the end of the exposure.

Example:

<STX>19,2048,1024,3072,3072,3072,0,0,0,4095,4095,4095,4095,
4095,4095,4095,0,<CSUM><ETX>

4.4.2 Request Status

Description:

The host requests that the firmware sends the power supply status.

Direction:

Host to supply

Syntax:

<STX><22><,><CSUM><ETX>

Example:

<STX>22,<CSUM><ETX>

Response:

<STX><22><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><ARG5><,><ARG6><,><ARG7><,><ARG8><,><ARG9><,><ARG10><,><ARG11><,><ARG12><,><ARG13><,><ARG14><,><ARG15><,><ARG16><,><ARG17><,><ARG18><,><ARG19><,><ARG20><,><ARG21><,><ARG22><,><ARG23><,><ARG24><,><ARG25><,><ARG26><,><<CSUM><ETX>

Where: (ARG# in ASCII format representing unscaled value)

- <ARG1> X-Ray On/Off = 1 – On, 0 - Off
- <ARG2> Safety Interlock = 0 - Open, 1 - Closed
- <ARG3> Fault Condition = 1 – Fault, 0 - No Fault
- <ARG4> Prep = 1 – Prep Active, 0 = Not in prep
- <ARG5> Status Bit 1
- <ARG6> Status Bit 2
- <ARG7> Status Bit 3
- <ARG8> Tube Selection Bit 1
- <ARG9> Tube Selection Bit 2
- <ARG10> Tube Selection Bit 3
- <ARG11> Tube Selection Bit 4
- <ARG12> Load Tube Default Table to FRAM memory.
- <ARG13> Ready Status = 1 – Ready, 0 – Not Ready
- <ARG14> Setup Status = 1 –Invalid Setup, 0 – Setup is valid
- <ARG15> Calibration Active = 1-In calibration mode.
- <ARG16> Filament Open Loop
- <ARG17> AC/DC Fault Bypass
- <ARG18> OPEN FILAMENT Bypass
- <ARG19> ANALOG PROG
- <ARG20> “Over Duty” Bypass
- <ARG21> kV/mA FDBK HOLD Bypass

- <ARG22> OVP BYPASS
- <ARG23> Manual Filament OFF
- <ARG24> Duty Cycle Limit Ok = 1 – Ok (ready), 0 –Not Ready
- <ARG25> Brake After Exposure = 1 – On, 0 - Off
- <ARG26> HSS Speed = 1 – High, 0 - Low

Description of System Status

ARG1 = X-Ray On / Off Status, 1 = High Voltage output is active, 0 = High Voltage output is not active. Note: The X-Ray “On” status is held for a minimum of 1 second regardless of how short the actual exposure time is. The reason for this is to allow the host time to poll and see the X-Ray was active. It does not indicate that the X-Ray was actually on for the entire second.

ARG2 = Safety Interlock status, 1 = Safety interlock is Open (not ok to make high voltage). 0 = Safety interlock is closed (ok to make high voltage).

ARG3 = Fault Condition. 1 = There are 1 or more active faults, supply will not make high voltage unless faults are cleared. 0 = no active faults. (See also Request Faults and Clear Faults Command).

ARG4 = Prep Condition. 1 = Unit is in Prep state (preparing to make X-Ray shot). 0 = Unit is not in Prep state.

ARG7-ARG5 = Status Flags [2:0]. These flags mimic the state of the Fault status LEDs.

ARG5	ARG6	ARG7	Message
0	0	0	No Messages / No Faults
1	0	0	Tube Temp/Flow Fault/HSS Fault/Safety Interlock
0	1	0	Arc Detected/Shutdown
0	0	1	Over power / MAS / Over-Time / Under-Time / Duty / Setup Fault
1	1	0	Over Voltage/Over Current/Regulation Error
1	1	1	Open Filament / Filament Fault

ARG11-ARG8 = Currently Selected Tube Table. Four bit binary value with ARG[11:8] = Bit[3:0] (example ARG8 = 1, ARG9 = 0, ARG10 = 0, ARG11=0 would be Tube = 0001b = 1.

ARG12 = Load Tube Default to FRAM. If this bit is 1 then switch 8 on the Dip Switches is set, and the unit is set to load the tube table selected by switches 1-4 From FPGA ROM into FRAM. This is done to initialize the tube table to default values. This is not the correct setting for normal operation, and the predictive filament preheat adjustments will be

- overwritten if the unit is powered up. 0 = Unit keeps current FRAM contents (normal operation).
- ARG13 = Ready Status, 1 = Unit is ready to make X-Rays, 0 = Unit is not Ready.
- ARG14 = Setup Error, 1= The current exposure setup programmed into the unit is invalid. The unit will not be allowed to turn on high voltage, and attempting to do so will result in a “setup fault”. 0 = The current exposure setup is valid.
Note that this status ARG is not a “fault”. You do not have to clear the fault register to clear the Setup Error flag, you just have to correct the setup.
- ARG15 = Calibration Mode. 1 = The unit is in calibration mode. It has received a command to enter calibration mode, and the calibration is in progress, or waiting for the user to start it. 0 = The unit is not in calibration mode. (See section 11 on calibration for more information)
- ARG16 = Filament Open Loop. 0 = Normal operation (Filament closed loop). 1 = Test mode - Filament control feedback loop is disabled.
- ARG17 = AC/DC Fault bypass. 0 = Normal operation (line voltage input fault not bypassed). 1 = Test mode (line voltage fault is bypassed).
- ARG18 = Open Filament Fault bypass, 0 = Normal operation (unit faults on open filament). 1 = Test mode (unit will not fault if open filament).
- ARG19 = Analog Programming Mode, 0 = Normal operation (unit is under digital control from serial interface). 1 = Test mode (unit is programmed via analog control).
- ARG20 = Over duty Fault bypass. 0 = Normal operation (over duty fault not bypassed). 1 = Test mode. Unit will not fault if maximum duty cycle exceeded.
- ARG21 = kV / mA hold Bypass. 0 = Normal operation, kV and mA feedback values are held for 2 seconds after the end of the exposure. 1 = Values are not held. (See note 3 for the analog monitor read back command for more information).
- ARG22 = Over Power Bypass. 0 = Normal Operation. 1 = Test mode over power fault bypassed.
- ARG23 = Inverter Over Temperature. 0 = Inverter Temperature OK. 1 = Inverter Temperature Sensor reads over 60c, not OK to start an exposure. (See note 2 below)
- ARG24 = Duty cycle limit ok. 1 = Ok to enter Prep. 0 = Not ready to enter prep because to do so would put the unit in an Over-duty condition. This bit indicates if the unit over-duty protection will allow a new exposure cycle to begin. It combines the 20 second between exposure, 5 second on time in 2 minutes, and 2 Rotor starts in 1 minute limitations.

4.4.3 Request Fault Status

Description:

The host requests that the firmware report Faults.

Direction:

Host to supply

Syntax:

<STX><68><,><CSUM><ETX>

Response:

<STX><68><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><ARG5><,><ARG6><,><ARG7><,><ARG8><,><ARG9><,><ARG10><,><ARG11><,><ARG12><,><ARG13><,><ARG14><,><ARG15><,><ARG16><,><ARG17><,><CSUM><ETX>

Where: (ARG# in ASCII format)

<ARGx> 1 = Fault, 0 = No Fault

ARG1 = Interlock 1 (Tube Temp)

ARG2 = Interlock2 (Tube Flow)

ARG3 = HSS Fault

ARG4 = ARC

ARG5 = Over Power

ARG6 = Over Time

ARG7 = Over mAs

ARG8 = Over Duty

ARG9 = Over Voltage

ARG10 = Over Current

ARG11 = Regulation

ARG12 = Open Filament

ARG13 = Filament

ARG14 = AC/DC

ARG15 = Under Time

ARG16 = Safety Interlock Fault

ARG17 = Setup Fault

Fault Description

ARG1 = Tube Over temperature Indicator or general purpose interlock 2. Unit input Logic High / Open is fault state, Logic Low / Closed (shorted to ground) is good state.

ARG2 = Tube Flow switch or general purpose interlock 3. Unit input Logic High / Open is fault state, Logic low / Closed (shorted to ground) is good state.

ARG3 = High Speed Starter Fault. One (or more) of the possible High Speed Starter faults have occurred. Information on the specific faults can be obtained using the "Request Expanded HSS Status" Command.

ARG4 = ARC fault. There has been a high voltage arc.

ARG5 = An attempt was made to turn X-Ray on with an invalid setting that would result in an over power condition (power > 5kW).

ARG6 = Over Time. This fault is possible only when AEC Mode is Active. It indicates that the exposure was terminated by the supply internal exposure timer, rather than the AEC Control signal. That is, the exposure time programmed into the unit expired with the AEC control and exposure control signals on.

ARG7 = Over MAS. The exposure mAs, was 25% or greater over the programmed setting.

ARG8 = Over Duty. An over duty fault will be generated if prep is entered when any of the following conditions is true:

- The total exposure time for previous exposures exceeds 5 seconds in any 2 minute period.
- An attempt to start a new exposure is made less than 20 seconds after the previous exposure ended.
- An attempt to start a new exposure is made when the Inverter Temperature Sensor reading exceeds 60c.

The system is limited to a total exposure time of 5 seconds over a 2 minute period. If the cumulative exposure time exceeds 5 seconds, the exposure will be allowed to complete normally, and the system will not fault. However, if an attempt is made to turn X-Ray on again before the sufficient has elapsed, the system will set this fault. The system also can't begin another exposure until 20 seconds has elapsed from the last exposure. An attempt to start an exposure before 20 seconds has passed from the end of the previous exposure will result in an over duty fault. The Inverter Temperature sensor detects excessive heat buildup on the Inverter IGBTs, and new exposures are not allowed when the sensor reads > 60c.

ARG9 = Overvoltage – Set if the output voltage exceeds 42765V for more than 1msec.

ARG10 = Overcurrent – Set if the output current exceeds 213.828 mA for more than 100msec.

ARG11 = Regulation – Set if the output voltage (kV) or current (mA) is more than +/- 25% of the set value. Note that the kV value is allowed 30 msec from X-Ray on and the mA value is allowed 250 msec from X-Ray on to settle before the fault can occur.

4.4.4 Reset Faults

Description:

The host requests that the firmware resets all Fault messages and indicators. Note that if the fault persists after the reset fault message the fault will immediately reoccur. For example if the DC rail voltage is low (AC/DC fault) and you clear the faults, again reading the faults will still show a DC rail fault.

Direction:

Host to supply

Syntax:

<STX><31><,><CSUM><ETX>

Example:

<STX>31<CSUM>,<ETX>

Response:

<STX><31><,><\$><,><ETX>

4.4.5 Set Exposure Settings

Description:

The host requests that the firmware change the exposure settings of kV, mA, exposure time and filament large/small. Note: This command changes the same parameters as the individual “Set Exposure” commands. It can be used in place of or along with these commands, or not used at all. Using this command allows for additional parsing and expanded error code response over using individual commands but otherwise performs the same function. This command should only be used when the unit is in 3-Point Mode. If you are in 2-Point mode the command will not change the exposure settings.

Direction:

Host to supply

Syntax:

<STX><50><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><CSUM><ETX>

Where: (ARG# in ASCII format)

ARG1 = Exposure Time (in milliseconds)

ARG2 = kV program (0-4095 = 0-50,000V)

ARG3 = mA program (0-4095 = 0-200mA)

ARG4 = Large/Small Filament = 1 – Large, 0 - Small

Example:

<STX>50,4095,4095,4095,1,<CSUM><ETX>

Response:

<STX><50><,><\$><,><CSUM><ETX>

Notes:

The maximum allowed exposure time is the smaller of 12000msec or the value specified by the Tube Table. The tube table value is a function of kV, mA, Filament and HSS Speed. The default Minimum allowed exposure time is 5 milliseconds.

kV program is $50\text{kV}/4095 = 12.21\text{V/Bit}$

mA program is $200\text{mA}/4095 = 0.04884\text{mA/Bit}$

Error / Warning Code Responses:

<STX><50><,><E><,><CSUM><ETX>

Where E is:

- 3 = Argument 1, Exposure time is out of bounds.
- 4 = Argument 2, kV set point is out of bounds
- 5 = Argument 3, mA set point is out of bounds
- 6 = Argument 4, filament selection is invalid (must be 0 for small, or 1 for large)
- 7 = mAs out of range. The requested exposure time * mA set point is too large
- 8 = kV-mA-fil error. The requested combination of kV, mA and filament settings is invalid. (Individually all arguments are in valid range, but the combination is not).
- 9 = State Error. An attempt to change exposure settings was made while X-Ray was on.
- 10 = Invalid Setup (Warning) – When the current settings are combined with the HSS Speed the setup is invalid.
- 11 = Mode Error – The unit is in 2-Point Mode, not 3-Point mode. This command is used in 3-Point Mode only.

Note 1:

To clarify the meaning error codes, please note the following. Error Code 8 is returned if the Tube Table for that kV/mA/Filament setting has zero exposure time for both High and Low speed, meaning there is no possible combination of exposure time and HSS speed that is valid for that combination of kV/mA/filament. If the Tube Table has a non-zero exposure time, and the set exposure time (argument 1) is greater than the maximum exposure time with HSS = Fast, then an Error code of 3 is returned. This means that it is possible to make exposures with that kV/mA/Filament, but not at the requested exposure time. Finally, if the setup would be valid for HSS = Fast, but HSS is currently set to Slow, a warning code of 10 is returned.

Note 2:

This command can be used to set up the 2nd part of a Smart AEC exposure, but the new filament setting must be the same as the current filament or a State Error will occur. In addition the AEC control signal must be in the “X-Ray Off” state or a State Error will occur.

4.4.6 Get Exposure Settings

Description:

The host requests that the firmware return the current exposure settings of kV, mA, exposure time and filament.

IMPORTANT NOTE: The values read may not be the same as written with the “Set Exposure Settings” Command if you are in 2-Point Mode. In 2-Point mode mA and Exposure Time settings are automatically determined by the firmware using the kV and mAs settings.

Direction:

Host to supply

Syntax:

<STX><51><,><CSUM><ETX>

Example:

<STX><51><,><CSUM><ETX>

Response:

<STX><51><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><CSUM><ETX>

Where: (ARG# in ASCII format)

ARG1 = Exposure Time (in milliseconds)

ARG2 = kV program (0-4095 = 0-50,000V)

ARG3 = mA program (0-4095 = 0-200mA)

ARG4 = Large/Small Filament = 1 – Large, 0 - Small

Notes:

kV program is $40\text{kV}/4095 = 12.21\text{V/Bit}$

mA program is $200\text{mA}/4095 = 0.04884\text{mA/Bit}$

Example:

<STX><51>,<2000,4095,4095,1,<CSUM><ETX>

4.4.7 Set Exposure mAs and mA

Description:

This command is valid only when mAs+mA mode is selected via the set Mode 3-Point / 2-Point / mAs + mA command. (Command = 55)

The host requests that the firmware change the exposure settings by specifying kV, mAs, mA and filament. The exposure time will be dependent of the mAs and mA selected.

Note: This command changes the same parameters as the individual "Set Exposure" commands. It can be used in place of or along with these commands, or not used at all. Using this command allows for additional parsing and expanded error code response over using individual commands but otherwise performs the same function. This command should only be used when the unit is in mAs + mA Mode. If you are in 2-Point or 3-Point, mode the command will not change the exposure settings.

Direction:

Host to supply

Syntax:

<STX><71><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><CSUM><ETX>

Where: (ARG# in ASCII format)

ARG1 = kV program, 0-4095 = 0-50,000V

ARG2 = mAs program, 0 to 6000 = 0 – 600mAs (0.1mAs / bit)

ARG3 = mA program, 0-4095 = 0-200mA

ARG4 = Large/Small Filament = 1 – Large, 0 - Small

Example:

<STX>71,4095,4095,4095,1,<CSUM><ETX>

Response:

<STX><71><,><\$><,><CSUM><ETX>

Notes:

The maximum allowed exposure time is the smaller of 12000msec or the value specified by the Tube Table. The tube table value is a function of kV, mA, Filament and HSS Speed. The default Minimum allowed exposure time is 5 milliseconds.

kV program is $50\text{kV}/4095 = 12.21\text{V/Bit}$
mAs program is $600\text{mAs}/6000 = 0.1\text{mAs/Bit}$
mA program is $200\text{mA}/4095 = 0.04884\text{mA/Bit}$

Error / Warning Code Responses:

<STX><71><,><E><,><CSUM><ETX>

Where E is:

- 3 = Argument 1, kV set point is out of bounds
- 4 = Argument 2, mAs set point is out of bounds
- 5 = Argument 3, mA set point is out of bounds
- 6 = Argument 4, filament selection is invalid (must be 0 for small, or 1 for large)
- 7 = Exposure time too long or short. The selected mAs & mA result in an exposure time longer than the maximum allowed for the tube, or less than 5ms.
- 8 = kV-mA-fil error. The requested combination of kV, mA and filament settings is invalid. (Individually all arguments are in valid range, but the combination is not).
- 9 = State Error. An attempt to change exposure settings was made while X-Ray was on.
- 10 = Invalid Setup (Warning) – When the current settings are combined with the HSS Speed the setup is invalid.
- 11 = Mode Error – The unit is not in mAs+mA Mode, this command is not allowed in 2-Point Mode or 3-Point mode.

Note 1:

To clarify the meaning error codes, please note the following. Error Code 8 is returned if the Tube Table for that kV/mA/Filament setting has zero exposure time for both High and Low speed, meaning there is no possible combination of exposure time and HSS speed that is valid for that combination of kV/mA/filament.

Note 2:

This command can be used to set up the 2nd part of a Smart AEC exposure, but the new filament setting must be the same as the current filament or a State Error will occur. In addition the AEC control signal must be in the “X-Ray Off” state or a State Error will occur.

4.4.8 Set HSS Speed

Description:

The host requests that the firmware set the High Speed Starter (X-Ray tube Rotor Speed) to Fast or Slow.

Note: There is no get HSS Speed command. The current speed setting can be found using the Request Status command (ARG26 = HSS Speed)

This command should only be used when the unit is in 3-Point Mode. If you are in 2-Point mode the HSS Speed is automatically set based on kV and mAs settings.

Direction:

Host to supply

Syntax:

<STX><59><,><ARG1><,><CSUM><ETX>

Where:

ARG1 = Speed in ASCII format = Fast – 1, Slow - 0

Example:

<STX>59,1,<CSUM><ETX>

Response:

<STX><59><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><59><,><E><,><CSUM><ETX>

Where E is:

3 = Invalid Argument (was not 1 or 0)

10 = Invalid Setup (Warning) – When the current settings are combined with the new HSS Speed the setup is invalid.

11 = Mode Error, unit is in 2-Point mode not 3-Point Mode.

4.4.9 Set Exposure Time

Description:

The host requests that the firmware set the Exposure Time. This is the time an exposure will be allowed to run (high voltage on) unless it is otherwise terminated by an external control signal such as the exposure control, or the AEC control signal.

This command is used in 3 point exposure mode (also called manual exposure mode). The setting of this value is ignored when the unit is operated in 2 point or mAs+mA exposure mode, and a mode error is returned. In 2 point exposure mode the exposure time is calculated from the mAs setting. In mAs+mA mode it is determined by the mAs and mA settings.

If the new setting is in the valid range, and the new setting in combination will the current settings of the other exposure parameters is valid the unit will respond with a "\$ " following the command field. If the new setting is valid, but the combination of the new setting plus the current settings of the other exposure parameters is illegal the unit will respond with a warning code of 10. In this case the host will be required to correct the setup problem before the exposure can begin. If the setting is invalid / out of range the unit will respond with and error code of 3 and the previous value of the exposure time will remain in effect. If the X-Ray is currently on the unit will return an error code of 9 (state error). The host is not allowed to modify exposure settings while the high voltage is on.

Direction:

Host to supply

Syntax:

<STX><72><,><ARG1><,><CSUM><ETX>

Where:

ARG1 = Exposure time setting in milliseconds. Range 20 to 12000.

Note: Actual maximum allowed will vary depending other parameters.

Example:

<STX>72,100,<CSUM><ETX>

Response:

<STX><72><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><72><,><E><,><CSUM><ETX>

Where E is:

3 = Exposure time out of bounds

9 = State Error (can't change when X-Ray is on)

10 = Invalid Setup Warning

11 = Mode Error, unit is not in 3-Point Mode

4.4.10 Set Exposure kV

Description:

The host requests that the firmware set the Exposure kV set-point. This is the desired voltage output of the supply for the next exposure.

If the new setting is in the valid range, and the new setting in combination with the current settings of the other exposure parameters is valid the unit will respond with a "\$ " following the command field. If the new setting is valid, but the combination of the new setting plus the current settings of the other exposure parameters is illegal the unit will respond with a warning code of 10. In this case the host will be required to correct the setup problem. If the setting is invalid / out of range the unit will respond with an error code of 3 and the previous value of the kV program (set-point) will remain in effect. If the X-Ray is currently on the unit will return an error code of 9 (state error). The host is not allowed to modify exposure settings while the high voltage is on.

Direction:

Host to supply

Syntax:

<STX><10><,><ARG1><,><CSUM><ETX>

Where:

ARG1 = Exposure kV program.

Range = 0-4095 = 0-50,000V

Scaling = 50kV/4095 = 12.21V/Bit

Example:

<STX>10,2047,<CSUM><ETX>

Response:

<STX><10><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><10><,><E><,><CSUM><ETX>

Where E is:

3 = kV setting is out of bounds

9 = State Error – (Can't change with X-Ray on)

10 = Invalid Setup Warning

4.4.11 Set Exposure mA

Description:

The host requests that the firmware set the Exposure mA set-point. This is the desired current output of the supply for the next exposure. This command is used in 3 point exposure mode (also called manual exposure mode) and mAs+mA mode. The setting of this value is ignored when the unit is operated in 2 point exposure mode. In 2 point exposure mode the exposure mA is calculated from the mAs setting.

If the new setting is in the valid range, and the new setting in combination will the current settings of the other exposure parameters is valid the unit will respond with a "\$ " following the command field. If the new setting is valid, but the combination of the new setting plus the current settings of the other exposure parameters is illegal the unit will respond with a warning code of 10. In this case the host will be required to correct the setup problem. If the setting is invalid / out of range the unit will respond with an error code of 3 and the previous value of the mA program (set-point) will remain in effect. If the X-Ray is currently on the unit will return an error code of 9 (state error). The host is not allowed to modify exposure settings while the high voltage is on.

Direction:

Host to supply

Syntax:

<STX><11><,><ARG1><,><CSUM><ETX>

Where:

ARG1 = Exposure mA program.

Range = 0-4095 = 0-200 mA

Scaling = 200mA/4095 = 0.04884mA/Bit

Example:

<STX>11,2048,<CSUM><ETX>

Response:

<STX><11><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><11><,><E><,><CSUM><ETX>

Where E is:

3 = mA setting is out of bounds

9 = State Error – (Can't change with X-Ray on)

10 = Invalid Setup Warning

11 = Mode Error, unit is in 2-Point mode not 3-Point Mode

4.4.12 Set Exposure Filament (large spot / small spot)

Description:

The host requests that the firmware set the Exposure filament. This is the filament to be used for the next exposure. This command is used both in 3 point exposure mode (also called manual exposure mode), 2 point exposure mode and mAs+mA Mode. In 2 point mode his value is used along with the kV and mAs values to calculate the exposure mA and Time. If the new setting is in the valid range, and the new setting in combination will the current settings of the other exposure parameters is valid the unit will respond with a "\$ " following the command field. If the new setting is valid, but the combination of the new setting plus the current settings of the other exposure parameters is illegal the unit will respond with a warning code of 10. In this case the host will be required to correct the setup problem. If the setting is invalid / out of range the unit will respond with and error code of 3 and the previous value of the filament program will remain in effect. If the "Prep" signal is active the unit will return an error code of 9 (state error). The host is not allowed to modify the filament setting while an exposure sequence is active. Also, in Smart AEC Mode the filament must be the same in all exposures. You can set it large or small in the first exposure in the smart AEC sequence, but it must be set the same in all subsequent exposures.

Direction:

Host to supply

Syntax:

<STX><73><,><ARG1><,><CSUM><ETX>

Where:

ARG1 = Filament Select.

Range = 0 or 1 (0 = Small, 1 = Large)

Example:

<STX>73,1,<CSUM><ETX>

Response:

<STX><73><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><73><,><E><,><CSUM><ETX>

Where E is:

3 = invalid argument (not 1 or 0)

9 = State Error – (Can't change with X-Ray on)
10 = Invalid Setup Warning
11 = Mode Error, unit is in Smart AEC Mode.

4.4.13 Set Exposure mAs

Description:

The host requests that the firmware set mAs (milliamp-seconds) for the next exposure. This command is used in 2 point exposure mode and mAs+mA. When the unit is in 2 point mode the mA, exposure time, and HSS Speed are automatically calculated based on its setting plus the tube table. The setting of this value is ignored when the unit is operated in manual (3 point) exposure mode. If the new setting is in the valid range, and the new setting in combination with the current settings of the other exposure parameters is valid the unit will respond with a "\$ " following the command field. If the new setting is valid, but the combination of the new setting plus the current setting of the kV is illegal the unit will respond with a warning code of 10. In this case the host will be required to correct the setup problem. If the setting is invalid / out of range the unit will respond with an error code of 3 and the previous value of the mAs will remain in effect. If the X-Ray is currently on the unit will return an error code of 9 (state error). The host is not allowed to modify exposure settings while the high voltage is on.

Direction:

Host to supply

Syntax:

<STX><74><,><ARG1><,><CSUM><ETX>

Where:

ARG1 = Exposure mAs program.

Range = 0 to 6000 = 0 – 600mAs

Scaling = 0.1 mAs / Bit

Example (set mAs to 50.5 milliamp-seconds):

<STX>74,505,<CSUM><ETX>

Response:

<STX><74><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><74><,><E><,><CSUM><ETX>

Where E is:

3 = Argument is out of bounds

9 = State Error – (Can't change with X-Ray on)

10 = Invalid Setup Warning

11 = Mode Error, unit is in 3-Point mode not 2-Point Mode

4.4.14 Request Exposure Time Set-point

Description:

The host requests that the firmware report the current exposure time set point. This is the current value of the exposure control timer, not the actual time of the last exposure. The value is 0-12000 in mSec. Note: This command reads the value currently being used by the system, which is mode dependent. In 2 point mode this value is calculated using the mAs value along with the tube table. In manual mode this value is set using the "Set Exposure Time" command. When in 2 point mode the value read by this command is not the same as what is set using the "Set Exposure Time" Command.

Direction:

Host to supply

Syntax:

<STX><52><,><CSUM><ETX>

Response:

<STX><52><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 12000 in ASCII format, scaling = msec/Bit

Example:

<STX>52,<CSUM><ETX>

4.4.15 Request kV Set-Point

Description:

The host requests that the firmware report the kV set point. This is the current value of the exposure kV setting. The value is 0-4095 scaled the same as the kV program value: $50\text{kV}/4095 = 12.21\text{V/Bit}$

Direction:

Host to supply

Syntax:

<STX><14><,><CSUM><ETX>

Response:

<STX><14><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format, scaling = 12.21V/Bit

Example:

<STX>14,<CSUM><ETX>

4.4.16 Request Exposure mA Set-Point

Description:

The host requests that the firmware report the current mA set point. The range is 0-4095 corresponding to mA values of 0-200 mA = 0.04884mA/Bit Note: This command reads the value currently being used by the system, which is mode dependent. In 2 point mode this value is calculated using the mAs value along with the tube table. In 3-Point or mAs+mA mode this value is set using the "Set mA Set-point" command. When in 2 point mode the value read by this command is not necessarily the same as what may have been previously set using the "Set mA Set-point" Command.

Direction:

Host to supply

Syntax:

<STX><15><,><CSUM><ETX>

Response:

<STX><15><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format

Example:

<STX>15 ,<CSUM><ETX>

4.4.17 Request Exposure Filament Setting

Description:

The host requests that the firmware report the current filament selected. Returns the ASCII char "0" if small filament, "1" if large filament: This command reads the value currently being used by the system, which is mode dependent. In 2 point mode this value is selected using the mAs value along with the tube table. In manual (3 point) mode this value is set using the "Set filament" command. When in 2 point mode the value read by this command is not necessarily the same as what is set using the "Set filament" Command

Direction:

Host to supply

Syntax:

<STX><53><,><CSUM><ETX>

Response:

<STX><53><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 or 1 in ASCII format. 0 = Small, 1 = Large

Example:

<STX>53,<CSUM><ETX>

4.4.18 Request Exposure mAs setting

Description:

The host requests that the firmware report the current mAs setting. The range is 0-6000 corresponding to mAs values of 0-600 mAs = 0.1 mAa/Bit. Note: This command reads the value set by a previous "Set Exposure mAs" command. If the system is in 2 point or mAs+mA mode, this is the current mAs setting. If the system is in manual (3 point) mode then this value is calculated from the set mA and set exposure time (msec).

Direction:

Host to supply

Syntax:

<STX><54><,><CSUM><ETX>

Response:

<STX><54><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 – 6000 in ASCII format, Scale = 0.1 mAs / Bit

Example:

<STX>54 ,<CSUM><ETX>

4.4.19 Request Last Exposure kV Monitor

Description:

The host requests that the firmware report the kV monitor value for the last exposure. This is the average value of the exposure kV for the previous exposure. If this value is read during the exposure the average value to that point is reported.

The last exposure average value will be held until either a new exposure is started or a new prep cycle is started (Prep goes from inactive to active). If either of these conditions occurs, the held value is discarded and the current kV value is reported.

The kV monitor value is from 0 – 4095, corresponding to voltages 0V – 53476V, (10.44V / Bit).

Direction:

Host to supply

Syntax:

<STX><60><,><CSUM><ETX>

Response:

<STX><60><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format (0-4095 = 0-53476 V)

Scaling = 53476/4095 = 13.06 V / Bit

Example:

<STX>60,4095,<CSUM><ETX>

4.4.20 Request Last Exposure mA Monitor

Description:

The host requests that the firmware report the mA monitor value for the last exposure. The monitor value reporting is as follows:

If the exposure is active (X-Ray is On) is on the value is updated continuously, and the request will report the average mA value up to the point where the request was made.

If an exposure has completed (X-Ray On to Off) the request will report the average value of the mA for the entire period of the last exposure (X-Ray On).

The last exposure value will be held until either a new exposure is started or a new prep cycle is started (Prep goes from inactive to active). If either of these conditions occurs, the held value is discarded and the current mA value is reported.

The mA monitor value is from 0 – 4095, corresponding to currents 0mA – 213.828mA, (10.44V / Bit).

Direction:

Host to supply

Syntax:

<STX><61><,><CSUM><ETX>

Response:

<STX><61><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format (0-4095 = 0-213.828 mA)

Scaling = 0.0522168 mA / Bit

Example:

<STX>61,4095,<CSUM><ETX>

4.4.21 Get Last Exposure Time

Description:

The host requests that the firmware sends the last exposure time length, as measured from the 75% of programmed value points. This is the actual exposure time of the last exposure, not the value set by the “Set Exposure Settings” Command.

Direction:

Host to supply

Syntax:

<STX><65><,><CSUM><ETX>

Example:

<STX>65,<CSUM><ETX>

Response:

<STX><65><,><ARG1><,><CSUM><ETX>

Where:

<ARG1> = last exposure time in milliseconds (in ASCII format)

Example:

<STX>65,4095,<CSUM><ETX>

4.4.22 Set Brake After Exposure

Description:

The host requests that the firmware set the Brake After Exposure setting. When Break After Exposure is on, the unit will begin breaking (stopping the rotor) immediately after the end of the current exposure. In this mode it is required that the host begin a new Prep cycle (Prep inactive to active) before a new exposure can be started. When Break After Exposure is off, the rotor remains running past the end of the exposure for a period of time specified by the Break after Exposure Hang time. As long as prep remains active and the Break after Exposure Hang time does not expire, a new exposure can be started without cycling Prep. See Section 7.0 for more details on Break After Exposure operation. Note, there is no corresponding Get Break After Exposure command. The current Break After Exposure setting is available using the Request Status Command.

Direction:

Host to supply

Syntax:

<STX><35><,><ARG1><,><CSUM><ETX>

Where:

<ARG1> = Brake after exposure, 1 or 0 in ASCII format
1 = Break After Exposure mode is On
0 = Break After Exposure mode is Off

Example:

<STX>35,1,<CSUM><ETX>

Response:

<STX><35><,><\$><,><CSUM><ETX>

4.4.23 Set Break After Exposure Hang Time

Description:

The host requests that the firmware change the break after exposure hang time. This is the amount of time the X-Ray tube rotor will be kept running after the end of an exposure. The time is in milliseconds. See the Set Break After Exposure Command for more details. Also see Section 7.0 for more details on Break After Exposure operation.

Note 1: The Break After Exposure Hang Time setting has no effect when Break After Exposure is set ON. In this case the rotor begins breaking immediately regardless of this setting.

Note 2: The default Hang Time is 30 seconds, and the last value set by this command is stored in non-volatile memory and reloaded the next time the unit is powered up.

Direction:

Host to supply

Syntax:

<STX><36><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 – 65536 in ASCII format, Break after Exposure Hang Time in milliseconds.

Example: (Sets the hang time to 30 seconds = 30000 msec)

<STX>36,30000,<CSUM><ETX>

Response:

<STX><36><,><\$><,><CSUM><ETX>

4.4.24 Get Break After Exposure Hang Time

Description:

The host requests that the firmware report the current Break After Exposure Hang Time. This is the amount of time the X-Ray tube rotor is driven after the end of an exposure. The time is specified in milliseconds. See the Set Break After Exposure Command for more details. Also see Section 7.0 for more details on Break After Exposure operation.

Direction:

Host to supply

Syntax:

<STX><37><,><CSUM><ETX>

Response:

<STX><37><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 65535 in ASCII format. This is the Break After Exposure Hang time in milliseconds.

Example:

<STX>37,<CSUM><ETX>

4.4.25 Set AEC Mode (Standard Automatic Exposure Control Mode)

Description:

The host requests that the set the AEC (Automatic Exposure Control) Mode On or Off. This mode is sometimes also called “Standard AEC Mode” in this document to differentiate it from “Smart-AEC Mode”. When AEC is set “On”, the unit will operate in AEC mode. The AEC control signal, also called the X-Ray disable signal, will be allowed to turn the X-Ray On / Off. If the AEC mode is Off the AEC control signal will be ignored.

Direction:

Host to supply

Syntax:

<STX><57><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 or 1, 0 = AEC Mode Off, 1 = AEC Mode On

Example: (Sets the AEC Mode On)

<STX>57,1,<CSUM><ETX>

Response:

<STX><57><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><57><,><E><,><CSUM><ETX>

Where E is:

3 = invalid argument (not 1 or 0)

9 = State Error – (Can't change with X-Ray on)

Note: Standard AEC mode and Smart AEC Mode are mutually exclusive. When a set AEC mode “On” command is received Smart-AEC mode is automatically set “Off”.

4.4.26 Request AEC Mode

Description:

The host requests that the firmware report the current setting of the AEC (Automatic Exposure Control) Mode, On or Off.

Direction:

Host to supply

Syntax:

<STX><58><,><CSUM><ETX>

Response:

<STX><58><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 1 in ASCII format. 0 = AEC Mode Off / 1 = On

Example (AEC Mode is OFF):

<STX>58,0,<CSUM><ETX>

4.4.27 Set Mode 3-Point / 2-Point / mAs + mA

Description:

The host requests that the set the unit to operate in 2-Point, 3 Point, or mAs+mA mode. (Note that 3-Point mode also called manual mode).

In 3-Point mode the host programs the unit by specifying kV and mA set-points, exposure time, filament size, and HSS Speed.

In 2-Point mode the host specifies the filament, kV set point and the mAs (milliamp-seconds) for the exposure and the exposure mA, exposure time and HSS Speed are automatically set based on those. The exposure mA chosen will be the highest allowed mA for the tube for the given filament and kV settings.

In mAs+mA mode the host programs the unit by specifying filament, kV, mAs and mA. The exposure time is automatically determined by those parameters.

IMPORTANT NOTE: Changing the modes does NOT change any of the current exposure settings. The host should set 2-Point, 3-Point or mAs+mA mode before programming the appropriate exposure settings.

Direction:

Host to supply

Syntax:

<STX><55><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0,1, or 2, 0 = 3-Point (manual) mode, 1 = 2-Point mode, 2 = mAs+mA mode

Example: (Sets 2-Point mode)

<STX>55,1,<CSUM><ETX>

Response:

<STX><55><,><\$><,><CSUM><ETX>

4.4.28 Request mode 2-point / 3-point / mAs+mA

Description:

The host requests that the firmware report the current operating mode, 2-Point or 3-Point.

Direction:

Host to supply

Syntax:

<STX><56><,><CSUM><ETX>

Response:

<STX><56><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 1 in ASCII format. 0 = 3-Point / 1 = 2-Point / 2 = mAs+mA

Example: (3-Point mode)

<STX>56,0,<CSUM><ETX>

4.4.28 Set Smart AEC Mode

Description:

The host requests that the set the Smart-AEC On or Off. When Smart-AEC mode is “On”, the unit will operate in Smart AEC mode. See section 10 for a description of Smart AEC (S-AEC) mode.

Direction:

Host to supply

Syntax:

<STX><75><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 or 1, 0 = AOP Mode Off, 1 = AOP Mode On

Example: (Sets the AOP Mode On)

<STX>75,1,<CSUM><ETX>

Response:

<STX><75><,><\$><,><CSUM><ETX>

Error / Warning Code Responses:

<STX><75><,><E><,><CSUM><ETX>

Where E is:

3 = invalid argument (not 1 or 0)

9 = State Error – (Can't change with X-Ray on)

Notes: Smart AEC mode and Standard AEC mode are mutually exclusive. When a set Smart AEC mode mode “On” command is received Standard AEC mode is automatically set “Off”.

4.4.29 Request Smart AEC Mode

Description:

The host requests that the firmware report the current setting of the Smart AEC Mode, On or Off.

Direction:

Host to supply

Syntax:

<STX><76><,><CSUM><ETX>

Response:

<STX><76><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 1 in ASCII format. 0 = AOP Mode Off / 1 = On

Example (Smart AEC Mode is ON):

<STX>76,1,<CSUM><ETX>

4.4.30 Request Current X-Ray Tube Anode Heat Loading

Description:

The host requests that the firmware report the current anode heat load of the X-Ray tube as a percentage of the allowed maximum for the tube.

Direction:

Host to supply

Syntax:

<STX><77><,><CSUM><ETX>

Response:

<STX><77><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 100 in ASCII format, representing 0% (no heat), to 100% (maximum allowed heat).

Example:

<STX>77,<CSUM><ETX>

4.4.31 Request Auxiliary Status

Description:

The host requests that the firmware report the Auxiliary Status.

Direction:

Host to supply

Syntax:

<STX><78><,><CSUM><ETX>

Example:

<STX>78,<CSUM><ETX>

Response:

<STX><78><,><ARG1><,><ARG2><,><CSUM><ETX>

Where: (ARG# is 0 or 1 in ASCII format)

<ARG1> RTC Battery Ok (1 = Ok, 0 = Not Ok)

<ARG2> Anode Heat Load Ok (1 = Ok, 0 = Head Load near maximum allowed)

Description of Auxiliary Status

ARG1 = RTC Battery OK. 1 = RTC Battery Ok. 0 = RTC Battery is Low and requires replacement. If this status flag is zero the RTC may not track shutdown time properly. This may cause incorrect calculation of anode cooling during shut down and result in an incorrect anode heat load reading.

ARG2 = Anode Heat Load Ok. 1 = The Anode heat load is Ok to make another exposure. 0 = The Anode heat load is 90% or greater of the maxim allowed. The user should wait for the Anode to cool before making another exposure.

Notes: The battery status checked at power up, and again once every 24 hour period. In-between these times the battery status will not change.

4.4.32 Request Expanded Fault Status

Description:

The host requests that the firmware report the expanded Fault Status. The expanded fault status provides additional information about faults that are reported in the Request Fault Status command. Specifically it separates out kV and mA regulation faults. If a regulation fault is reported by the Request Fault Status command, this command can be used to determine if the fault was due to bad kV or mA regulation. It also indicates if an over-duty fault occurred because an exposure was started when the inverter temperature sensor read > 60c.

Direction:

Host to supply

Syntax:

<STX><69><,><CSUM><ETX>

Example:

<STX>69,<CSUM><ETX>

Response:

<STX><69><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><CSUM><ETX>

Where: (ARG# is 0 or 1 in ASCII format)

<ARG1> kV Regulation Fault, (1 = Fault, 0 = No Fault). The regulation fault reported in the request faults command was due to kV regulation error.

<ARG2> mA Regulation Fault, (1 = Fault, 0 = No Fault). The regulation fault reported in the request faults command was due to mA regulation error.

<ARG3> Inverter Temperature Fault (1 = Fault, 0 = No Fault). The Over-Duty fault reported in the request faults command was due to an attempt to start an exposure when the Inverter Temperature sensor reads over 60c.

<ARG4> Spare – For future expansion, will read as 0

Notes:

The expanded faults are also cleared by the “Reset Faults” command.

There is normally no need to use this command operationally, as the “Request Faults” command will indicate if

there was a regulation error. However it does provide useful information for system debugging.

4.4.33 Request Expanded HSS Status

Description:

The host requests that the firmware report the expanded HSS Status. The expanded HSS status provides additional information about the reason for HSS fault(s) that are reported in the Request Fault Status command. This command can be useful in system debugging, as it reports the reason for HSS failure, which is not included in the normal "Request Fault Status" Command. All Arguments are '1' = Faulted, '0' = Not Faulted, with the exception of the mis-wire fault, which can be ASCII 0 – 3.

Direction:

Host to supply

Syntax:

<STX><84><,><CSUM><ETX>

Example:

<STX>84,<CSUM><ETX>

Response:

<STX><84><,><ARG1><,><ARG2><,><ARG3><,><ARG4><,><ARG5><,><ARG6><,><ARG7><,><ARG8><,><ARG9><,><ARG10><,><ARG11><,><ARG12><,><ARG13><,><CSUM><ETX>

Where: (ARG# is 0 or 1 in ASCII format, except for ARG<11> which can be 0 to 3)

- <ARG1> Bus Under Voltage Fault, (1 = Fault, 0 = No Fault)
- <ARG2> Phase Under Current Fault, (1 = Fault, 0 = No Fault).
- <ARG3> Phase Over Current Fault, (1 = Fault, 0 = No Fault).
- <ARG4> Phase Under Voltage Fault, (1 = Fault, 0 = No Fault).
- <ARG5> Power Feed Out Of Range, , (1 = Fault, 0 = No Fault).
- <ARG6> Output Shorted Fault, (1 = Fault, 0 = No Fault).
- <ARG7> Low Voltage Power Supply Fault, (1 = Fault, 0 = No Fault). One of the low voltage supplies on the HSS / Power PCB has failed.
- <ARG8> No Load Fault, (1 = Fault, 0 = No Fault).
- <ARG9> HSS Not up to Speed Fault. (1 = Fault, 0 = No Fault). The HSS could not get up to speed in the required 2 seconds from the start of Prep.

<ARG10> More than 2 starts requested in a 60 second period. (1 = Fault, 0 = No Fault).

<ARG11> HSS Miswire Fault. The Wiring for the Tube Rotor between the Tube and PMX is incorrect. See the following table:

Miswire fault code	Miswire fault condition
0	Normal operation, Wiring is Correct
1	Phase wire in Run slot AND (Run wire in Phase slot OR Run wire in Common slot and Common wire in Phase slot).
2	Phase wire in Common slot AND (Common wire in Phase slot OR Common wire in Run slot and Run wire in Phase slot).
3	Run wire in Common slot and Common wire in Run slot.

Note: P = Phase Wire, R = Run Wire, C = Common Wire.

<ARG12> Not Used, for future expansion, will Read as 0.

<ARG13> HSS Communication Fault. The serial link between the control board and the HSS has failed. If this bit reads as "1" (Faulted) the control board was not able to communicate with the HSS to retrieve the status. Since the control board could not get the status from the HSS the values of ARGs 1-11 are not known. They will report as "0" but may in fact be faulted. Note that this serial link is not used in regular operation, and is only used to retrieve the detailed fault status. If the link fails the unit will still continue to function normally, with the exception of getting expanded status using this command.

Notes:

The expanded HSS faults are cleared along with the rest of the faults by the "Reset Faults" command, however if the condition causing the fault is still present, it may immediately fault again.

Mis-wire detection is done at the beginning of run mode. The wiring may be incorrect, but no fault will be detected until the HSS is actually turned on.

4.5 Service Mode Structure

Service mode commands are not generally meant to be used as part of normal operation. Some commands are safe to use (such as the various request commands) and will not disturb system operation. However, some service mode commands are intended for use in system testing not normal operation. These are commands allow the user to change system limits (such as the “Set Exposure Settings Set Maximum Exposure time” command). These commands should generally not be used, or at least be used with extreme caution. These limits are set to protect the supply and the X-Ray tube from damage due to improper programming. Commands that modify system limits should not be used as part of normal operation. See the individual command description for warnings.

4.5.1 Program Filament Limit

Description:

The host requests that the firmware change the Filament Limit.

Note: This command is intended for system testing. The Filament limit is normally set to a safe value for a given X-Ray tube. Increasing this value beyond the safe limit may allow damage to the X-Ray tube. Once changed the new setting will remain in effect until it is either changed again with this command or the system is powered down, and up again.

Direction:

Host to supply

Syntax:

<STX><12><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format (0-4095 = 0-6.0A)

Example:

<STX>12,4095,<CSUM><ETX>

Response:

<STX><12><,><\$><,><CSUM><ETX>

4.5.2 Request Filament Limit Set Point

Description:

The host requests that the firmware report the current Filament Limit set-point. Filament currents above this limit will result in a fault.

Direction:

Host to supply

Syntax:

<STX><16><,><CSUM><ETX>

Response:

<STX><16><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format (0-4095 = 0-6.0A)

Example:

<STX>16,4095,<CSUM><ETX>

4.5.3 Request Filament Pre-Heat Set Point

Description:

The host requests that the firmware report the current Filament Pre-Heat set point.

Direction:

Host to supply

Syntax:

<STX><17><,><CSUM><ETX>

Response:

<STX><17><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format

Example:

<STX>17,4095,<CSUM><ETX>

4.5.4 Set Exposure Settings Max Exposure Time

Description:

The host requests that the firmware change the maximum exposure time. Note: The maximum exposure time is the maximum time you can set using the “Set exposure” settings” command (command = 50), and the “Set exposure Time” command (command = 72). It does not change the current exposure time set by command 50 or 72. This is a service command and should be used with caution because it over-rides the tube table and allows exposure times that may damage the supply or X-Ray tube. This command should not be used in general operation.

Direction:

Host to supply

Syntax:

<STX><40><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 20000 in ASCII format, where <ARG> is the time in milliseconds.

Example:

<STX>40,5000,<CSUM><ETX>

Response:

<STX><40><,><\$><,><CSUM><ETX>

4.5.5 Request Max Exposure Time

Description:

The host requests that the firmware report the maximum exposure time. This is the maximum exposure time that can be set by the “Set Exposure Settings” command, or “Set Exposure Time” command. Note: Unless the “Set Max Exposure Time” Command (Command = 40) has been sent this value will be the contents of the Tube Table for the current exposure setting, assuming the current exposure setting is valid.

Direction:

Host to supply

Syntax:

<STX><32><,><CSUM><ETX>

Response:

<STX><32><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 20000 in ASCII format (time in milliseconds)

Example:

<STX>32 ,<CSUM><ETX>

4.5.6 Set Exposure Settings Pre-Heat Value

Description:

The host requests that the firmware change the filament pre-heat current value. The value scaling is 1.465 mA / Bit. The range is 0 to the current maximum filament limit set point or 6.0A, whichever is smaller. Warning: changing the pre-heat value may result in improper operation or X-Ray tube damage.

Direction:

Host to supply

Syntax:

<STX><33><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format (0-4095 = 0 – 6.0 A)

Example:

<STX>33,4095,<CSUM><ETX>

Response:

<STX><33><,><\$><,><CSUM><ETX>

4.5.7 Set Ready For Exposure Time

Description:

The host requests that the firmware change the ready for exposure time. This is the amount of time after entering Prep before X-Ray On is allowed. Values of less than 2 seconds will result in improper operation. This command is intended for system testing only.

Direction:

Host to supply

Syntax:

<STX><34><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 5000 in ASCII format (time in milliseconds)

Example:

<STX>34,4095,<CSUM><ETX>

Response:

<STX><34><,><\$><,><CSUM><ETX>

Note: The PMX unit has a maximum prep time of 30 seconds, meaning that no matter what you program. If the total time in prep (Prep + Exposure control on time) exceeds 30 seconds the exposure will be terminated. Increasing the Ready for Exposure time reduces the amount of time you have to actually make the exposure.

4.5.8 Get Ready For Exposure Time

Description:

The host requests that the firmware report the ready for exposure time. This is the amount of time after entering Prep before X-Ray On is allowed.

Direction:

Host to supply

Syntax:

<STX><42><,><CSUM><ETX>

Response:

<STX><42><,><ARG><,><CSUM><ETX>

Where:

<ARG> = Time in milliseconds in ASCII format

Example:

<STX>42,4095,<CSUM><ETX>

4.5.9 Set Maximum mAs

Description:

The host requests that the firmware change the upper limit of mAs. Note: This command changes the system mAs limit (exposure mA setting * exposure time) that you can set with the exposure command, not the set mAs. This is a service mode command intended for system testing only. Changing this limit beyond the default may allow damage to the supply or X-Ray tube. The scaling is 1mA*Sec / Bit.

Direction:

Host to supply

Syntax:

<STX><38><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 600 in ASCII format (units are mA*Sec)

Example:

<STX>38,500,<CSUM><ETX>

Response:

<STX><38><,><\$><,><CSUM><ETX>

4.5.10 Get Maximum mAs

Description:

The host requests that the firmware report the current maximum mAs limit. (This is the maximum limit, not the current exposure mAs setting)

Direction:

Host to supply

Syntax:

<STX><39><,><CSUM><ETX>

Response:

<STX><39><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 600 in ASCII format (units are mA*Sec)

Example:

<STX>39,600,<CSUM><ETX>

4.5.11 Request Filament Current Feedback

Description:

The host requests that the firmware report the current Filament Current Feedback. This value is from 0 – 4095 corresponding to filament currents of 0 – 6.415A, (0.0015665A / Bit). The filament current feedback value is also available using the “Request Analog Monitor Readbacks” command.

Direction:

Host to supply

Syntax:

<STX><62><,><CSUM><ETX>

Response:

<STX><62><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 - 4095 in ASCII format

Example:

<STX>62,4095,<CSUM><ETX>

4.5.12 Get Revision

Description:

The host requests that the firmware sends the current revision of the DSP and FPGA firmware.

Direction:

Host to supply

Syntax:

<STX><27><,><CSUM><ETX>

Example:

<STX>27,<CSUM><ETX>

Response:

<STX><27><,><ARG1><,><ARG2><,><CSUM><ETX>

Where:

<ARG1> DSP firmware revision ASCII format 0 – 10000

<ARG2> FPGA firmware revision ASCII format 0 – 10000

Example:

<STX>27,29,62,<CSUM><ETX>

4.5.13 Set Baud Rate

Description:

The host requests that the firmware change the Baud Rate of the serial port. Note that the command response is sent at the old baud rate, and the host should wait 500msec before sending another command at the new baud rate to allow the new baud rate to take effect.

Direction:

Host to supply

Syntax:

<STX><07><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 2 or 5 in ASCII format, 2 = 19200, 5 = 115200

Example:

<STX>07,1,<CSUM><ETX>

Response:

<STX><07><,><\$><,><CSUM><ETX>

(Response sent at old baud rate)

4.5.14 Set Calibration Mode On / Off

Description:

The host requests that the PMX unit enter or exit calibration mode. The user may request calibration of large filament only, small filament only, or both small and large filaments.

Direction:

Host to supply

Syntax:

<STX><28><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 3 to 0 in ASCII format

3 = Enter Calibration mode, Large filament only

2 = Enter Calibration mode, Small filament only

1 = Enter Calibration mode, Both Filaments

0 = Exit / Abort Calibration

Example: Enter Calibration, both large and small filaments

<STX>28,1,<CSUM><ETX>

Response:

<STX><28><,><\$><,><CSUM><ETX>

Notes:

This command is needed to start the calibration sequence, but the sequence will not start until the Prep and Exposure control signals are both ON (high). The proper procedure is to send this command with Prep and Exposure Control OFF. The calibration function will go to the "Paused" state, waiting for the external exposure controls to enable the actual exposure. Once the Prep and Exposure control signals go high the actual calibration sequence will run. The calibration routine will automatically exit calibration mode when the calibration is complete or if the system faults. Sending this command with an <ARG> of 0 aborts any active or waiting calibration sequence and returns the calibration status to 0. See Section 11 for more information on using calibration mode. If <ARG> = 1 (both filaments) is sent, the unit will calibrate the large filament first, followed by small filament. If <ARG> = 2 is sent, only the small filament will be calibrated. If <ARG> = 3 is sent only the large filament will be calibrated.

4.5.15 Get Calibration Status

Description:

The host requests that the PMX unit send the calibration status.

Direction:

Host to supply

Syntax:

<STX><29><,><CSUM><ETX>

Response:

<STX><29><,><ARG><,><CSUM><ETX>

Where:

<ARG> = 0 to 4, in ASCII format

0 = Not running / No result, no calibration sequence has been started.

1 = Calibration Paused. The unit is in calibration mode but is not actively running calibration because Prep and Exposure control are not both in the ON state.

2 = Calibration Running. The unit is in calibration mode actively doing the calibration sequence. The X-Rays will be generated.

3 = Calibration Successful. The unit has successfully completed calibration and exited calibration mode. The new preheats have been written to FRAM.

4 = Calibration Fault. The unit faulted during calibration and aborted the process as a result. Calibration mode has been exited. The fault must be cleared, and the process restarted from the beginning if calibration is desired.

Example:

<STX>29,<CSUM><ETX>

Response: (In this example, calibration is running)

<STX><29><,><2><,><CSUM><ETX>

Notes: Once calibration has been run and either a Calibration Successful or Calibration Fault code is set it is held until another calibration sequence is started or the power is turned off.

Terminating a calibration sequence by writing a “Set Calibration Mode” command with an argument of zero will cause the status to return to 0.

4.6 Serial Command Handling

4.6.1 Command Time Out

The host computer should set a serial time out at approximately 100mS. This allows the DSP to process the incoming message, and transmit a response. The DSP will initiate a reply to incoming messages in approximately 1-2mS, with a worst case of 5mS.

4.6.2 Buffer Flushing

The DSP will flush the incoming serial data buffer every time an STX is received. This provides a mechanism to clear the receive buffer of partial or corrupt messages.

4.6.3 Handshaking

The only handshaking implemented on the host interface, is built in to the implementation of this protocol. That is, the host must initiate all communications. If the supply receives a program command, an acknowledge message is sent back to the host via the "\$" message. If the host does not receive an acknowledge within the time out window, the host should consider the message lost or the device off-line.

Similarly, if the supply receives a request command, the requested data is sent back to the host. If the host does not receive the requested data within the time out window, the host should consider the message lost or the device off-line.

This essentially uses the full-duplex channel in a half-duplex communication mode.

5.0 Predictive filament

The current level to be used during the preheat time for the coming exposure is decided as follows (see fig 12):

- 1) ADC values of the mA feedback current are sampled at the end of preheat just prior to mA servo and stored in memory.
- 2) At the end of the exposure the actual mA at the end of preheat is compared to the set mA value and the difference calculated.
- 3) If the error zero then the preheat is left unchanged, if the error is less than .25 mA the preheat will be adjusted up or down by 1 LS-Bit (1.4 mA of filament current). If the error is more than .25mA then the amount of adjustment is calculated by taking the tube curve (delta filament current / delta mA for that delta filament current), multiplying by the mA error and taking 80% of that value.
- 4) If the exposure is terminated normally the preheat will be updated. If the exposure terminated because of a fault, the preheat is left unchanged. In addition of the exposure is less than 20msec long the preheat will not be updated, instead the value for previous exposure will be used.
- 5) If the value from the reading differs more than 0.5 A from the last value it will still only be changed 0.5 A.

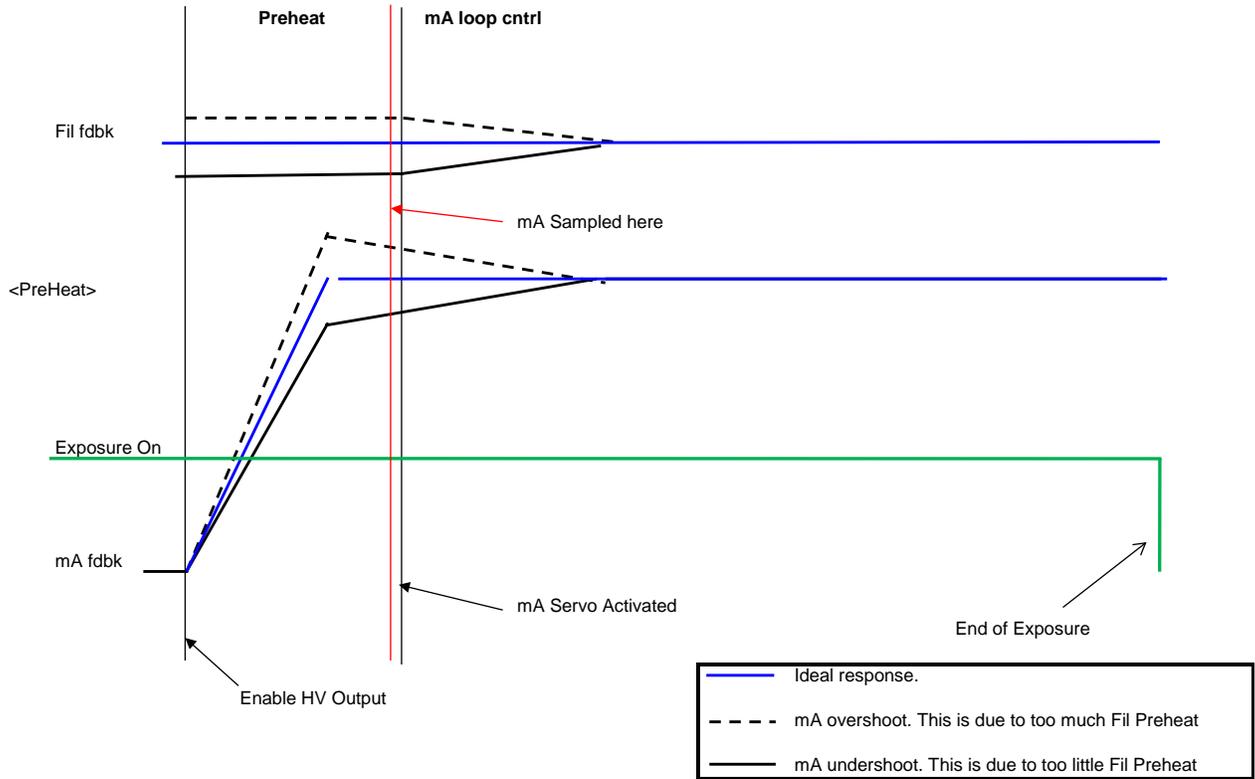


Figure 1 Figure showing the time sampling of mA feedback during transition from preheat to mA servo.

6.0 General Timing

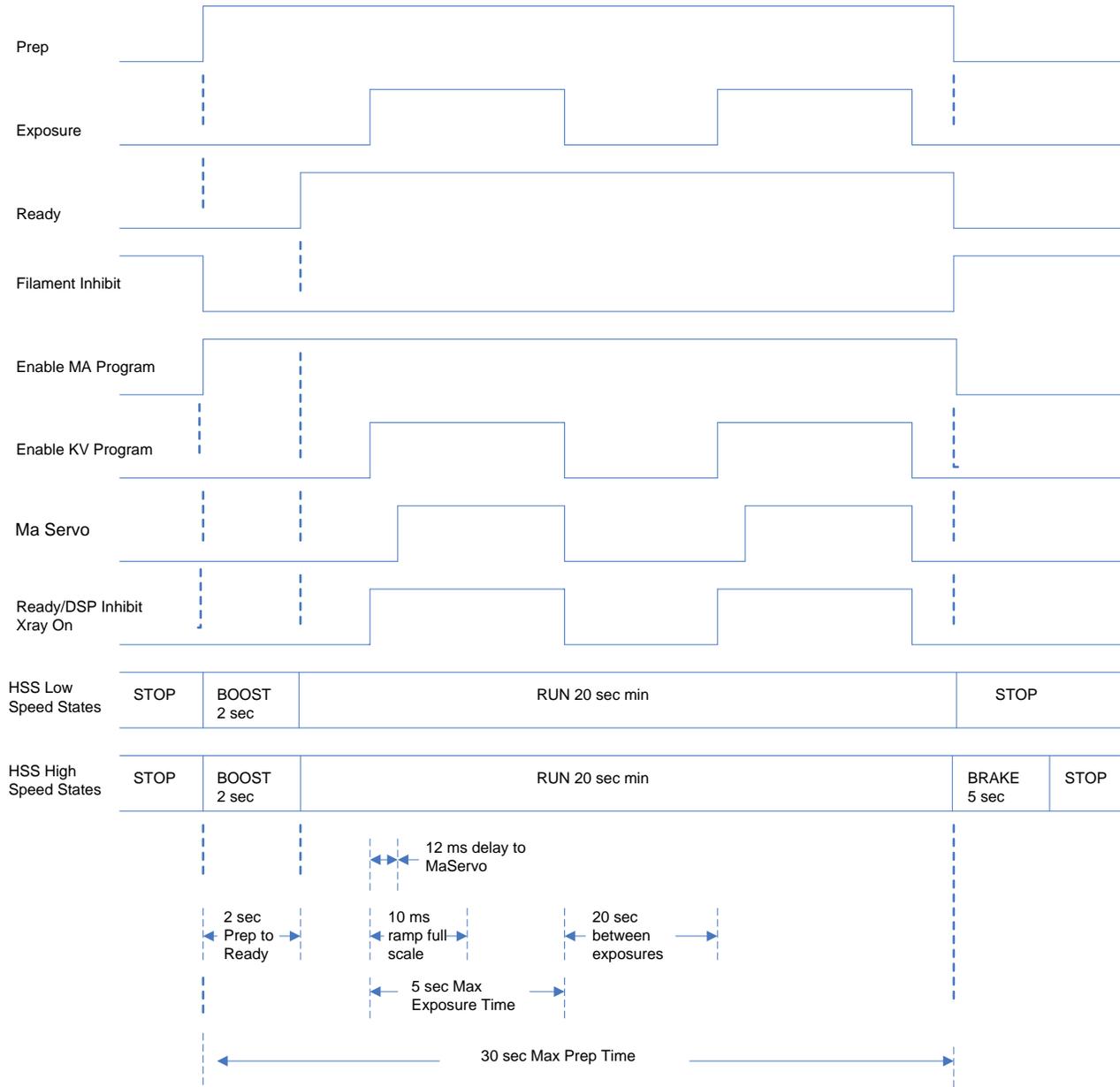


Figure 13 General Timing

7.0 Brake After Exposure

When 'BAE' is disabled, the Brake should happen after the hang timer reaches the set Hang Time or the Prep is removed whichever occurs first. If Hang Time = 0, the brake will happen once the exposure command is removed (the same as BAE enabled)..

When 'BAE' is enabled, the brake should happen once Exposure command goes inactive.

After brake occurs, the generator is no longer at READY status. Prep sequence has to be initiated (Prep goes low then high).

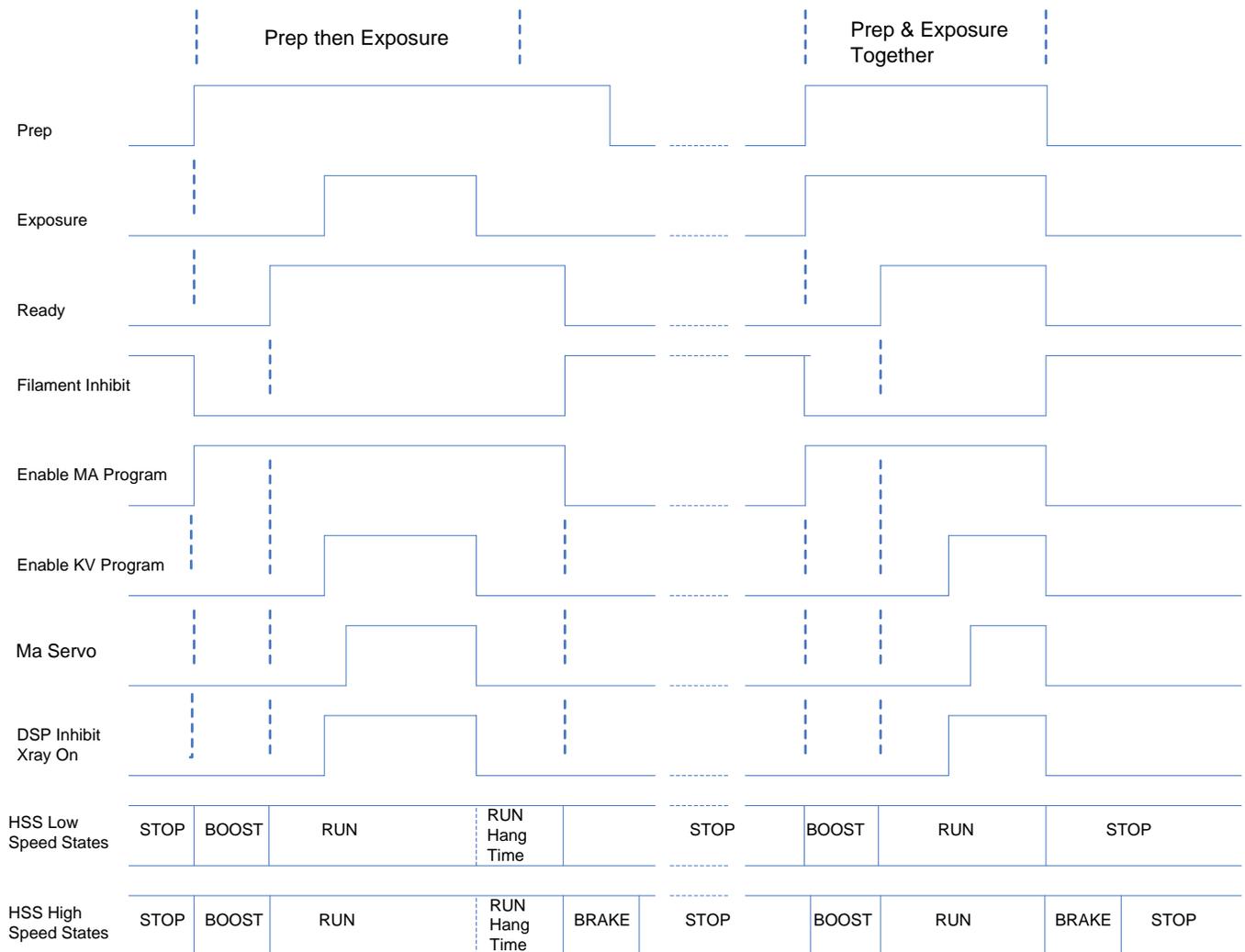


Figure 14: BAE Disabled Timing

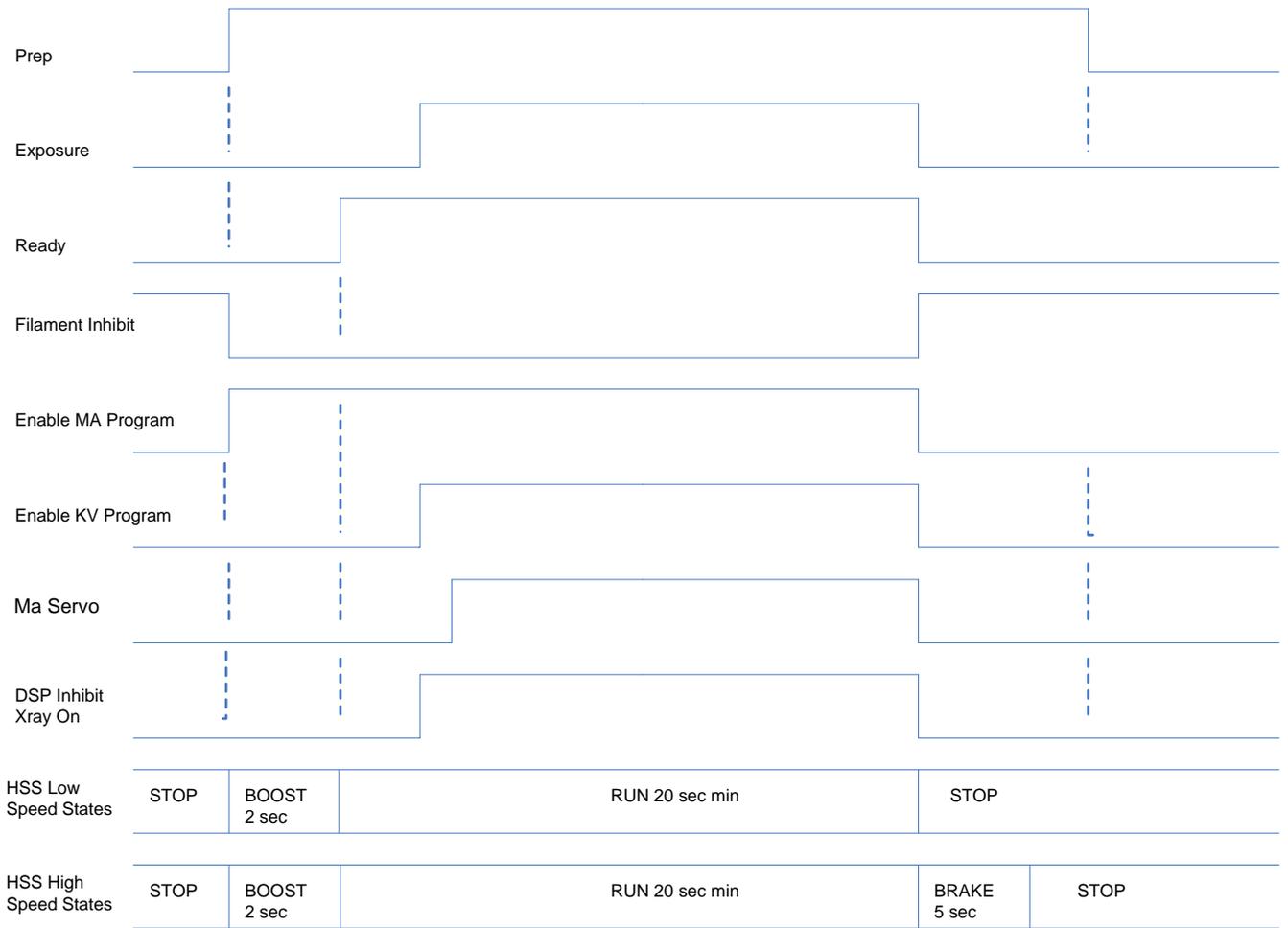


Figure 15: BAE Enabled Timing

8.0 AEC (Automatic Exposure Control) Mode

In Standard AEC Mode the external AEC control input, also called “Exposure Disable”, is allowed to gate the high voltage on and off. In order to generate X-Rays Prep, Exposure Control and AEC must all be in the “ON” state, which is High (Logic 1). In addition the unit must be in the ready state. When running in AEC mode the exposure control timer only runs when the AEC signal is high. The exposure sequence terminates when any of the following are true:

1. Prep goes inactive (low)
2. Exposure control goes inactive (low)
3. The exposure timer times out. (Timer is set as part of exposure command)
4. The 30 second Prep time is exceeded.

When in AEC Mode it is assumed that the AEC signal will be in the Off state when the exposure sequence terminates. If the AEC signal is ON, an under-time fault will occur. The rotor continues to run when the X-Ray is shut off by the AEC signal. An example of AEC timing is show below for the case of Prep & Exposure together + HSS slow speed. Also note, in AEC mode Break After Exposure is automatically disabled, and will not occur even if it is set. In addition the Break after exposure hang time will be 30 seconds, regardless of the current setting.

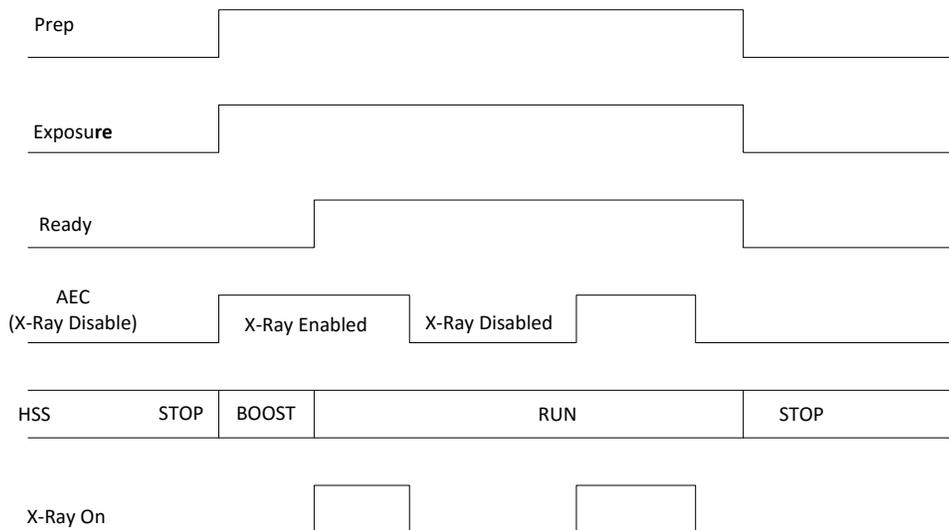


Fig 16 - AEC Timing

9.0 2-Point / 3-Point Mode / mAs+mA Mode

This mode setting determines how the exposure parameters are specified to the system. In 3-Point mode (also called manual mode) all parameters must be explicitly set by the user. These parameters are kV set-point, mA set-point, exposure time, filament size (large / small), and rotor speed (Fast / Slow). In 2-Point mode the desired filament (spot size), kV and mAs (milliamp-seconds) of the exposure is set. The mA, exposure time and rotor speed are then automatically selected using the tube tables. The selection algorithm is given in the following flow chart (Figure 17). Finally, in mAs+mA mode kV, mAs, mA, filament and HSS speed are specified by the user. The exposure time will be determined by the specified mAs and mA. (Time = mAs/mA).

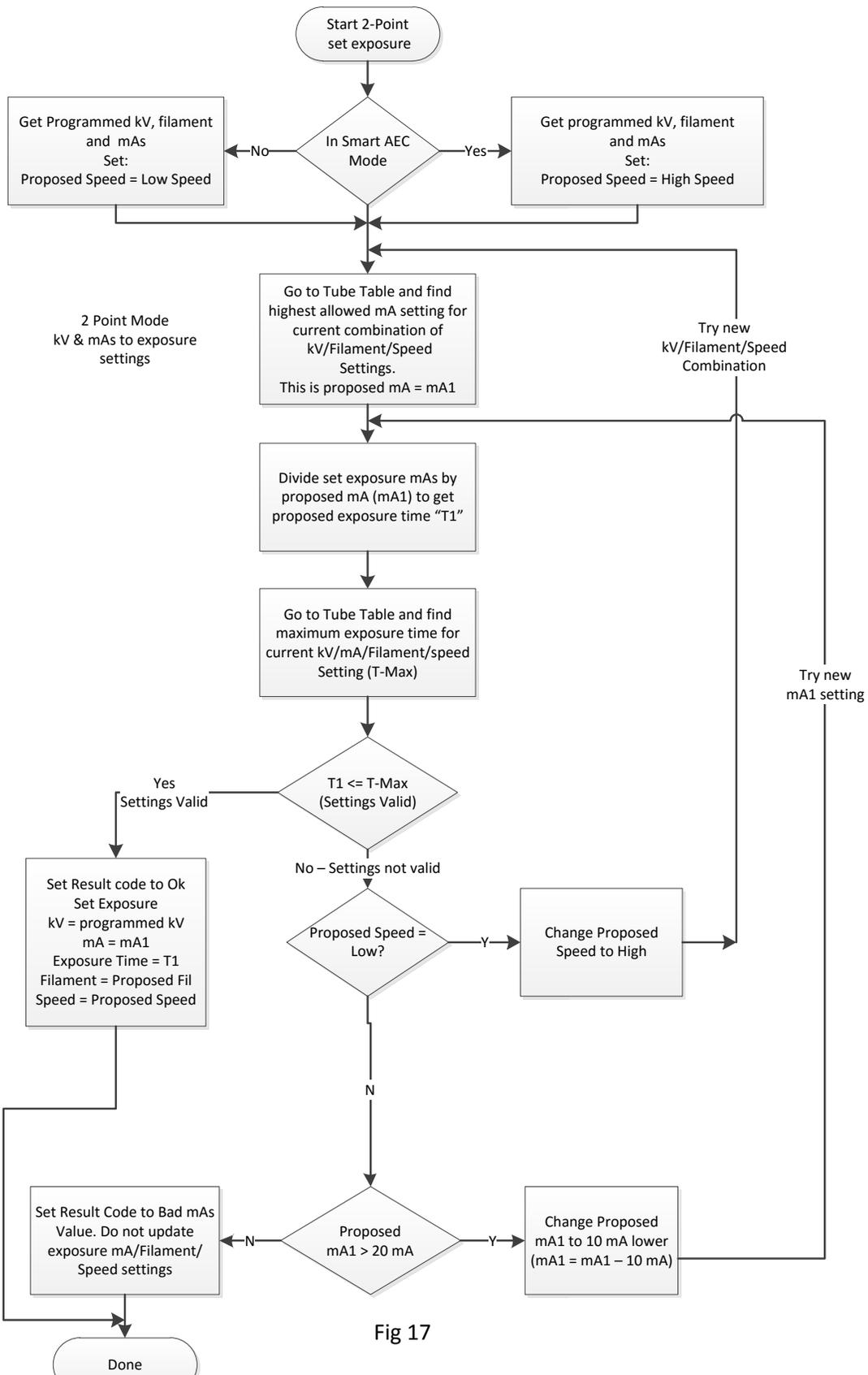


Fig 17

10.0 Smart AEC Mode

In Smart AEC Mode (S-MAC) the exposure is split into multiple parts. All parts of the exposure are required to use the same filament and HSS speed, but the kV / mA / exposure time are allowed to change between parts of the exposure. The Prep, Exposure Control, X-Ray On (status), and AEC signals, along with the serial command port are all involved with Smart AEC mode. The sequence of events for doing a Smart AEC exposure is as follows:

1. The host sends the required commands to set up the exposure. These are HSS Speed, Filament, kV, mA, and exposure time for 3 point mode, Filament, kV and mAs for 2 point mode, or kV, mAs, mA, Filament and HSS Speed in mAs+mA mode. (Note that in, 2 point mode HSS Speed is automatically set to Fast).
2. The host sets Prep "On". The unit will go into the Boost / Preheat phase on the filament. (See Note 1).
3. The host sets exposure control ON and AEC control ON to enable X-Rays. AEC may be set ON before or simultaneous with exposure control ON.
4. The unit will turn High voltage ON. High voltage will remain ON until the programmed exposure time has elapsed. The host should monitor the X-Ray On status.
5. After the X-Ray On status transitions from ON to OFF the Host should set the AEC control to the X-Ray disabled state (Low). The host must also leave the Prep and exposure control signals ON during this time.
6. The host must now send the settings for the next part of the exposure over the serial interface. Any combination of kV, mA, exposure time if in 3-point mode, or kV and mAs if in 2-point mode may be changed. HSS Speed and Filament may not be changed. Note that the host is required to send a new set of kV/mA/time or mAs control settings, even if they are the same as the previous settings.
7. The host must wait a minimum of 20 milliseconds after the end of the last command for the PMX unit to process the commands. By the end of the 20 millisecond period the next part of the exposure will be set up and a new value of preheat current applied to the filament. (See Note 2).
8. The host sets the AEC signal High to indicate the next part of the exposure can begin.
9. The PMX unit will turn High voltage ON. High voltage will remain ON until the programmed exposure time has elapsed. The host should monitor the X-Ray On status.
10. When the X-Ray transitions to OFF the host should again set AEC signal low (X-Ray disabled state).
11. If the user requires more exposures, steps 6 – 10 can be repeated as many times as required, the only limitation being the total sequence must be less than the 30 second "Time in Prep" limit.

Note 1: The time to ready is 2 seconds. The exposure control signal can be set ON prior to the end of the 2 second time, but the High Voltage will not actually turn ON until the 2 seconds have elapsed from Prep active.

Note 2: Even though the new exposure settings will be programmed and the new preheat set for the next part of the exposure within 20 milliseconds of receiving the last setup command, the actual filament temperature will not change instantaneously. Turning on the high voltage immediately after the 20 millisecond period ends will not allow enough time for the filament to reach the correct temperature. This may result in large mA variations at the start of the next part of the exposure. It is the user's responsibility to allow sufficient time for the filament to reach the correct temperature before raising the AEC signal to start the next exposure.

Note 3: In Smart AEC mode, Break after exposure is forced to "OFF", and the Break after exposure hang time set to 30 seconds, regardless of the previously programmed values. (This is the same as in standard AEC mode).

Note 4: There is no specified maximum time between the exposures in a Smart AEC sequence. The limiting factor is that the unit can have Prep active for a maximum of 30 seconds, so the entire exposure sequence of all exposures including the 2 second time to ready, can't be longer than 30 seconds.

Note 5: The AEC control signal MUST be in the X-Ray disabled state (low) during the exposure settings update for the 2nd and later parts of the exposure. The state of the AEC control signal does not matter when setting up the 1st part of the exposure because Exposure Control and Prep are low.

Note 6: In Smart AEC Mode, Commands 60 and 61, request last exposure kV monitor and request last exposure mA monitor treat each part of the exposure as separate exposures. For example if the kV monitor is requested after the first part of the exposure has finished, but before the second part has started, the average kV of the first part is reported. If the kV monitor is then requested after the second part of the exposure has finished, the average will be for the second part of the exposure only. See Fig 18.

Note 7: It is allowed to have only a single exposure in Smart AEC mode without generating a fault. The new Smart AEC mode has a variable number of exposures.

Figure 18 illustrates the Smart AEC sequence, for an example of 2 exposures.

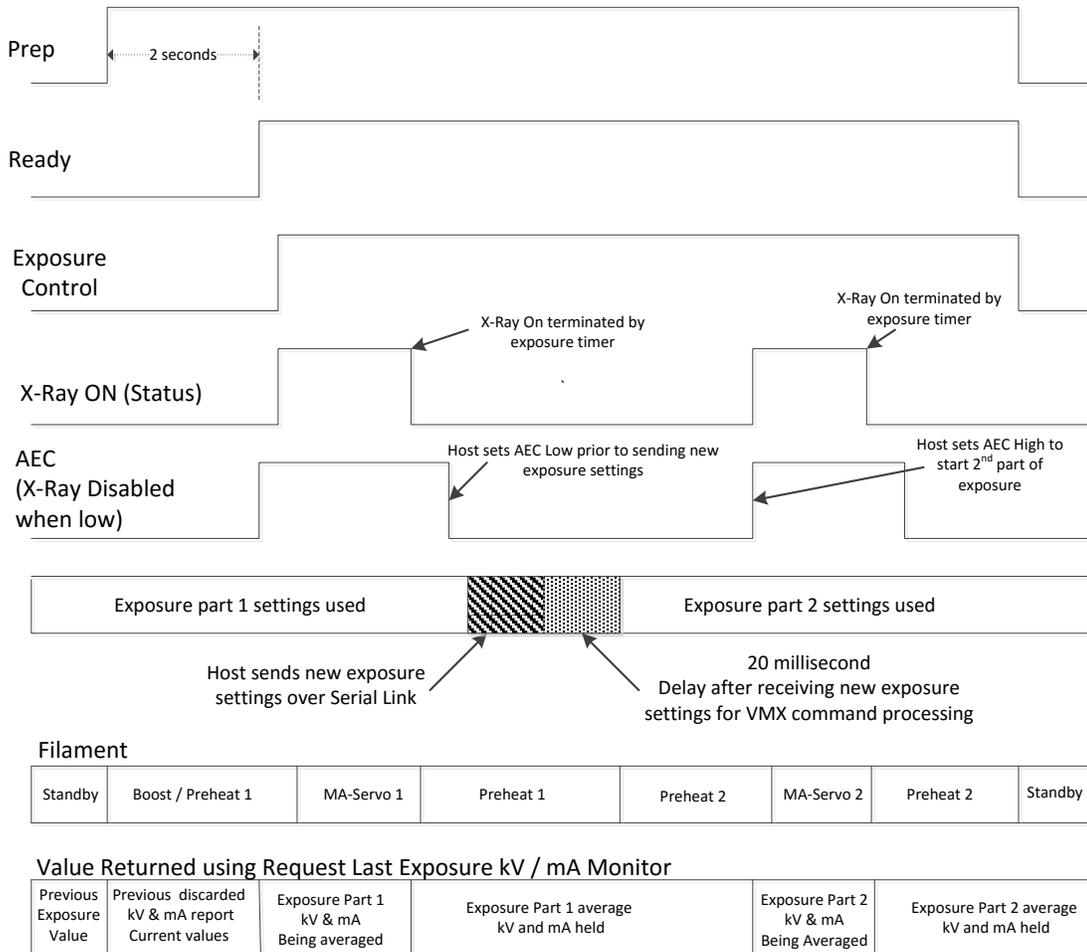


Fig 18 – Smart AEC Mode (2 exposures shown)

Notes:

Setting the AEC signal low before X-Ray On status goes low (X-Ray Off) will cause an under-time fault.

Exposure commands sent at an illegal time such as when AEC is high or X-Ray is On will be ignored and will return a “State Error” code. Exposure commands used to set up the 2nd part (or later parts) of the exposure must be sent at the time indicated in the diagram.

It is required to send a new setup between each part of the exposure, even if the new setup is exactly the same as the old. This can be done using the “Set Exposure Settings” command, or Individual set commands such as “Set

Exposure kV”, “Set Exposure mA” and “Set Exposure Time” if in 3 point mode, or “Set Exposure kV”, and “Set Exposure mAs” in 2 point mode. It is allowed but not required to send a Set Filament or Set HSS Speed command in between exposures. If either of these commands are sent; however, the setting must be the same as in the part 1 exposure.

It is not allowed to change from 2-Point Mode to 3-Point mode or the reverse in the middle of a Smart AEC exposure

11.0 Calibration Mode

PMX calibration mode is started by sending a “Set Calibration Mode” command (command number 28) with an argument of 1, 2 or 3 depending on which filament(s) you wish to calibrate. This should be done with Prep and Exposure control in the OFF state. When the set calibration mode on command is received the unit will enter calibration mode, but it will be in a “paused” state. It will not start running exposures until both Prep and Exposure control are set to the ON state. The calibration status will show “Paused” when the unit is in this state. When the operator is ready to begin actual calibration they must bring Prep and Exposure control to the ON state. Note that the state of the AEC control signal into the unit doesn’t matter. It is not used for calibration. Once the sequence has started the unit will automatically cycle through the exposure settings as long as the Prep and Exposure control are ON until it either finishes calibration or there is an exposure fault. An exposure fault will cause the calibration routine to abort, and the unit to exit calibration mode. If the user removes Prep and / or Exposure control during the sequence, the calibration routine will enter a “Paused” state. It will not exit calibration mode, but it will stop doing exposures and wait until Prep and Exposure control are both returned to the ON state. If the user returns Prep and Exposure control ON, the PMX will continue the calibration. Usually it will continue from where it was when the sequence was paused, but depending on what it was doing when the calibration sequence was interrupted it may go back and repeat a previous step. The user may cancel calibration at any time by first setting Prep and / or exposure control off, and then sending a “Set Calibration Mode” Command with an argument of 0. Sending this command resets the calibration sequence. The next time calibration is started it will go back to the beginning. Once calibration is started previous values for preheat will be overwritten. Stopping calibration in the middle will result in some points being calibrated and others not being calibrated. This may result in poor or inconsistent preheat adjustment. If you choose to calibrate large and small filaments separately, only the chosen filament will be affected. For example if small filament is calibrated and you attempt to calibrate the large filament, but the calibration fails, it does not affect the small filament calibration. In this case you would have to rerun the large filament calibration, but not the small filament calibration.