Andros Incorporated

7210 Product Manual
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Model 7210
Digital Opacimeter
Subsystem

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Table Of Contents

Preface

Andros Notation

Hexadecimal numbers are preceded by a $ (dollar sign). The $90 Store Instrument Data command requires transmitting the hexadecimal command code $90, which is equivalent to 144 decimal or 10010000 binary.

Individual bytes or bits in host system commands and ACK/NAK responses are specified in the following format:

CommandCode—ByteName—BitNumber. When the whole byte is being referred to, the bit numbers are not included.

Example1: $01—SYSF—6 refers to the $01 Status command, System Fault Status byte, bit 6 (Fan Fail).

Example2: $05—DC refers to the $05 System Control command's DC (Device Control) byte.

Example3: GENS—0 refers to the GENS (General Status) byte, bit 0 (Calibration Request) returned in the ACK responses of both the $01 Status and $10 Opacity Data commands.

Manual History

Rev #	Revision Date	Description Of Changes
1	August 11, 1995	Preliminary version of 7210 Digital Opacimeter product manual supporting early prototype units.
2	August 16, 1995	Corrections and updates to the preliminary 7210 Digital Opacimeter product manual.
A	May 2, 1996	First publication of the 7210 Digital Opacimeter product manual.

About This Manual

Chapter 1 **Introduction**	Introduces the 7210 Opacimeter Subsystem. Its configurations, key features, and accessories.
Chapter 2 **Specifications**	7210 product performance specifications.
Chapter 3 **Operation**	An introduction to how the 7210 measures diesel exhaust opacity. The functional elements of the smoke tube and each printed circuit board assembly are described. A method of calculating the absorption coefficient k is defined.
Chapter 4 **Calibration**	The 7210's Calibration and Linearity Check† commands and procedures are covered in detail.
Chapter 5 **Hardware Interfaces**	The 7210's power and host communications hardware interfaces, and the 7210's configuration jumpers are specified in detail.
Chapter 6 **Host Communications**	The host system communications protocol and command set are specified in detail.
Chapter 7 **Service and Support**	7210 cleaning, adjustment, and removal and replacement procedures are covered. Technical support, training, and service programs are detailed.
Appendix A **Drawings And Schematics**	7210 drawings, block diagrams, and schematics.

† Linearity Check System AVL.

Introduction 1

The 7210 Opacimeter Subsystem is designed for diesel engine exhaust opacity measurement.

It meets or exceeds the following opacimeter performance requirements:

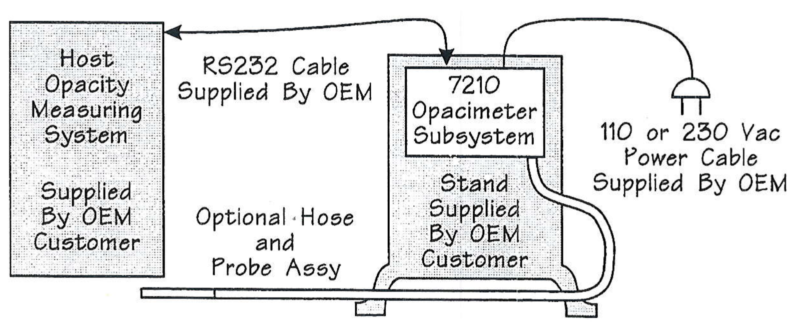
- ISO (worldwide).
- PTB-AUII (Germany).
- MOT (United Kingdom).
- 1996 French Regulations.

To aid the OEM system designer during integration of the 7210 Subsystem into the final Opacimeter system, Andros has designed the 7210 Opacimeter Subsystem to be a complete opacity measuring instrument with no OEM design effort required other than the following:

- ***Host System***. The host system hardware and software manage the 7210 and present the 7210's opacity data output as required by the finished system's intended application. If required by the application, the host system must calculate the absorption coefficient k or identify and calculate peak values. The final host system may interface to other sensors, including Andros multi-gas analyzers, vehicle diagnostic scanners, etc. To aid demonstration, evaluation and development, Andros makes IBM PC-AT compatible 7210 host software available.
- ***Host Interface Cables***. The host system supplier provides the AC power and RS232 serial communications cables required to interface the 7210 to the host system and local AC power.
- ***Stand***. The 7210 Subsystem is typically mounted on, or contained within, a stand, cart, or other type of housing incorporating the OEM's choice of design, color, logo, etc.

The 7210 Subsystem provides accurate opacity measurements transmitted to the host system in response to host system commands. Management, capture and display of the opacity data is under the control of the host system and its software.

The high performance capabilities of the 7210 Subsystem make it suitable for incorporation in both I&M OEM systems and in diagnostic OEM products.



7210 Digital Opacimeter Key Features

- Compete, integrated opacity subsystem.
- Rugged standalone unit.
- Convenient, standard fused AC power entry module.
- Simple three-wire RS232C serial interface (DB9 connector).
- Performance accuracy enhanced by innovative design.
- Solid frame stands up to use in the automotive service and test environment.
- Microprocessor controlled; no adjustments.
- Electronic solenoid selects between sample and zero gas.
- Heater blankets control sample cell temperature.
- Venturi/fan design keeps LED and detector lenses clean, enhances sample flow.
- Dual-LED Linearity Check.[†] Performed automatically with first calibration after power on and as commanded by host system.
- Standard Andros communications protocol minimizes OEM hardware and software engineering effort when incorporating the 7210 subsystem into current gas analyzer systems.

7210 Models And Configurations

The 7210 is available in 115 Vac and 230 Vac models.

Accessories

- Optional Neutral Density Filter, P/N 451280-000. Note, the Neutral Density Filter is not required for normal operation, calibration or maintenance. It is used during OEM integration activities including incoming inspection and engineering evaluation.
- Optional quick connect hose/probe assembly.

[†] Linearity Check System AVL.

Environmental Specifications

The 7210 will perform to the specifications in this chapter over the full range of ambient environmental specifications below.

	Operating Environment	Storage Environment
Ambient Temperature	–2 to +55°C +28 to +131°F	–29 to +60°C –20 to +140°F
Ambient Humidity	0 to 93% RH (non-condensing)	0 to 95% RH (non-condensing)
Ambient Altitude	–305 to +2,133 m. –1,000 to +7,000 ft.	–305 to +3048 m. –1,000 to +10,000 ft.

Weight And Dimensions

	Opacity Head Assembly	Optional Probe / Hose Assembly
Weight	12.0 kilos 26.5 lb.	0.55 kilos 1.2 lb.
Length	63.5 cm 25.0 inches	80.0 cm 31.5 inches
Width	26.7 cm 10.5 inches	n/a
Height	12. 7 cm 5.0 inches	n/a
Internal Diameter	n/a	1.27 cm 0.5 inch

International Standards Compatibility

The 7210 Opacimeter meets or exceeds the worldwide opacimeter performance requirements as specified in the following documents.

ISO CD11614 ISO CD11614 (July 10, 1992) specifies an apparatus for the measurement of opacity and for the determination of the light absorption coefficient of exhaust gas from internal combustion engines.

EEC 72/306 EEC 72/306, Counsel Directive, August 2, 1972, On The Approximation Of The Laws Of The Member State Relative To The Measures To Be Taken Against The Emissions Of Pollution From Diesel Engines For Use In Vehicles.

MOT/07/24/SMOKE This specification covers smoke meters to be used for statutory testing in the HGV, PSV, and M.O.T. programs (United Kingdom).

NF R 10-025 The following regulation covers smoke meters used in France: Regulatory Standard NF R 10--025 "Measuring Opacity In Exhaust Emissions Of Diesel Engines — Part 2: Specifications For Commercial Partial Flow Opacimeters."

CE LABEL The 7210 complies with the health and safety requirements of the applicable EU Applied Directives and Standards. A Declaration of Conformity is on file at Andros.

Opacity And Sample Gas Temperature Data Specifications

Accuracy specifications are in effect throughout the environmental ranges specified.

Reporting range specifies the minimum range of readings that will be reported to the host system. Negative opacity is reported in order to indicate negative data measurement drift.

Measurement range is the range over which the measurement accuracy specification applies.

Reporting resolution is the smallest increment reported.

Measurement accuracy is measured using the Andros *Opacity Data Accuracy Test Method.*

	Opacity, N%	**Opacity, k (m^{-1})**
Reporting Range (min.)	–2.0% to +102.0%	See Note 1
Measurement Range	0.0% to +100.0%	See Note 1
Reporting Resolution	0.1%	See Note 1
Measurement Accuracy	±0.5% abs	See Note 1
Note 1: Opacity in units of k (m^{-1}) is not currently reported or specified.		

	Mean Sample Gas Temperature	**Inlet Sample Gas Temperature**
Reporting Range	+25.0°C to +225.0°C	+15.0°C to +220.0°C
Measurement Range	+40.0°C to +200.0°C	Not specified.
Reporting Resolution	0.1°C	0.1°C
Measurement Accuracy	+40.0 to +100.0°C = 1.0°C Absolute +100.1 to +200.0°C = 1% Relative	Not specified.

Opacity Data Accuracy Test Method

Opacity data measurement accuracy is measured by the following test method:

1. The test environment must be held constant within the 7210 environmental limits specified.
2. The 7210 should be powered up from cold start, and allowed to "warm up" for 30 minutes (minimum).
3. The 7210 must be calibrated ($03 Calibrate command).
4. An Andros Neutral Density Filter, P/N 451280-000, must be inserted in the 7210's optical path while opacity data is being recorded. The opacity data must be taken at the 7210's maximum data output rate for 10 seconds. The 7210 must not be reporting any operational or data errors. The opacity data must be taken between Calibrate Requests.
5. Calculate the statistical mean of the opacity data taken above. From the difference between this calculated value and the Neutral Density Filter's marked value, subtract the Neutral Density Filter's tolerance (±0.5% abs). If the result is less than or equal to the 7210's stated accuracy (±0.5% abs), the 7210 is performing within its measurement accuracy specification.

Warmup Time

From cold power on, the 7210 will provide opacity measurements meeting the opacity data Measurement Accuracy specifications within 5 minutes maximum.

Physical Response Time

Physical Response Time is determined by the following test.

With the 7210 sample cell purged with fresh air, introduce a sample gas. The time between the beginning of sample gas introduction and the accurate reporting of the sample gas opacity is the physical response time.

The 7210's physical response time is ≤0.4 seconds.

Power Specifications

	Input Power Configuration	
	115 Vac	**230 Vac**
Voltage Range	88 to 138 Vac	187 to 264 Vac
Frequency	47 to 63 Hz	
Power Consumption	400 Watts Maximum	

General Theory Of Operations

The Model 7210 measures the particulate concentration (smoke) in Diesel engine exhaust by determining the optical transmission of green light at 555 nm wavelength through a 430 mm length of exhaust sample, established by a 2.54 cm diameter "smoke tube" open on both ends. Sample is drawn via an electrically actuated valve and is "pumped" by the combination of the positive pressure in the vehicle exhaust pipe at the sample probe inlet and the small negative pressure at the smoke tube ends produced by forced air flow through large venturis. This air flow also creates an air curtain that prevents accumulation of dirt on the optics windows through which the light is transmitted. The sample cell geometry is such that the pressure differential from ambient is negligible, thus requiring no pressure compensation of the output.

Green light is produced by LEDs modulated at 921.66 Hz. This light is detected at the other end of the sample cell and synchronously demodulated to yield an analog signal proportional to light transmission. This signal is read by a 12-bit analog-to-digital converter (ADC) and brought into a microprocessor where the transmission (T) value is converted to Opacity. The modulation/demodulation process is controlled by the microprocessor, which outputs the processed data on a serial interface to the host system.

Hardware Organization

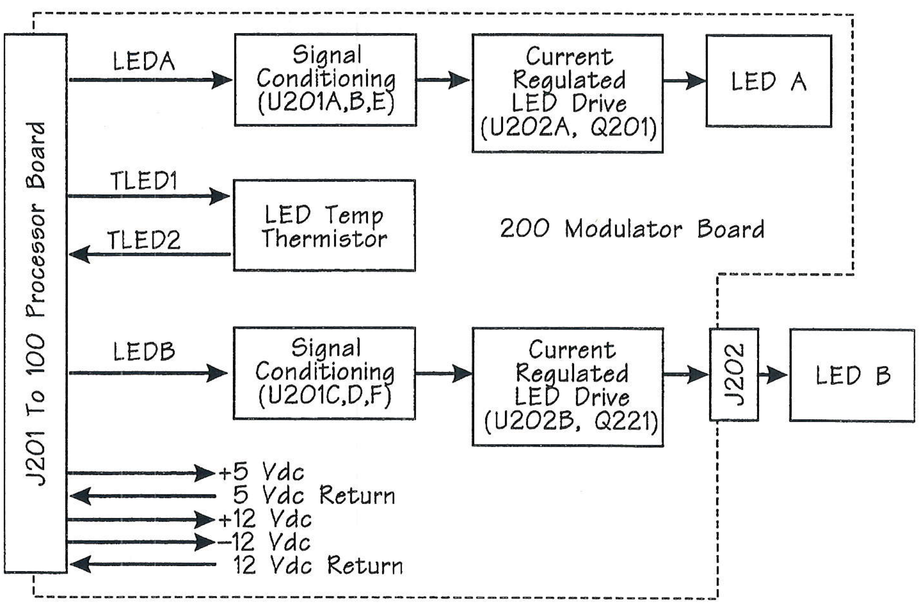
The structural frame of the instrument connects the two venturis and locks them into alignment. It also houses the power supply and the Processor board on which resides a Motorola 68HC11 microprocessor. In the left venturi is the Modulator assembly, a small circuit board that includes the source LEDs, their drive circuitry and the special beam splitter arrangement used to verify instrument linearity. The right venturi contains the Demodulator assembly, which includes the optical detector, preamp, demodulator, and ADC. The Modulator and Demodulator boards are connected to the Processor board by ribbon cables carrying only power and digital signals; no analog information is carried between these assemblies.

Modulator Board

Green light modulated at 921.66 Hz is produced by two LEDs whose outputs are combined in approximately a 45/55 ratio by a special beam splitter glass. The LEDs are controlled by separate 921.66 Hz square waves. In normal operation, both LEDs are driven. For the linearity check, which is part of Zero calibration, LED A and LED B are selectively turned OFF. Linearity is demonstrated by measuring the transmission (demodulator output) with LED A alone, then LED B alone, and ensuring that the sum of these responses is within 1% of the transmission obtained with both LEDs turned ON.

When the LED is ON, it produces a green light square wave at 921.66 Hz that alternates between a bright state at full drive current and a dim state at a small "keep-alive" current. When the LED is OFF, its output is constant dim state. Only the modulated (AC) part of the LED light results in output from the demodulator; constant or "DC" light is rejected. The 921.66 Hz frequency provides high signal-to-noise ratio and rejects 50 and 60 Hz line-related interference (e.g., from fluorescent lighting).

Modulator Board Block Diagram

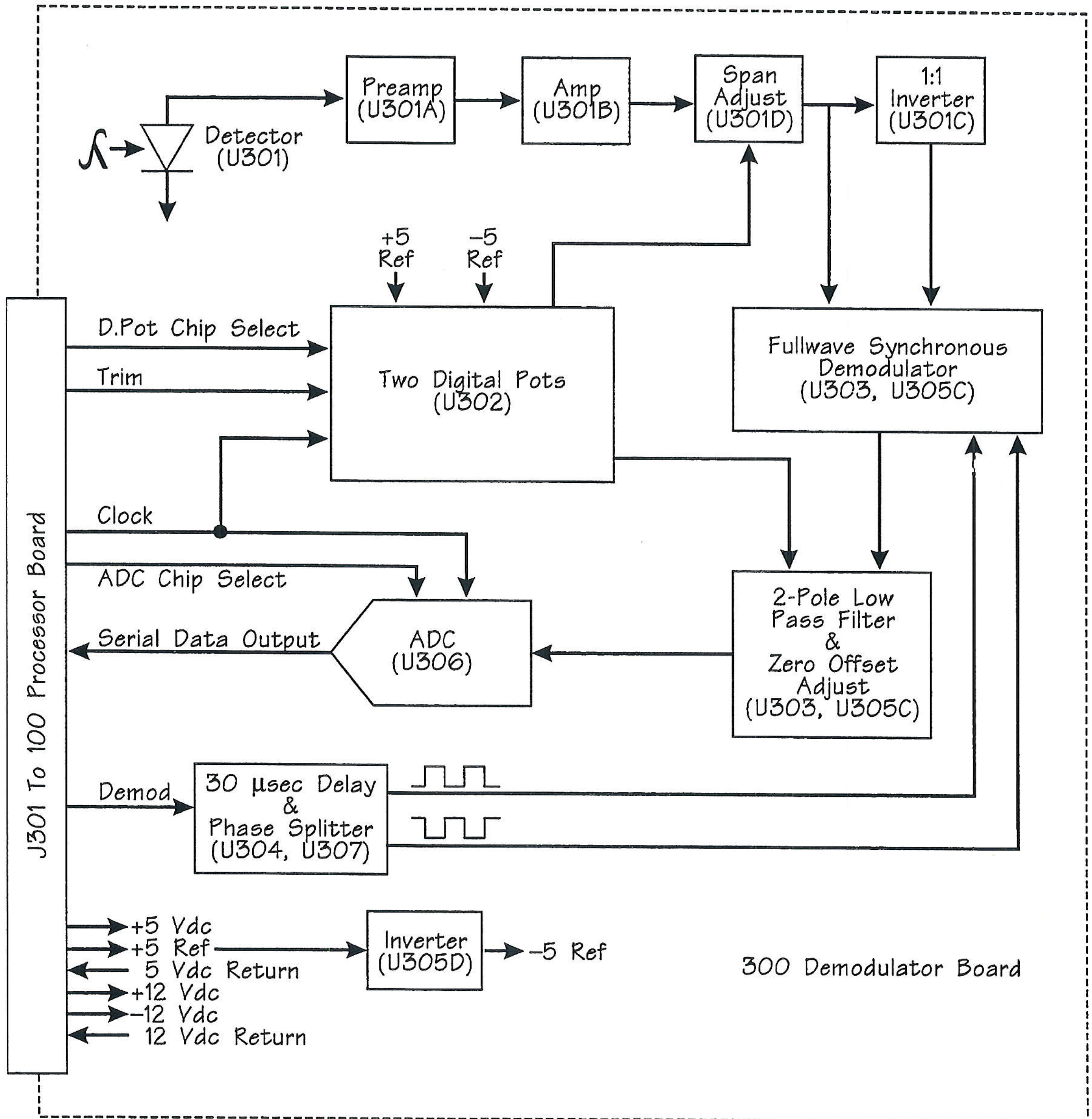


Demodulator Board

The Demodulator board assembly includes the optical detector and complete signal processor, including Zero and Span controls and a 12-bit ADC. The signal processor is a precision full-wave synchronous demodulator, a special kind of active rectifier that responds only to signals at the modulation frequency. DC signals are rejected completely, and AC signals at other than the modulation frequency are rejected more or less depending on the particular frequency. The demodulator produces a continuous "varying DC" output of 20 Hz bandwidth whose amplitude is exactly proportional to the strength of the detected AC signal. This demodulator has a high degree of rejection to random noise and to the types of interfering AC signals likely to be encountered.

The 7210 is calibrated in response to a host system commanded calibration sequence. This includes demodulator Zero calibration (lower boundary trim) and a Span calibration gain adjustment in the AC signal channel (upper boundary trim). Both are done with a microprocessor-controlled dual digital potentiometer with 8-bit (1 in 256) resolution. The ADC input range is 0-5 V, but the working signal range is set with a lower boundary of 0.5 V (corresponding to zero transmission) and an upper boundary of 4.5 V (100% transmission). Signal excursions too close to the ends of the ADC range are detected and flagged as errors.

Demodulator Board Block Diagram



Processor Board

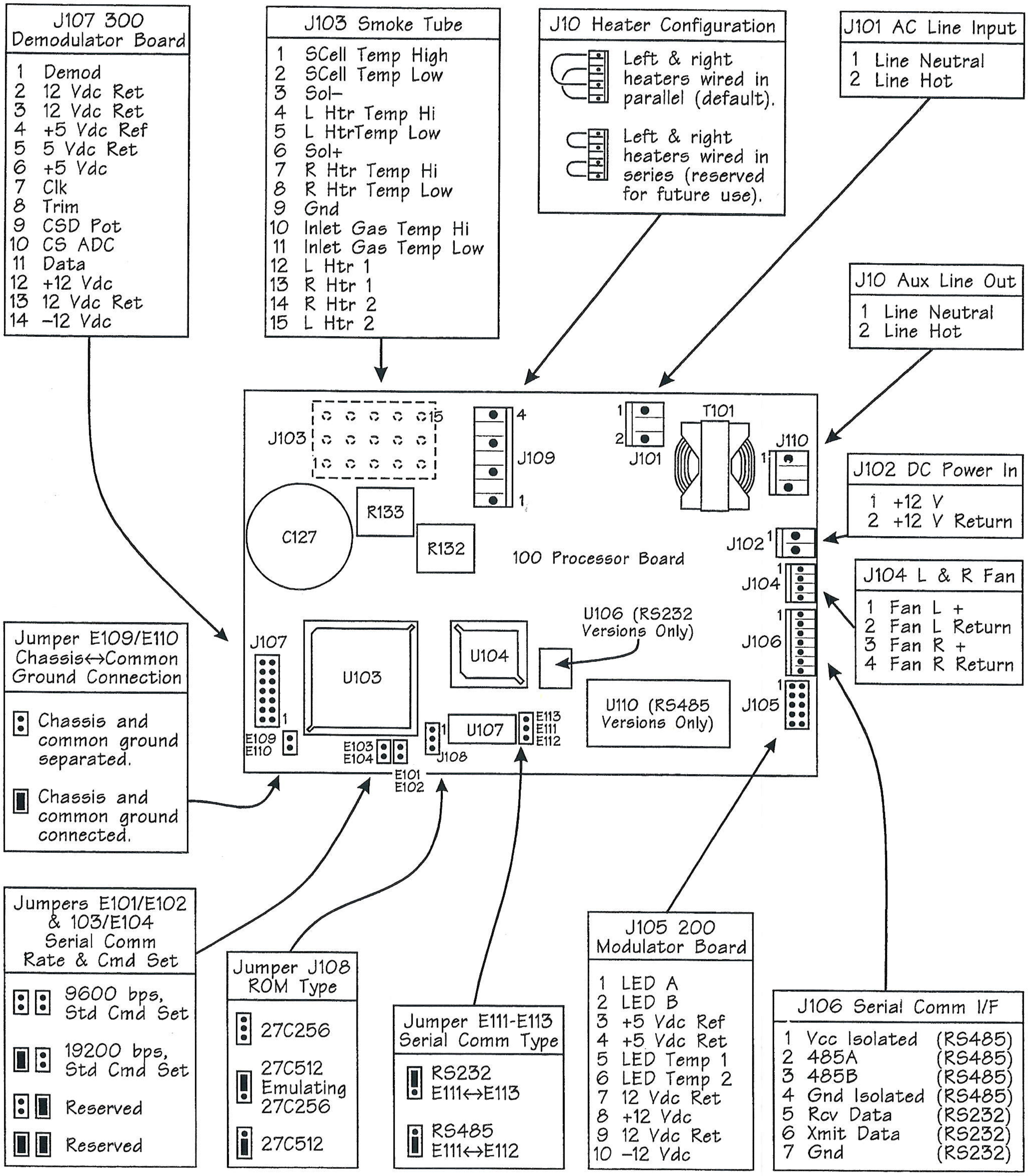
The Processor board's 68HC11 microprocessor reads the demodulator ADC output every 11.25 ms and averages two successive readings to report out an opacity data measurement every 22.5 ms.

In addition to the microprocessor, the Processor board contains a number of other support and peripheral functions. These include a small power converter providing +5Vdc to the microprocessor and logic circuitry and ±12 Vdc to analog circuitry; the sample valve actuator driver; an optically isolated triac power switch to control the sample cell heater blankets; and the RS-232C host serial interface. Space is provided for 256K extra RAM needed for certain applications.

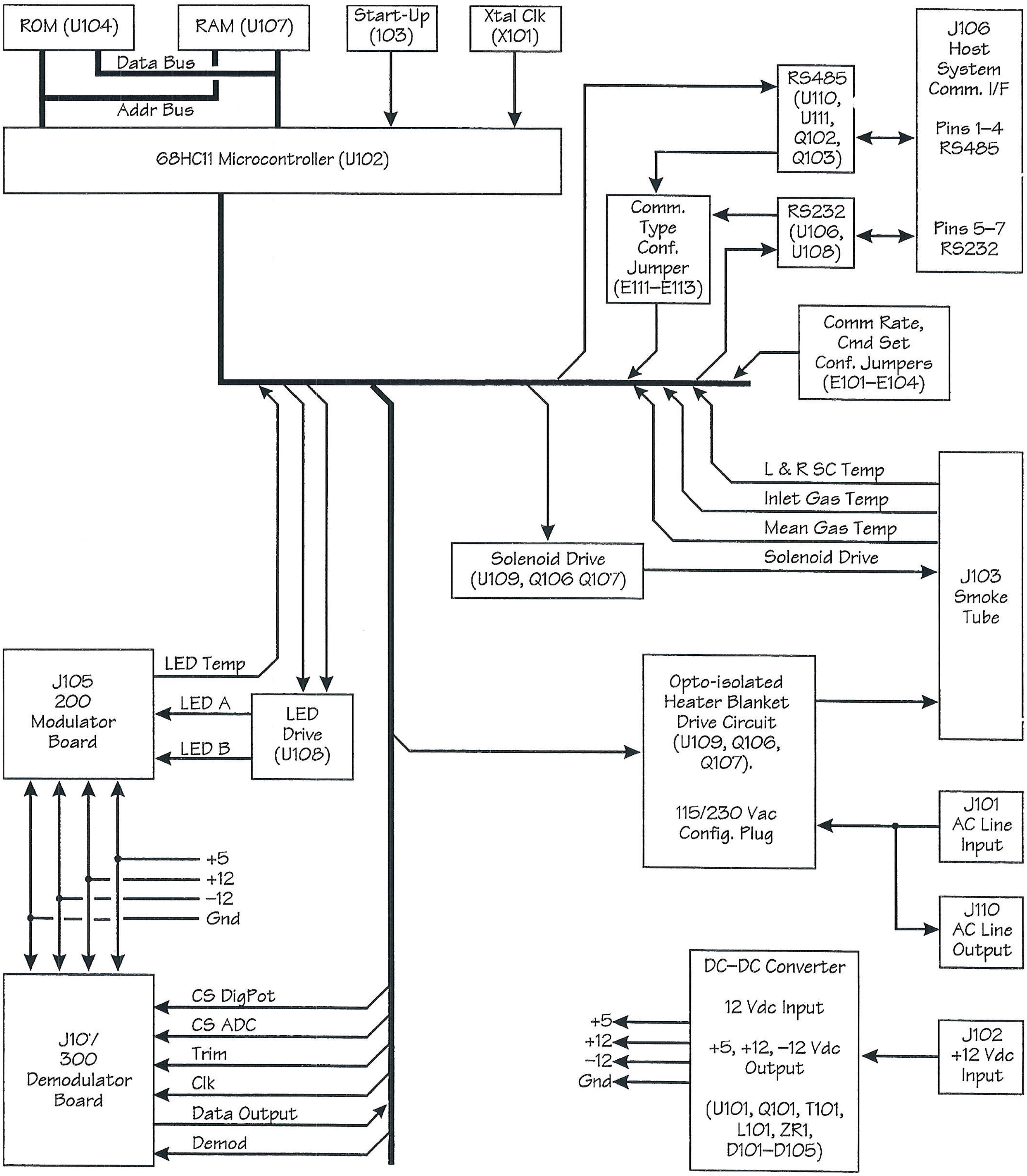
The processor board supports five temperature sensors:

- To prevent moisture condensation, the sample cell is heated to 100°C. Sample cell temperature is regulated by software algorithm using feedback from two temperature sensors mounted on the sample cell.
- A probe mounted temperature sensor projects into the sample cell and measures mean sample gas temperature.
- A temperature sensor located on the Modulator board measures LED and ambient temperatures.
- A temperature sensor mounted at the solenoid valve measures inlet gas temperature.

Processor Board Component Locations



Processor Board Block Diagram



Power System

Utility line voltage enters via a fuse-protected IEC-320 multifunction receptacle on the recessed rear panel, and is applied to a universal-input off-line switching converter that provides 12 Vdc to the Processor board. On the Processor board, this 12 Vdc is turned around to the two venturi fans whose load currents are monitored for fan failure detection. The 12 Vdc is used directly for the sample valve driver and is the input to the small auxiliary power converter.

The +5 Vdc used by logic circuitry (and also as an analog reference voltage) is developed by a tightly regulated high frequency switching converter on the Processor board. This reference is used to set the LED drive currents (Modulator board) and also powers the lower-boundary part of the Demodulator board digital potentiometer. The ±12 Vdc produced by this converter powers analog circuitry in the Modulator and Demodulator boards.

Enclosure

The 7210 is fully enclosed by a strong steel enclosure that doubles as a Faraday cage EMI shield.

Operating Modes

There are two basic operational modes of 7210 operation, Warmup and Ready.

Warmup Mode

Warmup Mode exists from POR (power on/reset) until three minutes after the 7210 sample cell walls reach 98°C.

Warmup Mode is reported as $01—SYSS—0 = 1.

Warmup Mode will not exceed 5 minutes maximum.

Ready Mode

Three minutes after the sample cell walls reach 98°C, the 7210 enters Ready Mode.

Ready Mode is reported as $01—SYSS—0 = $00.

Calculating k (Absorption Coefficient)

The Absorption Coefficient (k) is an index of the absorptive quality of the sampled gas as measured by the opacity of the sampled gas compensated so as to normalize it to a standard path length and sample cell temperature, and to ambient pressure.

The uncompensated, observed absorption coefficient (k_{obs}) is

$$k_{obs} = -\left(\frac{1}{pl}\right) \times \ln\left(1 - \frac{op}{100}\right)$$

where: k_{obs} = Observed (uncompensated) absorption coefficient,
pl = Path length in mm, typically 430 mm,
op = Opacity in percent.

The correction factor (C_{norm}) used to compensate the uncompensated, observed absorption coefficient (k_{obs}) for sample cell temperature, sample cell pressure, and ambient pressure is

$$C_{norm} = \left(\frac{T_{sc} + 273}{373}\right) \times \left(\frac{P_{amb}}{P_{sc}}\right)$$

where: C_{norm} = Correction Factor,
T_{sc} = Mean Sample Cell Temperature,
P_{amb} = Ambient Pressure,
P_{sc} = Sample Cell Pressure.

Notes:

1. The 7210 sample cell geometry is such that the pressure differential from ambient is negligible, thus requiring no pressure compensation of the output opacity data. Consequently, the ratio between ambient and sample cell pressure is a constant 1:1.
2. The C_{norm} formula above results in the Correction Factor being normalized to 100°C (373° Kelvin). Some applications or government regulated programs will require normalization to other temperatures. E.g., to normalize to 70°C (243° Kelvin) replace the "373" divisor with "243."

The compensated absorption coefficient (k) is

$$k = k_{obs} \times C_{norm}$$

where: k = Compensated Absorption Coefficient,
k_{obs} = Observed (uncompensated) absorption coefficient,
C_{norm} = Correction Factor.

Host system monitors requiring the absorption coefficient k must calculate it. k is not available directly from the 7210.

7210 Calibration

The 7210 must occasionally be Zero and Span calibrated in order to maintain accurate opacity measurements. The 7210's optical detector output not only differs from one 7210 to another, but also differs over time and temperature for any individual 7210. The host system uses the $03 Calibrate command to initiate 7210 calibration.

The 7210 requests that the host system perform calibration by setting the Calibration Request status bit true ($01—GS—0 = 1). There are three reasons for a Calibration Request:

- An initial calibration must be performed after a POR (power on/reset). The Awaiting Initial Calibration status bit is set true ($01—CALS—0 = 1) after a POR until a $03 Calibrate is executed.
- Andros strongly recommends that the host system command 7210 calibration ($03, Calibrate) immediately prior to each test/opacity measurement cycle. 7210 calibration reduces, or minimizes, opacity measurement errors caused by soot accumulation on the detector lens, temperature drift, and other naturally occurring phenomena.
- Calibration is requested any time the LED/ambient temperature has changed by 5°C since the last calibration was performed. This condition is reported by $01—CALS—1 = 1.
- Calibration is requested any time an opacity data calculation results in reporting opacity outside of its valid –2.00% to +102.00% range. This condition is reported by $01—CALS—2 = 1.

7210 calibration includes two major functions—Zero calibration and Span calibration. Note that these functions are implemented in the Demodulator board hardware and affect the demodulated electrical signal. E.g., Zero calibration sets the minimum electrical signal level (both LED's turned OFF), a state normally seen when the sample tube is occluded by a 100% opacity gas.

- **Zero Calibration**. With fresh air in the sample cell, a new "low gain adjust" value is calculated when both LED's are turned OFF. This value is the 8-bit integer used to control a digital potentiometer on the Demodulator board and establishes the 7210's "Zero offset."
- **Span Calibration**. LED and optical detector degradation over the 7210's lifetime is expected, and is automatically compensated for by calculating the "high gain adjust" value when both LED's are turned ON. This value is the 8-bit integer used to control a second digital potentiometer on the Demodulator board and establishes the 7210's "Span gain."

7210 $03 Calibration Procedure

1. If a $03 Calibrate procedure is already being performed when another $03 Calibrate command is received, the second $03 Calibrate command is NAK'd (NAK error code $02, command currently not allowed).
2. The Calibration In Progress status bit is set true(GENS—7 = 1).
3. The sample solenoid is switched to the fresh air position if it is in the sample gas position. The Sample Solenoid status bit is set to fresh air (SYSS—2 = 0).

4. The sample cell is purged with fresh air for ten seconds. Note, if the sample solenoid was already in the fresh air position for at least 10 seconds prior to receipt of the $03 command, this step is skipped.

5. **Zero Calibration:** Both LEDs are turned OFF, and a 1.0 second delay provides time for system stabilization.

   10 successive samples of detector output data are averaged and compared to a "valid low transmission" range (399 to 414 ADC counts). If necessary, the 7210's Zero offset adjustment value is recalculated. The Zero offset adjustment value is an integer from 1 to 256 that controls the Zero offset digital potentiometer on the Demodulator board. This is an iterative process with a maximum retry limit.

   Zero calibration fails, and the Zero Fail status bit is set true (CALFAIL—4 = 1), if the retry limit is exceeded.

6. **Span Calibration**: Both LEDs are turned ON and a 1.0 second delay provides time for system stabilization.

   10 successive samples of detector output data are averaged and compared to a "valid high transmission" range (3000 to 3700 ADC counts). If necessary, the 7210's Span gain adjustment value is recalculated. The Span gain adjustment value is an integer from 1 to 256 that controls the Span gain digital potentiometer on the Demodulator board. This is an iterative process with a maximum retry limit.

   Span calibration fails, and the Span Fail status bit is set true (CALFAIL—5 = 1), if the retry limit is exceeded.

7. The following data is retained in RAM memory for immediate use in calculating corrected and compensated Opacity data:
   Zero offset adjustment value,
   Span gain adjustment value, and
   LED/ambient temperature.

8. If neither the Zero Fail (CALFAIL—4) nor the Span Fail (CALFAIL—5) status bits were set true in steps 5 and 6, the Calibration Request status bit is cleared (GS—0 = 0).

9. The Calibration In Progress status bit is cleared (GENS—7 = 0).

10. The sample solenoid is left in the fresh air position regardless of its position prior to the commanded $03 Calibrate procedure.

11. If the calibration sequence just finished was the first performed after a POR (power on / reset), a $16 Linearity Check is performed.

Linearity Check

Accurate 7210 opacity measurement is based on a linear optical/electrical response over the complete 0% to 100% opacity range. The Andros 7210 Opacimeter includes an automated Linearity Check feature.†

Neutral Density Filter Based Linearity Checks And Their Problems

Previous attempts to verify linearity have used one or more neutral density filters. These filters have a known attenuation factor for the source light. They are inserted into the opacimeter and an opacity reading is observed. The value obtained must correspond to the known attenuation factor for the given filter. Methods with one or more filters are commonly used.

The use of neutral density filters to verify linearity typically introduces problems including the following:

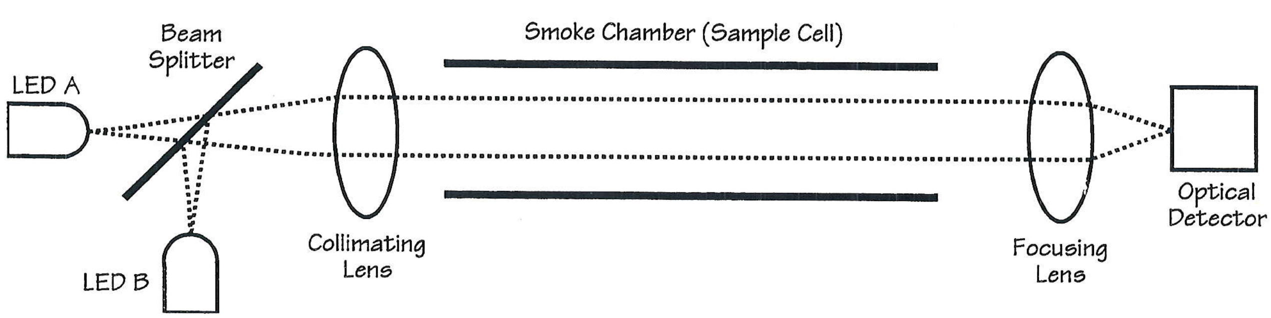
- Inconvenient—operator involvement is required.
- Expensive—either high-accuracy, high-cost filters must be used, or inexpensive filters must be individually characterized and labeled.
- Error Prone—false readings can be caused by poor handling of the filters (e.g., dust, scratches, finger prints).

The 7210's Dual-LED Based Linearity Check

The Andros 7210 Opacimeter uses an improved optical/electronic method for linearity checking that eliminates the disadvantages associated with neutral density filters:

- Convenient—the 7210 linearity check is automatically performed during each Zero calibration. No operator or host system action is required.
- Cost Effective—No operator accessories are required.
- Reliable—Superior test technology. No filters to lose or damage. No operator training required.

The Andros 7210 opacimeter uses the LED light source, beam splitter, and optical detector arrangement shown below:



† Linearity Check System AVL.

Light from LED A and LED B is combined by the beam splitter, collimated, directed through the 7210's sample cell, and focused onto the optical detector. The detector signal obtained from both light sources, S_{AB}, is used during normal opacity measurement. Any variation in S_{AB} is corrected during calibration.

During the 7210's Linearity Check, the principle of linear superposition is applied. A system is linear if, and only if, the sum of component signals is equal to the total signal. During the linearity check LED A is turned OFF (LED B is left ON) and signal SB is observed. Next, LED B is turned OFF (LED A is turned back ON) and signal SA is observed.

The 7210 is determined to be linear if $S_A + S_B = S_{AB}$.

If SA + SB ≠ SAB, the Linearity Check has failed, and the Linearity Check Fail status bit is set true (ZFAIL—7 = 1).

The first $03 Calibration performed after POR (power on / reset) is always followed automatically by a 7210 initiated Linearity Check. In addition, the host system can use the $16 Linearity Check command to initiate the Linearity Check.

Serial Communications

The 7210 serial interface is compatible with EIA-RS232.

Data format: eight data bits, no parity bit, and one stop bit.

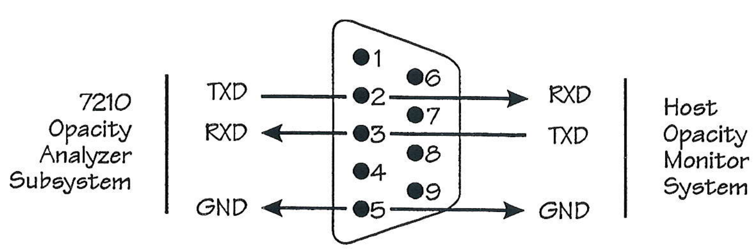
Standard communications rate: 9600 bps. Optional 19,200 bps communications rate selectable via configuration jumpers.

The 7210 serial interface conforms to EIA RS-232C electrical and timing specifications. Line drivers and receivers are Maxim MAX202ECSE.

The 7210 serial interface connector is a 9-pin, female, subminiature DB9.

Serial I/F Pinout

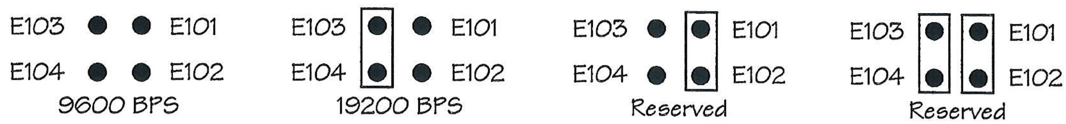
Pin #	Signal Name	Signal Source	Signal Description and Use
1	n/a	n/a	Not connected.
2	TXD	7210	Transmit Data. Data transmitted by the 7210 to the host system.
3	RXD	HOST	Receive Data. Data transmitted by the host system to the 7210.
4	n/a	n/a	Not connected.
5	GND	N/A	Signal Ground.
6	n/a	n/a	Not connected.
7	n/a	n/a	Not connected.
8	n/a	n/a	Not connected.
9	n/a	n/a	Not connected.



DB9 Connector

Configuration Jumpers

The communications data rate is selectable via the following Processor board configuration jumpers:



Input AC Power

The 7210 can be ordered in either of the following configurations:

- 115 Vac (88 to 138 Vac), 47 to 63 Hz, 400 Watts maximum.
- 230 Vac (187 to 264 Vac), 47 to 63 Hz, 400 Watts maximum.

A modular power entry module is used that contains the following:

- Double insulated On/Off switch rated for 10,000 operations at full load.
- 230 Vac configuration includes two line fuses: IEC-127 Class F 3.15A 250Vac.
  115 Vac configuration includes two line fuses: 5X20 mm, 5.0 A 125Vac.
- RFI filter (UL recognized, CSA certified, VDE and SEV approved).
- Accepts standard AC power cords.

Transient suppression is provided by a MOV.

Note: The following wording is included on a label affixed to each 7210:

> *"The mains plug shall only be inserted in a socket-outlet provided with a protective earth contact"*

7210 Preventive Maintenance Cleaning

Andros recommends that the following 7210 parts and assemblies be cleaned every 30 days in normal applications, or as required by the type and amount of use.

- LED and Detector Lenses.
- Inlet Gas Temperature Probe.
- Sample Gas Temperature Probe.
- Interior walls of the Sample Cell Tube.
- Solenoid Valve.

The recommended preventive maintenance procedure is as follows:

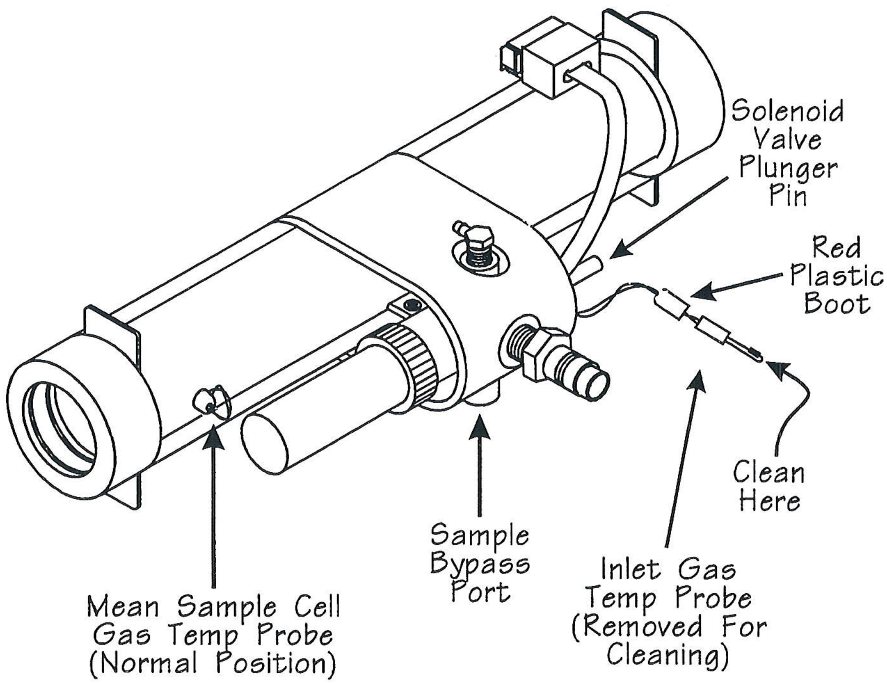
1. Tools and supplies required include the following:
   Slotted screwdriver,
   Spray type degreaser or contact cleaner,
   Clean, lint free cloth or tissue (e.g., Kim Wipes, lens tissue, etc.),
2. Turn OFF the 7210 power.
3. Ensure that the 7210's smoke tube has cooled off enough to safely handle.
4. ***Clean The Optics Lenses***. Using a clean, lint free cloth or tissue, reach into each venturi and clean the source and detector optics assembly lenses.
5. Open the front cover.
6. Unplug the smoke tube cable from processor board connector J103.
7. Using a slotted screwdriver, carefully pry off the ¼" polyurethane tubing from the brass 90° fresh air barbed fitting.
8. Move the right and left hand smoke tube collars about ½" towards the center of the 7210 and lift the smoke tube assembly out.

9. ***Clean The Solenoid Valve Plunger***. Spray the contact cleaner or degreaser into the sample by-pass port—located on the bottom of the sample valve casting—while manually moving the solenoid valve plunger back and forth. You can move the spring loaded plunger via the pin extending out the right hand side of the sample valve casting.

10. Repeat step 9 several times. The plunger should move freely and show no signs of binding.

11. ***Clean The Sample Gas and Inlet Gas Temperature Probes***. Slide the red plastic boot off the sample gas temperature probe port on the left hand end of the smoke tube. Grasp the sample gas temperature probe where its two wires enter it and pull it straight out of its black plastic port. Do not try to unscrew or otherwise remove the port itself.

12. Remove the inlet gas temperature probe port on the sample valve casting in the same manner as the sample gas temperature probe.



13. Gently clean both temperature probe thermistors with a dry tissue. Do not reinstall the temperature probes at this time.

14. ***Clean The Sample Tube***. Use a bottle brush or similar cleaning device to dislodge soot residue from the inner sample tube wall.

15. Replace both temperature probes, seating them against the shoulders inside their respective ports. Replace the red plastic boots on the temperature probe ports.

16. Reinstall the sample tube assembly into the 7210, sliding the sample tube collars out onto the venturi casting shoulders.

17. Replace the ¼" polyurethane tubing from the brass 90° fresh air barbed fitting.

18. Plug the smoke tube cable from processor board connector J103.

19. Close the front cover.

Removal and Replacement Procedures

Front Cover

If a front cover has been damaged and requires replacement, use the following procedure:

1. Tools and supplies required include the following:
   ¼" open end wrench.
   ¼" nut driver (optional).
2. Open and lower the front cover.
3. Using a ¼" nut driver or wrench, remove the five nuts and internal star lock washers. The center nut can best be removed with an open end wrench.
4. Install the replacement front cover, securing it with the five nuts and internal star lock washers.
5. Ensure that the front cover closes correctly.

Rear Cover

The 7210 rear cover must be removed to gain access to the 7210 fans, power supply and processor board. To remove the rear cover, use the following procedure:

1. Tools and supplies required include the following:
   #1 Phillips screwdriver.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Remove the single silver, pan-head Phillips head screw, flat washer and split lock washer immediately to the right of the AC power cord receptacle.
4. Remove the four black, counter sunk, Phillips head screws on the rear/top of the 7210.
5. Remove the four black, counter sunk, Phillips head screws on the rear/bottom of the 7210.
6. Remove the 7210's rear cover.
7. To replace the 7210's rear cover, reverse steps 2 to 6 above.

Main Cover

The 7210 main cover must be removed to gain access to the 7210 modulator and demodulator boards, and to the source and detector optics assemblies. To remove the rear cover, use the following procedure:

1. Tools and supplies required include the following:
   #1 Phillips screwdriver.
   #2 Phillips screwdriver.
   Four replacement black plastic decorative caps.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Remove the 7210's rear cover. Refer to the *Rear Cover Removal* procedure earlier in this chapter.

4. Remove the decorative black plastic caps covering the main cover mounting screws. Since they are usually damaged during removal, you may find it easiest to cut them off. Prying may damage the main cover's paint. Two are on the top and two are on the bottom.
5. Using the #2 Phillips head screwdriver, remove the four main cover mounting screws and the four decorative cap retaining washers.
6. Tilt the 7210 so that it is standing on its "rear." Lift OFF the main cover.
7. To replace the 7210's main cover, reverse steps 2 to 5 above, installing new black plastic decorative caps.

Fan Replacement

The 7210 continuously monitors the current required to drive each of its fans. Most fan or fan drive circuit failures can be detected. Fan failures are reported to the host system by the Fan Failure status bit ($01—SYSF—6). Changes in fan speed may cause effective changes in the 7210's optical path length, possibly causing inaccurate opacity measurement.

To replace a defective fan, use the following procedure:

1. Tools and supplies required include the following:
   Thin shank #0 Phillips screwdriver.
   Replacement fan.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Disconnect the serial interface cable on the back of the 7210.
4. Remove the 7210's rear cover. Refer to the *Rear Cover Removal* procedure earlier in this chapter.
5. Disconnect the two fan wires where they attach to the fan.
6. Remove the fan's four Phillips head screws, flat washers and split lock washers. The holes in the fan mounting flanges are small. Your screw driver's shank must be smaller than 3/16" (~0.47 cm). If necessary you may wish to carefully drill out these holes (and those in the replacement fan) to a larger size for improved access.
7. Install the replacement fan and its four sets of Phillips head screws, flat washers and split lock washers.
8. Reinstall the rear cover, plug in the serial interface cable, and plug in the AC line cord.
9. Turn ON the 7210 power
10. Transmit the $90 Save Instrument Data command to the 7210. The $90 command causes the 7210 to measure its current fan drive current and store these values in NVRAM memory. Any ±30% change in fan current results in setting the $01—SYSF—6 status bit.

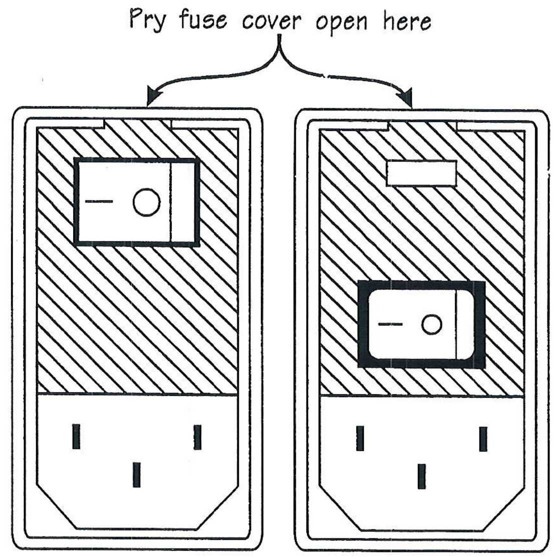
AC Line Fuse Replacement

AC line fuses are end user or service technician replaceable. Note that there are two slightly different power entry modules in use (they use the same AC line fuses). To check or replace AC line fuses, use the following procedure:

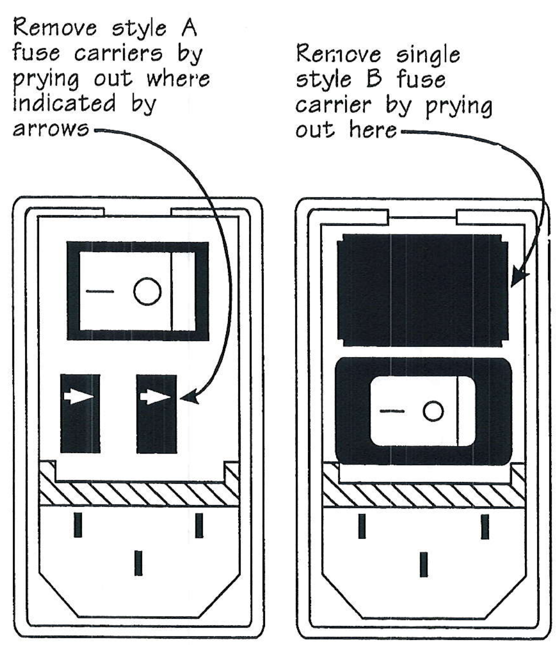
1. Tools and supplies required include the following:
   Small slotted screwdriver.
   DVM.
   230 Vac fuses = IEC-127 Class F 3.15A 250V; or
   115 Vac fuses = 5X20 mm 5.0A 125V.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Open the power entry module's fuse cover. Use a small screwdriver to pry open the fuse cover at its top edge. Refer to the illustration below. The fuse cover will pivot 90 degrees toward you.
4. Behind the fuse cover, you will find one or two fuse carriers.

   Style A: Below the On/Off switch, there are two fuse carriers. Use a small screwdriver to pry them out one at a time.

   Style B: Above the On/Off switch, there is a single fuse carrier. Use a small screwdriver to pry it out.
5. You can now check the fuses visually and with a DVM.
6. Remove a bad fuse by prying it out of its carrier with a small screwdriver.
7. Replace any bad line fuse with the correct new line fuse:
   230 Vac IEC-127 Class F 3.15A 250V.
   115 Vac 5X20 mm 5.0A 125V.
8. Replace the fuse carrier(s) in the power entry module.
9. Close the fuse cover and reinstall the AC line cord.



Style A Style B

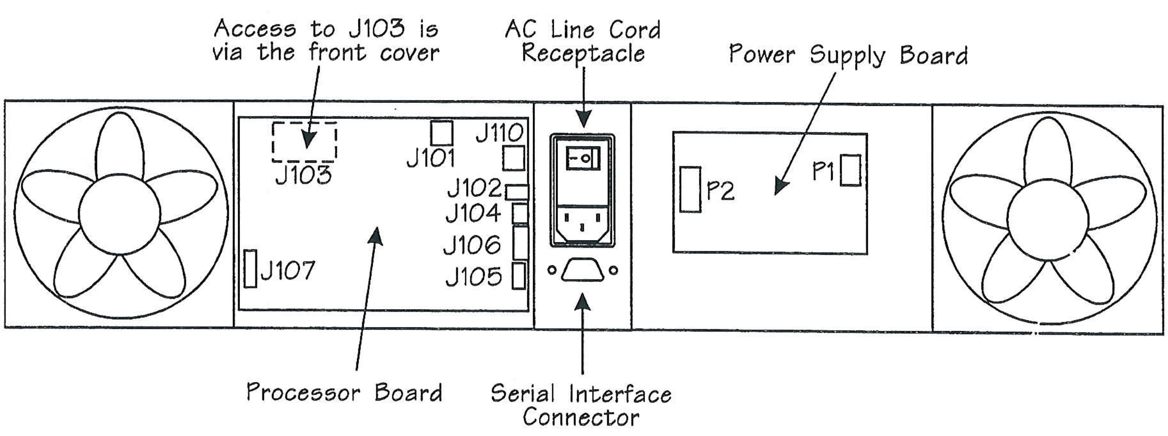


Style A Style B

Processor Board Replacement

If a processor board must be replaced, use the following procedure:

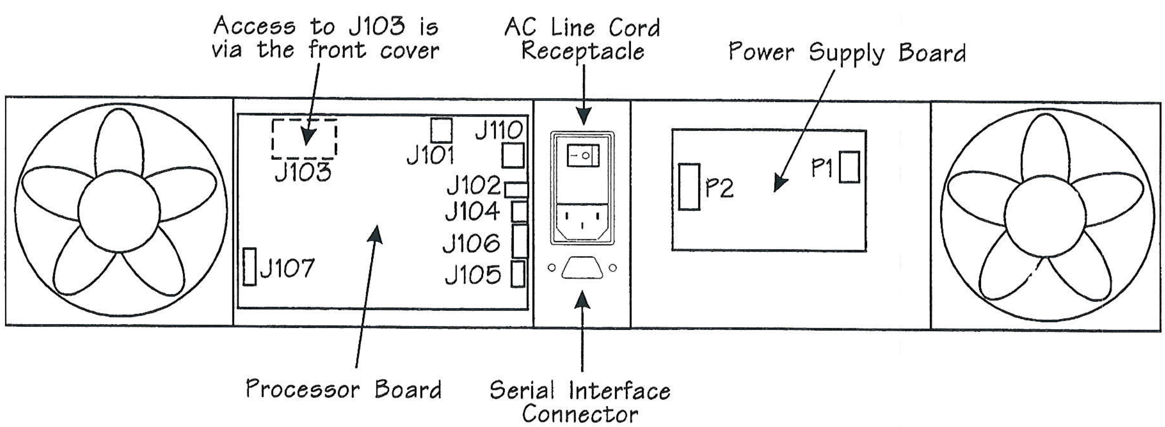
1. Tools and supplies required include the following:
   #1 Phillips screwdriver.
   Replacement processor board.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Disconnect the serial interface cable on the back of the 7210.
4. Open the front cover and unplug the smoke tube assy. to processor board cable connector J103. Close the front cover.
5. Remove the 7210's rear cover. Refer to the *Rear Cover Removal* procedure earlier in this chapter.
6. Unplug processor board cables at connectors J101, J102, J104, J105, J106, J107, and J110.
7. Remove the four processor board mounting screws.
8. Install the new processor board.
9. Reconnect the cables unplugged in step 4.
10. Reinstall the rear cover.
11. Open the front and plug the smoke tube assy. cable into processor board connector J103.
12. Plug in the serial interface cable, and plug in the AC line cord.
13. Turn ON the 7210 power
14. Transmit the $90 Save Instrument Data command to the 7210. The $90 command causes the 7210 to measure its current fan drive current and store these values in processor board resident NVRAM memory.



Power Supply Replacement

If a power supply board must be replaced, use the following procedure:

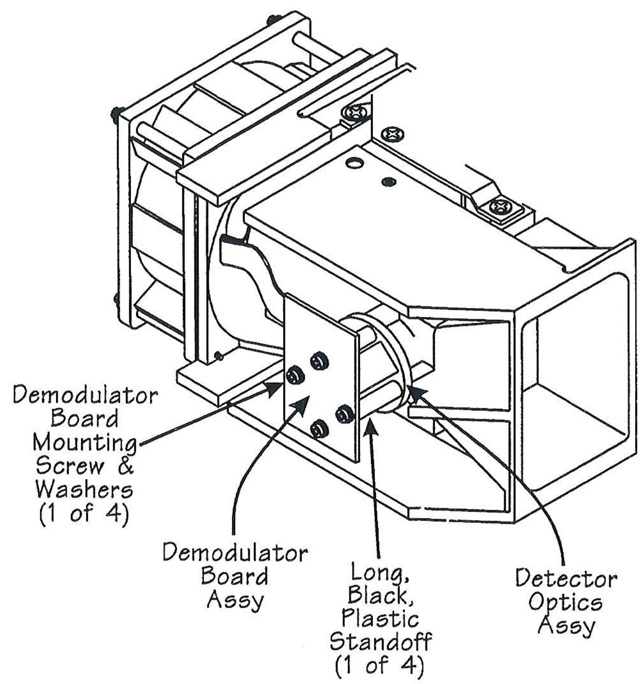
1. Tools and supplies required include the following:
   #1 Phillips screwdriver.
   Replacement processor board.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Disconnect the serial interface cable on the back of the 7210.
4. Remove the 7210's rear cover. Refer to the *Rear Cover Removal* procedure earlier in this chapter.
5. Unplug power supply board cables at connectors P1 and P2.
6. Remove the four power supply board mounting screws.
7. Install the new power supply board.
8. Reconnect the cables unplugged in step 5.
9. Reinstall the rear cover.
10. Plug in the serial interface cable, and plug in the AC line cord.



Demodulator Board and Detector Optics Replacement

If a demodulator board, or detector optics assembly must be replaced, use the following procedure:

1. Tools and supplies required include the following:
   #1 Phillips screwdriver.
   #2 Phillips screwdriver.
   Four replacement black plastic decorative caps.
   Replacement demodulator board or replacement detector optics assembly.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Disconnect the serial interface cable on the back of the 7210.
4. Remove the 7210's rear cover. Refer to the *Rear Cover Removal* procedure earlier in this chapter.
5. Remove the 7210's main cover. Refer to the *Main Cover Removal* procedure earlier in this chapter.
6. Remove the four 1¾" 6-32 screws, flat washers, and split lock washers that mount the demodulator board and detector optics assembly to the 7210 main casting. Note that on early units there are four individual 1⅛" long black plastic standoffs between the demodulator board and the detector optics mounting flange. Later units have the standoffs incorporated into the optics assembly.
7. If you are replacing the demodulator board, unplug the cable from demodulator board connector J301. If you are replacing the detector optics assembly, slide it out of the 7210 main casting.
8. Replace either the demodulator board or detector optics assembly.
9. Reinstall the cable unplugged from the demodulator board.
10. Reinstall the four 1¾" 6-32 screws, flat washers, and split lock washers that mount the demodulator board and detector optics assembly to the 7210 main casting.



11. The detector optics assembly does not require any mechanical adjustment or alignment.
12. Reinstall the main and rear covers. Reconnect the serial interface cable and AC line cord.
13. Turn ON the 7210.
14. Calibrate the 7210 (command $03, Calibrate). The first calibration after POR also performs a linearity check (command $16, Linearity Check). Confirm that none of the following errors are reported:

$01—CALS—2	Opacity Data Out Of Range
$01—CALFAIL—7	Linearity Check Fail.
$01—CALFAIL—5	Span Fail
$01—CALFAIL—4	Zero Fail.

Modulator Board and Source Optics Replacement

If a modulator board or source optics assembly must be replaced, use the following procedure:

1. Tools and supplies required include the following:
   #1 Phillips screwdriver.
   #2 Phillips screwdriver.
   Four replacement black plastic decorative caps.
   Replacement modulator board or replacement source optics assembly.
2. Turn OFF the 7210 power and remove the AC line cord from its receptacle on the back of the 7210.
3. Disconnect the serial interface cable on the back of the 7210.
4. Remove the 7210's rear cover. Refer to the *Rear Cover Removal* procedure earlier in this chapter.
5. Remove the 7210's main cover. Refer to the *Main Cover Removal* procedure earlier in this chapter.
6. Unplug the LED B cable from the modulator board at connector J202.
7. Remove the four 1¾" 6-32 screws, flat washers, and split lock washers that mount the modulator board and source optics assembly to the 7210 main casting. Note that on early units there are four individual 1⅛" long black plastic standoffs between the modulator board and the source optics mounting flange. Later units have the standoffs incorporated into the optics assembly.
8. If you are replacing the modulator board, unplug the cable from modulator board connector J201. If you are replacing the source optics assembly, slide it out of the 7210 main casting.
9. Replace either the modulator board or source optics assembly.
10. Reinstall any cables unplugged from the modulator board or source optics assembly.
11. Reinstall the four 1¾" 6-32 screws, flat washers, and split lock washers that mount the modulator board and source optics assembly to the 7210 main casting. Note that the correct source optics orientation places the source optics cable connector towards the 7210's top/front corner.
12. The source optics assembly does not require any mechanical adjustment or alignment.
13. Reinstall the main and rear covers. Reconnect the serial interface cable and AC line cord.
14. Turn ON the 7210.
15. Calibrate the 7210 (command $03, Calibrate). The first calibration after POR also performs a linearity check (command $16, Linearity Check). Confirm that none of the following errors are reported:

$01—CALS—2	Opacity Data Out Of Range
$01—CALFAIL—7	Linearity Check Fail.
$01—CALFAIL—5	Span Fail
$01—CALFAIL—4	Zero Fail
$01—DATAS—5	LED Temperature ADC Limit Error.

Technical Support and Training

If you have questions regarding the use or system integration of your Andros product, please contact technical Andros personnel.

Training courses covering the use, system integration, and service of Andros products is available. Please contact technical Andros personnel.

Andros Technical Support
Andros Inc.
2332 4th Street
Berkeley, CA 94710
USA
Voice (510) 849-5700
FAX (510) 849-5849

How to Return Products for Service

Before returning an Andros product for service or replacement, you must contact Andros and request a Return Material Authorization (RMA) number.

In all cases you are responsible for any brokerage charges, or any fees levied by customs, connected with international shipment.

Transportation Charges

The responsibility for shipping charges varies depending on why the product is being returned for service.

- **Products Rejected At Incoming Inspection**. Andros is responsible for the shipping costs in both directions. In the event of *Lot Sampling Plan Rejection*, Andros reserves the right to send Andros personnel to your location to 100% inspect the remainder of the lot. You are responsible for shipping costs in both directions on each returned product that is found not to be defective.
- **Service Covered By Andros Warranty**. Andros is responsible for return shipping costs. You are responsible for shipping costs to Andros. You are responsible for shipping costs in both directions on each returned product that is found not to be defective.
- **Non-Warranty Service**. You are responsible for shipping costs in both directions.

To Andros USA Service Depot From the USA

Before any product is returned to Andros for service or replacement, a Return Material Authorization (RMA) number must be obtained from the service depot. RMA numbers are valid for thirty (30) days after issuance. Serial numbers of all products must appear on the RMA.

1. Telephone or FAX the Andros USA Service Depot to obtain an RMA number.

   Andros Service Depot
   Voice (510) 849-5700
   Customer Service FAX (510) 849-5899
   Main FAX (510) 849-5849

2. When requesting the RMA, please provide the following information:

   a. Complete billing and shipping address.
   b. Purchase order number authorizing repair.
   c. Model, part number, and serial number of each product being returned.
   d. Reason for returning each product, including suspected cause of failure.
   e. Preferred method of return shipment.

3. Place the RMA number on the outside of the shipping container and on all accompanying documents (e.g., packing list, shipper, debit memo, failure report, etc.).

4. Ship the product to the following Andros location.

   Andros Service Depot
   Andros Inc.
   710 Bancroft Way
   Berkeley, CA 94710

To Andros USA Service Depot From International Locations

Before any product is returned to Andros for service or replacement, a Return Material Authorization (RMA) number must be obtained from the service depot. RMA numbers are valid for thirty (30) days after issuance. Serial numbers of all products must appear on the RMA.

1. Telephone or FAX the Andros USA Service Depot to obtain an RMA number.

   Andros Service Depot
   Voice (510) 849-5700
   Customer Service FAX (510) 849-5899
   Main FAX (510) 849-5849

2. When requesting the RMA, please provide the following information:

   a. Complete billing and shipping address.
   b. Purchase order number authorizing repair.
   c. Model, part number, and serial number of each product being returned.
   d. Reason for returning each product, including suspected cause of failure.
   e. Preferred method of return shipment.

3. Complete a Commercial Invoice and a Foreign Shipper's Declaration. Mark all accompanying documents with the following statement:

   "Goods originated in the USA — Return to USA for repair."

4. Place the RMA number on the outside of the shipping container and on all accompanying documents (e.g., commercial invoice, foreign shipper's declaration, packing list, debit memo, failure report, etc.).

5. Specify "SFO International Airport" in the space provided for Airport of Destination on the International Airway Bill.

6. Ship the product to the following Andros location.

   Andros Incorporated
   c/o Union Air Transport
   710 Bancroft Way
   Berkeley, CA 94710
   USA
   Attention: Customer Service Department

7. All freight charges, duties, brokerage and handling fees are to be paid by you. Andros will ship the products back freight and duty collect.

8. Forward to the address below, under separate cover, an exact copy of all documents that accompany the product shipment.

   Andros Inc.
   2332 4th Street
   Berkeley, CA 94710
   Attention: Customer Service Department

Drawings And Schematics A

You will find the following drawings and schematics in this Appendix. They are current as of the revision date of this manual. You may wish to contact your Andros representative to determine if more current schematics or drawings are available.

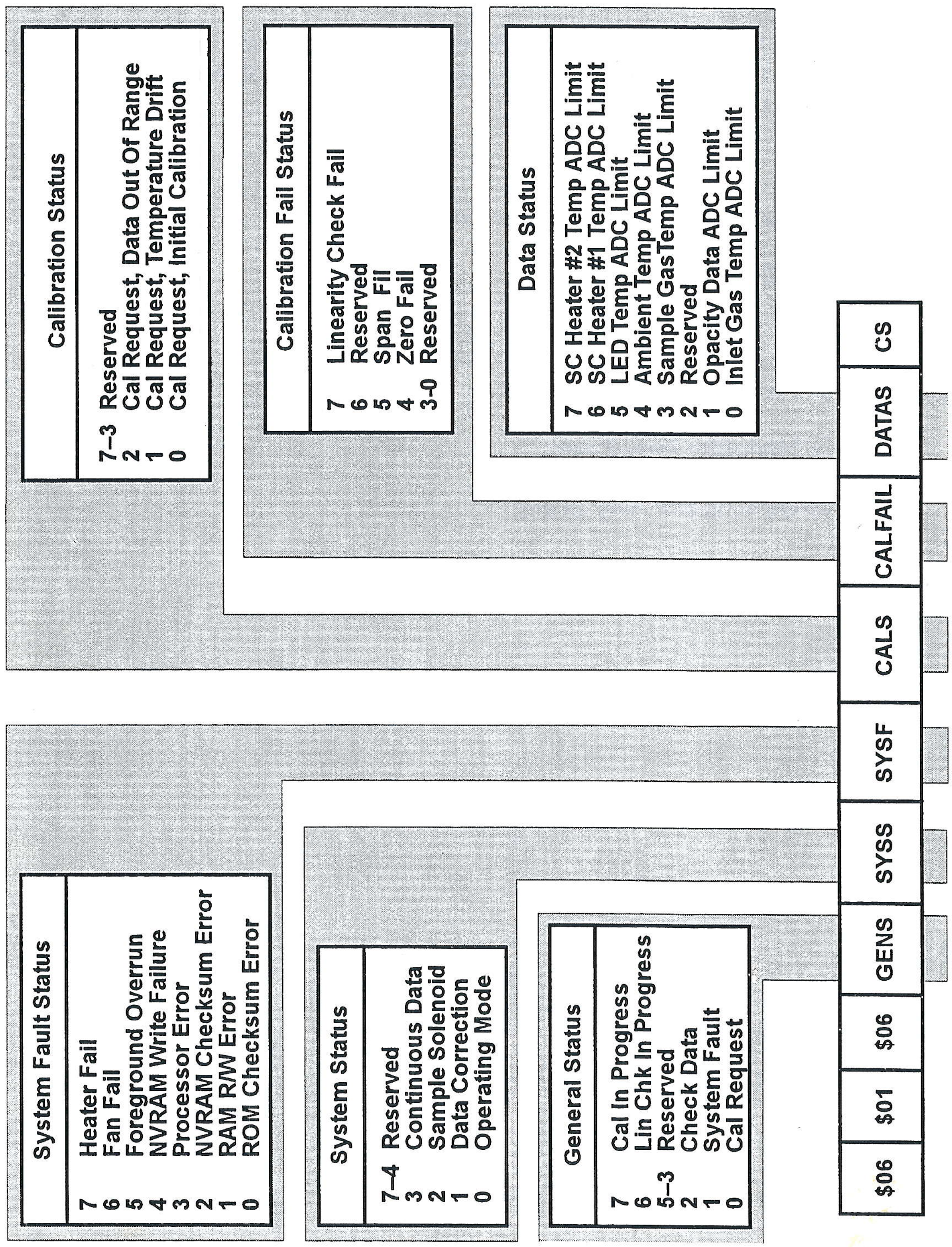
Drawings

- $01 Status ACK Response Summary
- 7210 Block Diagram

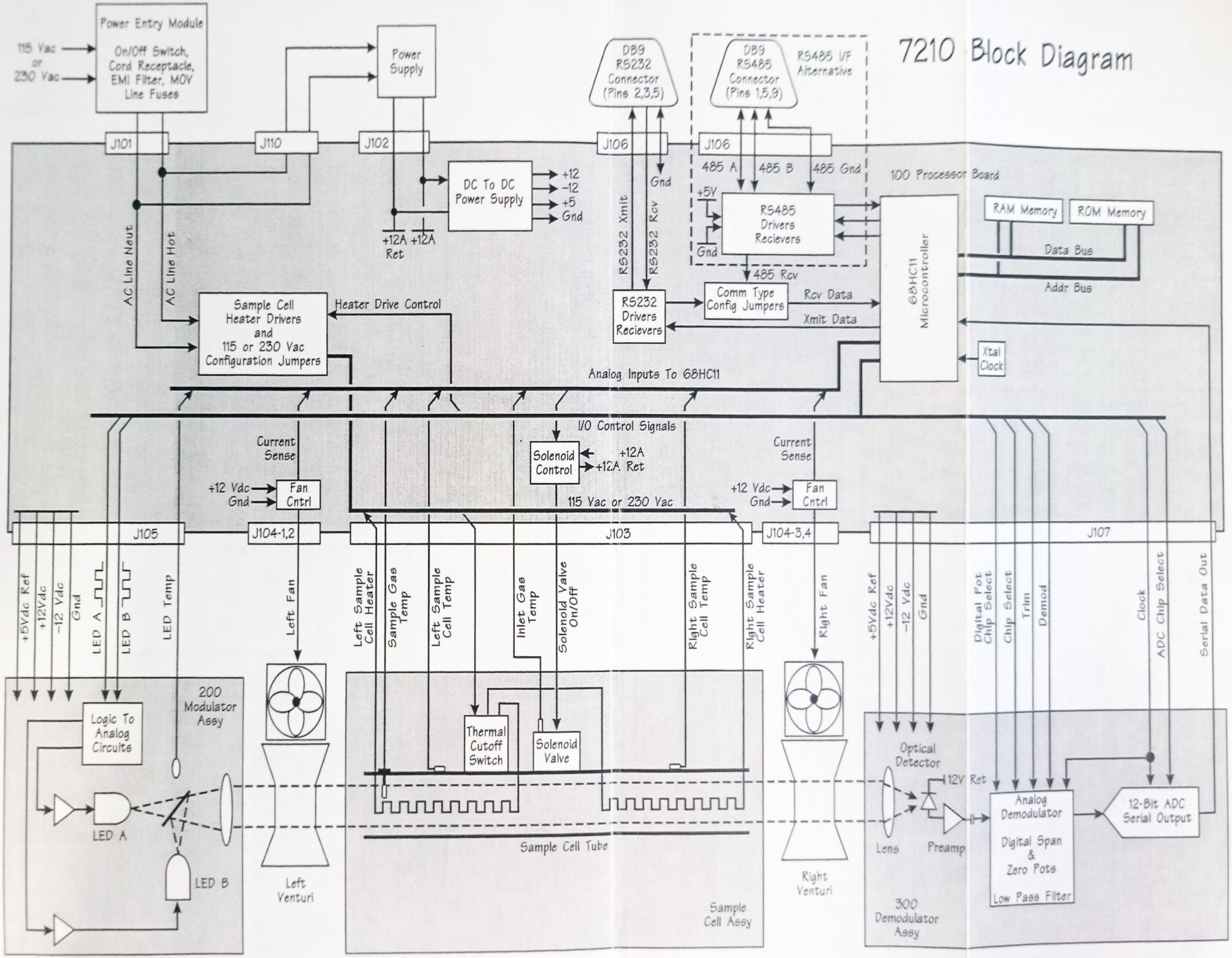
Schematics

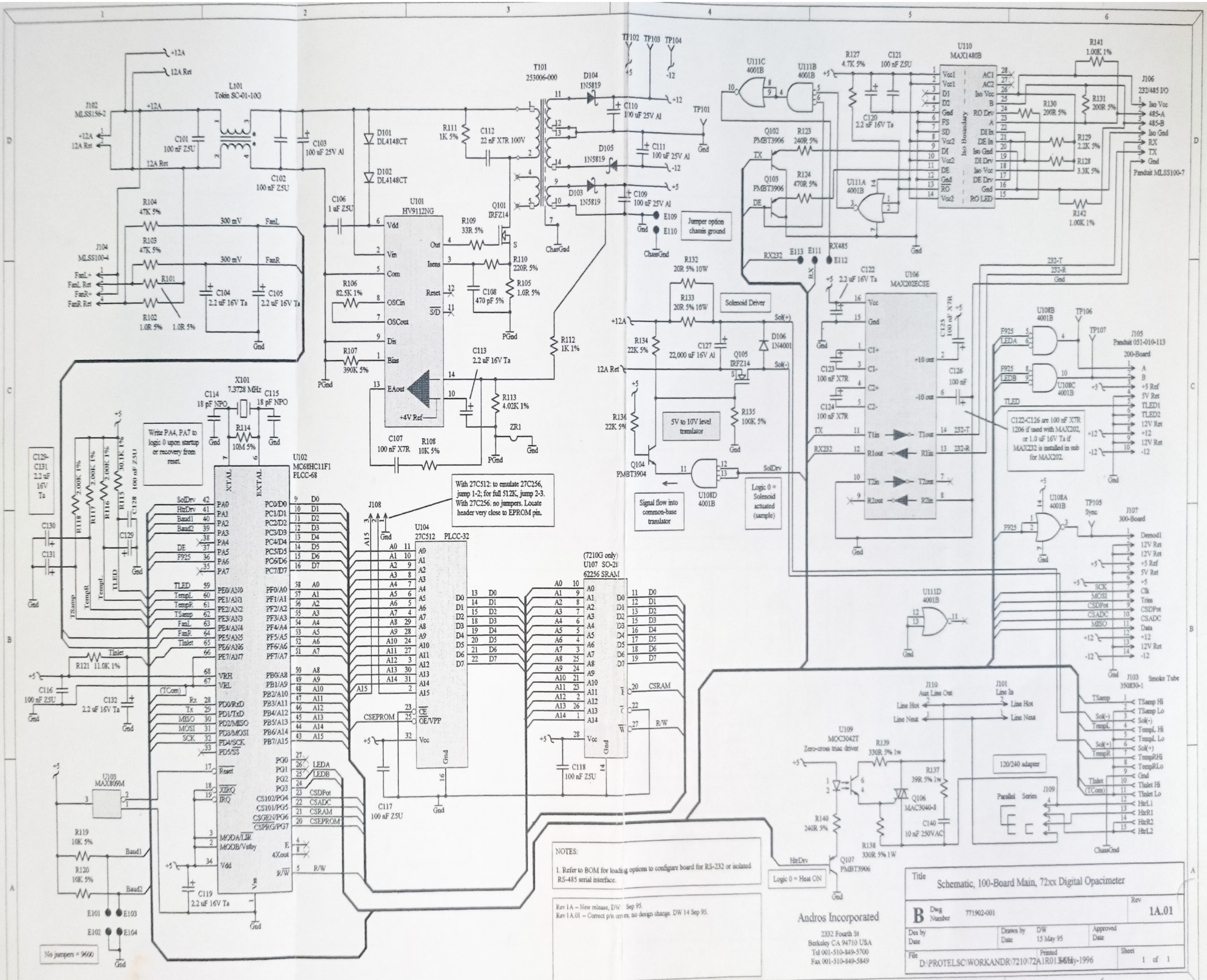
- 100 Processor & Power Board.
- 200 Modulator Assy Board.
- 300 Demodulator Assy Board.

$01 Status ACK Response Summary



7210 Block Diagram




Write PA4, PA7 to logic 0 upon startup or recovery from reset.
With 27C512: to emulate 27C256, jump 1-2; for full 512K, jump 2-3. With 27C256, no jumpers. Locate header very close to EPROM pin.
C129-C131 2.2 uF 16V Ta
No jumpers = 9600
Jumper option chassis ground
Solenoid Driver
5V to 10V level translator
Signal flow into common-base translator
Logic 0 = Solenoid actuated (sample)
C122-C126 are 100 nF X7R 1206 if used with MAX202, or 1.0 uF 16V Ta if MAX232 is installed in sub for MAX202.
120/240 adapter
Logic 0 = Heat ON
NOTES:
1. Refer to BOM for loading options to configure board for RS-232 or isolated RS-485 serial interface.
Rev 1A – New release, DW Sep 95.
Rev 1A.01 – Correct p/n errors, no design change. DW 14 Sep 95.
Andros Incorporated
2332 Fourth St
Berkeley CA 94710 USA
Tel 001-510-849-5700
Fax 001-510-849-5849
Title
Schematic, 100-Board Main, 72xx Digital Opacimeter
B
Dwg Number 771902-001
Rev 1A.01
Drawn by DW
Date 15 May 95
Sheet 1 of 1
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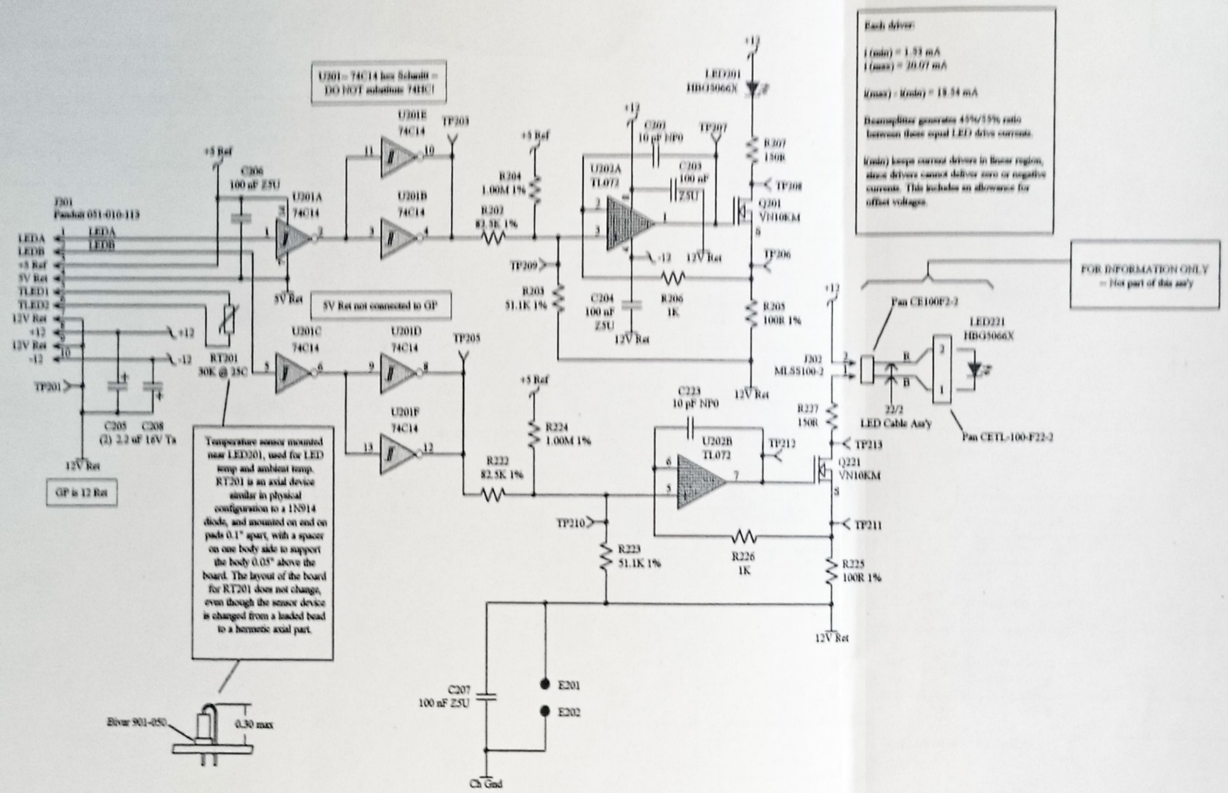


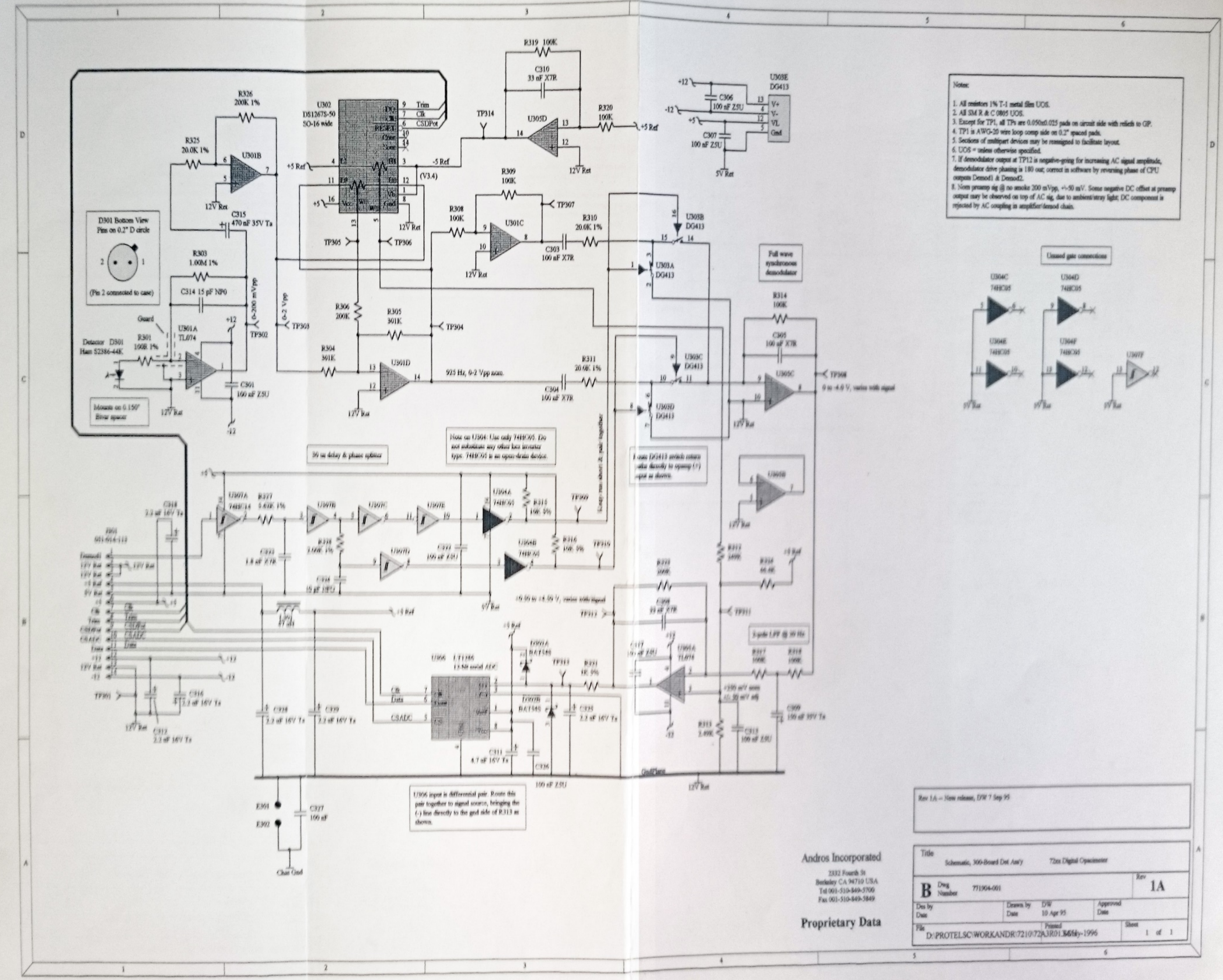
Notes: (UOS = Unless Otherwise Specified)

1. All resistors 1% metal film in 0805 SM.
2. All capacitors are in 0805 SM UOS.
3. J201 is straight pin header 2 X 5 thru-hole.
4. J202 is polarized pin header 1 X 2 thru-hole.
5. RT201 is thermistor, thru-hole.
6. LED 201 and 221 are green LEDs, thru-hole.
7. SM and thru-hole parts are both mounted on component side.
8. Component side faces inward when board is mounted.
9. Signal inputs A,B, are 5 V p-p squarewaves at the carrier frequency when enabled by the processor (100 Board), or logic 0 when not enabled.
10. This circuitry consists of two identical current-regulated LED drivers. Reference designators start with 201 in the A channel, and 221 in the B channel, so that the same parts in the two channels are similarly numbered.

Rev 1A – New release, DW 7 Sep 95.

Andros Incorporated
2332 Fourth St
Berkeley CA 94710 USA
Tel 001-510-849-5700
Fax 001-510-849-5849

Title: Schematic, 200-Board Source Ass'y, 72xx Digital Opacimeter			
B	Dwg Number: 771903-001		Rev: 1A
Drn by / Date	Drawn by: DW / Date: 6 Apr 95	Approved / Date	
File: D:\PROTELSC\WORKANDR\7210\72A2301	Printed: -1996		Sheet: 1 of 1


Notes:
1. All resistors 1% T-1 metal film UOS.
2. All SM R & C 0805 UOS.
3. Except for TP1, all TPs are 0.050x0.025 pads on circuit side with reliefs to GP.
4. TP1 is AWG-20 wire loop comp side on 0.2" spaced pads.
5. Sections of multipart devices may be reassigned to facilitate layout.
6. UOS = unless otherwise specified.
7. If demodulator output at TP12 is negative-going for increasing AC signal amplitude, demodulator drive phasing is 180 out; correct in software by reversing phase of CPU outputs Demod1 & Demod2.
8. Nom preamp sig @ no smoke 200 mVpp, +/-50 mV. Some negative DC offset at preamp output may be observed on top of AC sig, due to ambient/stray light; DC component is rejected by AC coupling in amplifier/demod chain.
Unused gate connections
D301 Bottom View
Pins on 0.2" D circle
(Pin 2 connected to case)
Detector D301
Ham S2386-44K
Mounts on 0.150" Bivar spacer
U302
DS1267S-50
SO-16 wide
U301A
TL074
U301B
U301C
U301D
U305D
U303B
DG413
U303E
DG413
Full wave synchronous demodulator
925 Hz, 0-2 Vpp nom.
0 to -6.0 V, varies with signal
50 us delay & phase splitter
Note on U304: Use only 74HC05. Do not substitute any other hex inverter type. 74HC05 is an open-drain device.
U306 LT1285
12-Bit serial ADC
U306 input is differential pair. Route this pair together to signal source, bringing the (-) line directly to the gnd side of R313 as shown.
Rev 1A -- New release, DW 7 Sep 95
Andros Incorporated
2332 Fourth St
Berkeley CA 94710 USA
Tel 001-510-849-5700
Fax 001-510-849-5849
Proprietary Data
Title
Schematic, 300-Board Det Ass'y
72xx Digital Opacimeter
B
Dwg Number
771904-001
Rev
1A
Des by
Date
Drawn by
Date
DW
10 Apr 95
Approved
Date
File
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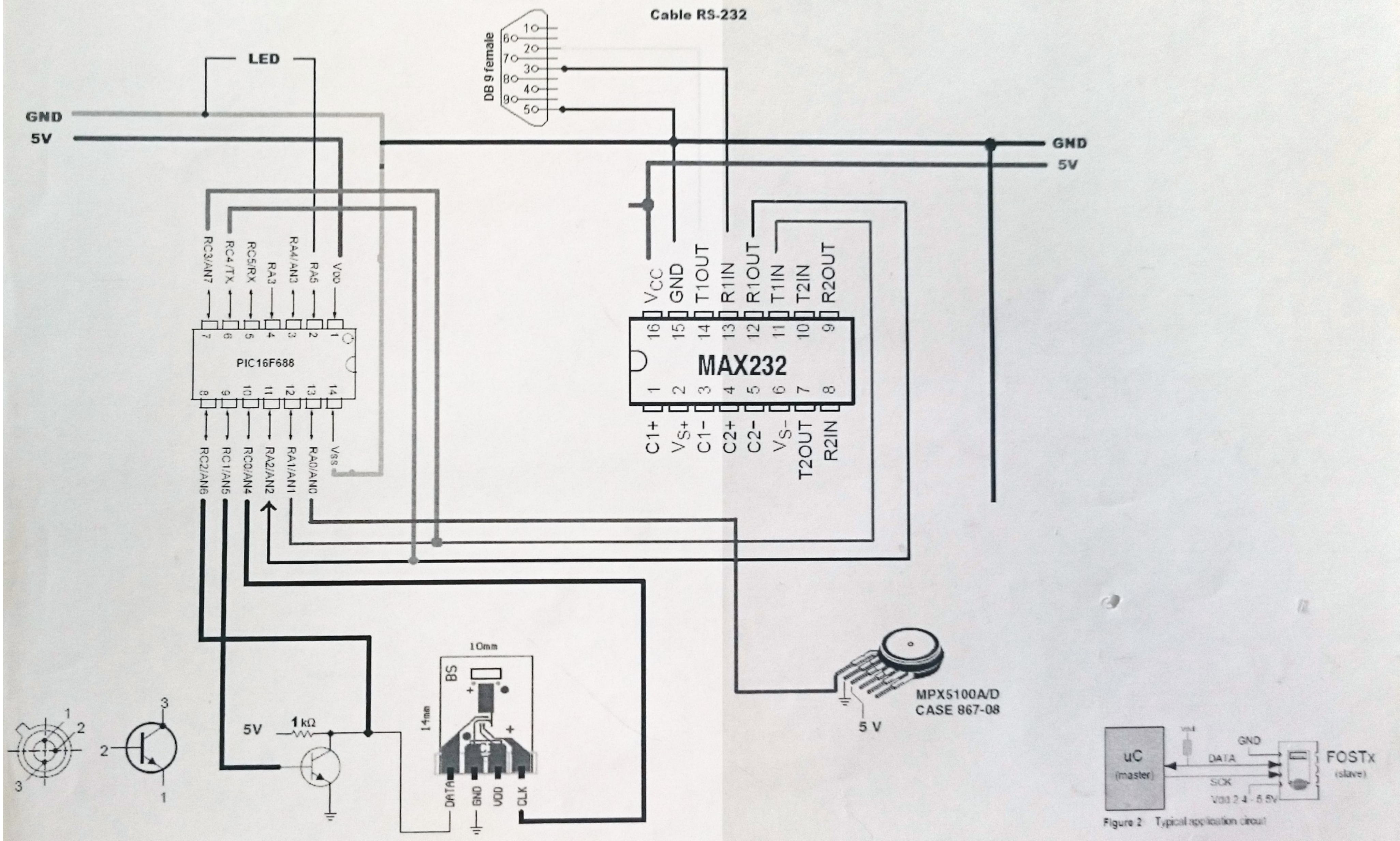
Printed
May-1996
Sheet
1 of 1


Cable RS-232
DB 9 female
LED
GND
5V
PIC16F688
VDD
RA5
RA4/AN3
RA3
RC5/RX
RC4/TX
RC3/AN7
VSS
RA0/AN0
RA1/AN1
RA2/AN2
RC0/AN4
RC1/AN5
RC2/AN6
MAX232
VCC
GND
T1OUT
R1IN
R1OUT
T1IN
T2IN
R2OUT
C1+
VS+
C1−
C2+
C2−
VS−
T2OUT
R2IN
MPX5100A/D
CASE 867-08
5 V
10mm
14mm
BS
DATA
GND
VDD
CLK
1 kΩ
uC
(master)
DATA
SCK
FOSTx
(slave)
Figure 2 Typical application circuit