

KEITHLEY

Model 213 Quad Voltage Source

Instruction Manual

A GREATER MEASURE OF CONFIDENCE

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Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

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Model 213
Quad Voltage Source
Instruction Manual

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The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Kcithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation Category II connections require protection for high transient over-voltages often associated with local AC mains connections. The user should assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. **NEVER** connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. **ALWAYS** remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.


The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.


Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.


When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.



SAFETY WARNINGS

The following safety warnings should be observed before using Model 213 Quad Voltage Source. Refer to main manual for detailed safety information and complete operation instructions.

The Model 213 Quad Voltage Source is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the manual carefully before using the instrument.

Before operating the instrument, make sure the line cord is connected to a properly grounded power receptacle.

Exercise extreme caution when a shock hazard is present. Lethal voltages may be present on connector jacks. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS or 42.4V peak are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the Quad Voltage Source connections, test cables or connections to any other instruments while power is applied to the circuit under test. Turn off all power and discharge any capacitors before connecting or disconnecting cables or jumpers.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground.

Do not exceed the maximum signal levels of the instrument, as shown on the rear panel and as defined in the specifications and operation section of the instruction manual.

Instrumentation and accessories should not be connected to humans.

Maintenance should only be performed by qualified service personnel. Before performing any maintenance, disconnect the line cord and all test cables from the instrument.



ADVERTENCIAS DE SEGURIDAD

Las advertencias de seguridad siguientes se deben observar antes de usar la fuente de tensión cuádruple modelo 213. Ver el manual principal para información detallada de seguridad e instrucciones completas de funcionamiento.

Se pretende que la fuente de tensión cuádruple modelo 213 sea usada por personal calificado que reconoce peligros de choque eléctrico y está familiarizado con las precauciones de seguridad requeridas para evitar posibles lesiones. Leer cuidadosamente el manual antes de usar el instrumento.

Antes de poner el instrumento en funcionamiento, asegurarse de que el cordón de alimentación está conectado a un enchufe de energía que tenga la conexión adecuada de tierra.

Tener mucho cuidado cuando existe peligro de choque eléctrico. En las clavijas de conexión puede haber presentes voltajes letales. El Instituto Nacional Norteamericano de Normas (ANSI) expone que existe peligro de choque cuando hay presentes niveles de voltajes de más de 30 V valor cuadrático medio ó 42,4 V pico. **Una buena práctica de seguridad es la de considerar que hay voltajes peligrosos presentes en cualquier circuito desconocido antes de medir.**

Inspeccionar para ver si existen roturas o desgaste en los cables de conexión, conductores de pruebas y puentes antes de cada vez que se vayan a usar.

Para máxima seguridad, no tocar las conexiones a la fuente de tensión cuádruple, los conductores de pruebas o las conexiones a ningún instrumento mientras haya energía aplicada al circuito bajo prueba. Desconectar la energía y descargar cualquier condensador que exista antes de conectar o desconectar los cables o puentes.

No tocar ningún objeto que pueda proveer un camino para la corriente al lado común del circuito bajo prueba o la tierra de la línea de energía.

No exceder los niveles máximos de señales del instrumento que se muestran en el panel posterior y que están definidos en la sección de especificaciones y funcionamiento del manual de instrucciones.

La instrumentación y los accesorios no deben ser conectados a las personas.

El mantenimiento debe ser realizado sólo por personal de servicio calificado. Antes de realizar cualquier mantenimiento, desconectar el cordón de alimentación y todos los conductores de prueba del instrumento.

NORME DI SICUREZZA

Le norme di sicurezza seguenti devono essere osservate prima di usare il generatore di tensione quadruplo modello 213. Fate riferimento al manuale principale per maggiori dettagli sulle norme di sicurezza e le istruzioni per l'uso.

Il generatore di tensione quadruplo modello 213 è stato progettato ad uso di personale qualificato, a conoscenza del rischio di scossa elettrica ed avente familiarità con le precauzioni necessarie per evitare ogni danno possibile a persone e cose. Leggete attentamente questo manuale prima di utilizzare lo strumento.

Prima di far funzionare lo strumento, assicuratevi che il cordone elettrico sia opportunamente collegato ad una presa di alimentazione con la messa a terra corretta.

Prestate estrema attenzione in situazioni in cui è presente il rischio di scossa elettrica. Possono riscontrarsi tensioni considerate letali sulle prese di connessione. L'ANSI (American National Standard Institute) riconosce il rischio di scossa elettrica in presenza di tensioni di picco maggiori di 30V RSM o 42,4V. **È buona norma considerare presenti tensioni pericolose in ogni circuito elettrico sconosciuto.**

Controllate i cavi di connessione ed i contatti prima dell'uso per evitare problemi creati da usura, crepe o rotture.

Per maggior sicurezza, non toccate il generatore quadruplo di tensione ai cavi di prova, o un qualsiasi altro strumento una volta applicata corrente al circuito di prova. Disinserite l'alimentazione e scaricate tutti i condensatori prima di connettere o sconnettere i cavi.

Non toccate alcun oggetto che possa consentire passaggio di corrente al lato comune del circuito in prova o alla massa (terra) della linea di tensione.

Non superate l'ingresso di tensione massimo, come specificato nell'apposito capitolo sul funzionamento, contenuto in questo manuale.

Sia le attrezzature che i loro accessori non devono mai venire collegati ad esseri umani.

La manutenzione deve essere effettuata esclusivamente dal personale di servizio qualificato. Prima di effettuare una qualsiasi procedura di manutenzione, staccate il cavo di connessione e tutti gli eventuali altri cavi di prova dallo strumento.

SICHERHEITSWARNUNGEN

Folgende Sicherheitswarnungen sollten vor dem Gebrauch des Modells 213 Viererspannungsquelle beachtet werden. Wenden Sie sich hinsichtlich ausführlicher Sicherheits- und Bedienungsanweisungen an das Haupthandbuch.

Die Modell 213 Viererspannungsquelle ist für den Gebrauch durch qualifizierte Personal ausgelegt, das eine Stromschlaggefahr erkennt und mit den Sicherheitsvorkehrungen zur Verhinderung von möglichen Verletzungen vertraut ist. Lesen Sie das Handbuch aufmerksam durch, bevor Sie das Gerät in Betrieb nehmen.

Achten Sie vor Inbetriebnahme des Gerätes darauf, daß das Stromkabel mit einer vorschriftsmäßig geerdeten Stromquelle (Steckdose) verbunden ist.

Gehen Sie äußerst vorsichtig mit dem Gerät um, falls eine Stromschlaggefahr vorhanden ist. An den Anschlußsteckern können sich tödliche Spannungen entwickeln. Das American National Standards Institute (ANSI) (Amerikanische Normungsbehörde) hat festgelegt, daß eine Stromschlaggefahr dann besteht, wenn die Spannungswerte mehr als 30V Effektivleistung oder 42,4V Spitzenleistung betragen. **Eine gute Sicherheitsmaßnahme besteht darin, daß Sie in jedem unbekanntem Stromkreis vor der Messung eine tödliche Spannung vermuten.**

Kontrollieren Sie die Anschlußkabel, Prüflleitungen und Brücken von jeder Verwendung auf mögliche Abnutzung, Risse oder Brüche.

Um eine maximale Sicherheit zu garantieren, sollten Sie die Viererspannungsquellenanschlüsse, -prüfkabel oder Verbindungen zu anderen Geräten berühren, während der zu prüfende Stromkreis mit Strom versorgt wird. Unterbrechen Sie die Stromzufuhr und entladen Sie alle Kondensatoren, bevor Sie Kabel oder Brücken anschließen oder trennen.

Berühren Sie keinen Gegenstand, der evtl. eine Stromleitung zur gemeinsamen Seite des zu prüfenden Stromkreises oder zur Stromleitungs(erdungs)masse darstellen könnte.

Überschreiten Sie nicht die Signalhöchstwerte des Gerätes, die auf der Rückseite des Gerätes und im Kapitel Technische Daten und Bedienung des Bedienungshandbuches vorgegeben sind.

Zwischen Geräten/Zubehör und Menschen sollte keine Verbindung bestehen.

Die Wartung sollte nur durch dazu ausgebildetes Personal vorgenommen werden. Trennen Sie vor der Wartung das Stromkabel und alle Prüfkabel vom Gerät.

CONSIGNES DE SÉCURITÉ

Il faut observer les consignes de sécurité suivantes avant d'utiliser la source de tension quadruple, modèle 213. Veuillez vous reporter au manuel principal qui contient tous les renseignements sur les consignes de sécurité ainsi que les directives d'utilisation.

La source de tension quadruple, modèle 213 est destinée à des spécialistes conscients des dangers de secousses électriques et connaissant les mesures de prévention à prendre pour éviter tout risque de blessures. Veuillez lire attentivement ce manuel avant d'utiliser l'instrument.

Vérifier, avant d'utiliser l'instrument, que le cordon est branché sur une prise convenablement reliée à la terre.

Redoubler de précautions lorsqu'il existe un risque de secousse électrique. Des tensions mortelles risquent d'être présentes au niveau du jack de raccordement de l'instrument. Selon l'institut américain des normes, l'American National Standards Institute (ANSI), il existe un risque de secousse électrique lorsque le niveau de la tension dépasse 30V efficaces ou 42,4V de tension crête. **Il est toujours prudent de considérer qu'une tension dangereuse est présente dans tout circuit inconnu avant de la mesurer.**

Examiner l'état des câbles de connexion ou les fils d'essais pour s'assurer qu'ils ne présentent ni dégâts d'usure, ni craquelures, ni fissures avant chaque essai.

Pour un maximum de sécurité, ne pas toucher les raccordements de la source de tension quadruple, les câbles d'essais, ni aucun branchement à un quelconque autre instrument lorsque le circuit en cours d'essais est sous tension. Couper l'alimentation en courant et décharger tous les condensateurs avant de brancher ou de débrancher des câbles.

Ne toucher aucun objet susceptible de fournir un chemin conducteur vers le côté commun du circuit en cours d'essais ou la terre (masse) du circuit d'alimentation.

Ne pas dépasser le signal maximum de l'appareil indiqué sur le panneau arrière de l'instrument et défini au chapitre caractéristiques de ce manuel.

Instruments et accessoires ne doivent pas être raccordés à des personnes.

Il ne faut faire exécuter la maintenance que par du personnel spécialisé. Débrancher le cordon d'alimentation et tous les câbles d'essais de l'instrument avant d'effectuer une quelconque opération de maintenance.

安全のための注意

クォード電圧源のモデル213を使用する前に、下記に示す安全のための注意を是非お読みください。安全性及び使用方法に関する詳細は、メイン・マニュアルをご参照ください。

クォード電圧源のモデル213を使用する際には、事故防止に必要な安全性についての予備知識及び感電に関する有資格者によって行ってください。また、装置を使用する前に、マニュアルをよくお読みください。

装置を使用する前に、電気コードが正しくアースされたコンセントに接続されているか確認して下さい。

感電性のある場合には、特に注意してください。致命的な電圧が接続ジャケットにかかっているかもしれません。RMSの電圧が30ボルト、またはピーク電圧が42.4ボルト以上の場合、アメリカ・ナショナル・スタンダード協会(ANSI)では感電性があると述べています。電圧が分からない回路を測定する場合には、常に危険な電圧があるということを心にとめておくことは、安全対策の一つです。

接続コード、テスト用コードそしてジャンプ用コードに擦り切れ、ひび割れ、断線などがないかどうか調べて下さい。

安全性を最大限に守るため、テスト中、回路に電流が流れている間、クォード電圧源の接続及びテスト用コード、そして他の器具に接続している部分に触れないでください。

テスト中、電流の流れている回路の部分及びアースしている電線には決して触れないでください。

最大シグナル・レベルを越えないでください。これに関しては後方のパネル、仕様書及び使用マニュアルのオペレーション・セクションに示されています。

器具や付属品を人につながないで下さい。

メンテナンスは有資格者によって行ってください。また、メンテナンスを行う前には、必ず電源コード及びテスト用コードすべてを装置から外して下さい。

213 Quad Voltage Source

SPECIFICATIONS

QUAD VOLTAGE SOURCE: Sources voltage from four independent, isolated ports. Includes 8-bit digital I/O port.

FUNCTION: Can be used as a constant DC source or as a voltage waveform generator.

INTERNAL BUFFER: An 8192-location internal buffer is used to store values for waveform generation.

CONTROL MODES: Four control modes may be chosen by the user:

Direct: Output changes upon execution of the "V" device dependent command.

Indirect: Output changes after receiving an external trigger.

Stepped: Step through internal buffer, under control of external triggers.

Waveform: Output voltage waveform from buffer, under control of an internal time base.

NUMBER OF WAVEFORM CYCLES: The number of cycles through the buffer in the Waveform Control Mode is user selectable, 1 to 65535 or continuous.

SYNCHRONIZATION OF PORTS: The ports can be forced to execute their voltage waveforms in a synchronized manner.

WAVEFORM STEP INTERVAL: 1ms to 65535ms.

TRIGGER AND SRQ: IEEE-488 bus or rear panel DB-25.

DIGITAL I/O: 8 TTL compatible level sensitive inputs. 8 outputs, internally selectable TTL compatible or open collector with 100mA drive and capable of withstanding 50V (for driving relays or other devices from an external voltage supply).

VOLTAGE

RANGE	MAXIMUM OUTPUT	STEP SIZE	ACCURACY 18°-28°C IOUT = 1mA
1V	±1.02375V	250 μV	±(0.05% + 1 mV)
5V	±5.11875V	1.25 mV	±(0.05% + 3 mV)
10V	±10.2375V	2.5 mV	±(0.05% + 10 mV)

TEMPERATURE COEFFICIENT OF ACCURACY (0°-18°C & 28°-50°C): ±(0.002% of setting + 100μV)/°C.

RANGING: Autorange or select one of three fixed ranges.

DC OUTPUT CURRENT: 10mA maximum.

OUTPUT RESISTANCE: <500mΩ, typical.

NOISE (p-p, typical):	RANGE	0.1-10Hz
	1V	<5ppm of range
	5V	<3ppm of range
	10V	<3ppm of range

WIDEBAND NOISE (p-p, typical): 0.1 to 20MHz, 8mV.

SETTLING TIME (typical): 750μs to rated accuracy into a 1kΩ load.

EXECUTION SPEED

RESPONSE TO IEEE-488 COMMAND: <10ms typical.

TRIGGER LATENCY: 1-2ms typical (all three types of external triggering), trigger to output voltage change.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: SDC, DCL, GET, UNL, UNI, SPE, SPD, MTA, MLA.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T4, TED, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0 (C28 during calibration), E1.

PROGRAMMABLE FUNCTIONS: Port select, output voltage, control mode, autorange enable, range select, waveform step interval, number of cycles, offset calibration, gain calibration, buffer allocation, buffer data, buffer location pointers, command trigger, trigger masking, SRQ masking, system defaults, digital output, EOI, IEEE-488 output terminator, IEEE-488 output format, system status output, system test, error query.

IEEE-488 address is set manually from the rear panel.

GENERAL

CHANNEL-TO-CHANNEL ISOLATION: 500V or 105V-Hz, whichever is less.

CHANNEL TO DIGITAL LOW ISOLATION: 500V or 105V-Hz, whichever is less.

CONNECTORS: Outputs: 12-pin quick disconnect.
Digital I/O: DB25 female.

ENVIRONMENT:

Operating: 0°-50°C: 0-70% relative humidity to 35°C. Linearly derate relative humidity 3%/°C, 35°-50°C.

Storage: -25° to 65°C.

WARM-UP: One hour to rated accuracy.

POWER: 90-125 or 180-250V AC (internally switch selectable); 50-60 Hz, 70VA max.

DIMENSIONS, WEIGHT: 425mm wide × 45mm high × 309mm deep (16 1/2 in × 1 3/4 in × 12 in). Net weight 3.52kg (7.75 lb).

ACCESSORIES SUPPLIED:

Instruction manual
213-CON Analog Output Connector

ACCESSORIES AVAILABLE:

213-CON Analog Output Connector
C126-1 DB25 male to DB25 female with 1.5m (5 ft) cable.

Specifications are subject to change without notice.

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Contains information on Model 213 features and accessories.

SECTION 1

General Information

Describes the instrument configuration, front and rear panels, and basic operation.

SECTION 2

Getting Started

Covers Model 213 operation, including triggering, internal buffering, port synchronization, and system defaults.

SECTION 3

Operation

Details information on IEEE-488 bus commands with programming examples.

SECTION 4

Command Description

Contains calibration procedures, connections, and reports.

SECTION 5

Calibration

Describes line voltage selection, fuse replacement, theory of operation, and a parts list.

SECTION 6

Service Information

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SECTION 1

General Information

1.1 INTRODUCTION

The Keithley Model 213 Quad Voltage Source is a quad output digital to analog converter (DAC) interface for the IEEE-488 bus. Each port uses a 12-bit plus sign D/A converter and is isolated from IEEE-488 common and the other ports by up to 500V. Each port can be programmed for full-scale output of $\pm 1V$, $\pm 5V$ and $\pm 10V$. Voltage values may be specified in volts or bits in increments of 1 part in 4096 plus sign. The resolutions of the ranges are $250\mu V$, $1.25mV$ and $2.5mV$, respectively.

Four operational modes are available to allow each port to be controlled directly from the IEEE-488 bus or in an automatic manner. An internal 8192 sample buffer is included, which can be loaded with waveform voltages. These voltages may then be output in sequence either on a periodic interval or in a triggered fashion. The sample buffer is automatically saved in non-volatile RAM as it is loaded, allowing a once only configuration of the device for many applications. All configuration settings may also be saved in non-volatile RAM for use as the permanent defaults.

Each of the ports can be triggered from three different sources: an external trigger, a trigger command, or a Group Execute Trigger (GET) bus command. Since each port can be triggered independently, different trigger sources may be selected for each port.

The interface also provides eight TTL level digital inputs and eight digital outputs. The digital outputs may be internally configured as either TTL level or 100mA outputs to allow interfacing with solenoids, relays or other devices. An external trigger/SRQ input is also provided, which can trigger the interface or generate an SRQ on either a falling or rising edge of a TTL compatible signal. All digital signals as well as +5V and ground are accessible via a 20-pin edge card connector located on the rear panel.

Calibration may be done automatically by connecting the interface to a Keithley Model 199 System DMM/Scanner.

No mechanical adjustments are required. After calibration, a complete calibration report will be printed if the interface is connected to an IEEE-488 printer.

1.2 WARRANTY INFORMATION


Warranty information is located on the inside front cover of this instruction manual. Should your Model 213 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.


1.3 MANUAL ADDENDA

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the unit. Be sure to note these changes and incorporate them into the manual before using or servicing the unit.

1.4 SAFETY SYMBOLS AND TERMS

The following symbols and terms may be found on an instrument or used in this manual:

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The  symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that could result in personal injury or death. Al-

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ways read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage might invalidate the warranty.

1.5 SPECIFICATIONS

Model 213 specifications can be found at the front of this manual.

1.6 UNPACKING AND INSPECTION

1.6.1 Inspection for Damage

Upon receiving the Model 213, carefully unpack it from its shipping carton and inspect the unit for any obvious signs of physical damage. Report any damage to the shipping agent immediately. Save the original packing carton for possible future reshipment.

1.6.2 Shipment Contents

The following items are included with every Model 213:

Description	Keithley Part No.
Feet (4)	FE-24-1
Fuse, 3/4A	FU-19
Instruction Manual	213-901-00
Line Cord	CO-19
Rack Ears (2)	B2361-311
Screws (4), for rack ears	10-32 × 3/8PFHBLKOX
Screws (8), nylon	10-32 × 1/4PBHBLKNY
12-pin Analog Output Connector	213-CON
25-pin Digital I/O Connector	CS-400

1.6.3 Instruction Manual

If an additional Model 213 Instruction Manual is needed, order the manual package (Keithley part number 213-901-00). The manual package includes an instruction manual and any applicable addenda.

1.7 REPACKING FOR SHIPMENT

Should it become necessary to return the Model 213 for repair, carefully pack the unit in its original packing carton or its equivalent, and include the following information:

- Advise as to the warranty status of the instrument.
- Write **ATTENTION REPAIR DEPARTMENT** on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.8 Optional Accessories

Model 7007 Shielded IEEE-488 Cables — A Model 7007 connects the Model 213 to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter (3.3 ft.) long and has an EMI shielded IEEE-488 connector at each end. The Model 7007-2 cable is identical to the Model 7007-1, but is 2m (6.6 ft.) long.

Model 7008 Unshielded IEEE-488 Cables — A Model 7008-3 cable is 0.9m (3 ft.) long and has standard IEEE-488 connectors at each end. The Model 7008-6 is identical, but is 1.8m (6 ft.) long.

CA-126-1 25-conductor cable — This is a 5 ft., 25-conductor cable with a male DB25 connector at one end (to mate with the digital I/O port) and a female DB25 connector at the other end.

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SECTION 2

Getting Started

2.1 INTRODUCTION

This section contains introductory information on operating the Model 213 Quad Voltage Source. The information presented includes front and rear panel familiarization, basic operation with programming examples, and performance verification.

2.2 FRONT PANEL INDICATORS

Six LEDs on the front panel of the Model 213 Quad Voltage Source display the status of the interface (see Figure 2-1). The function of each indicator is described below.

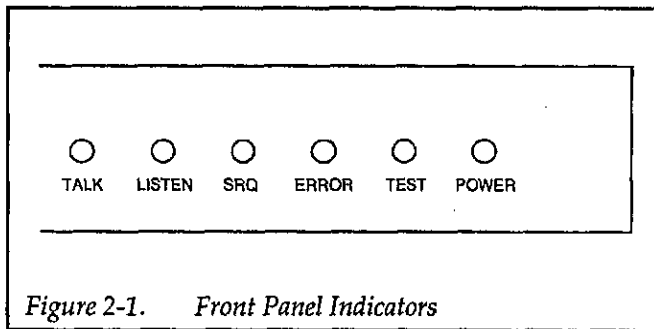


Figure 2-1. Front Panel Indicators

TALK — On when the unit is in the talker state, off when the unit is in the idle or listener state.

LISTEN — On when the unit is in the listener state, off when the unit is in the idle or talker state

SRQ — On when the unit has generated a service request, off when no SRQ is pending. (See Service Request Mask command for more information.)

ERROR — On when an error has occurred, off when no error condition exists. (See Error Query command for more information.)

TEST — Used in conjunction with the Test command to verify that communication has been established with the unit. The TEST light will flash when the unit is calibrating in the auto-calibration mode. It will then remain lit when finished.

POWER — On when power is applied to the unit and the power switch on the back panel is in the on position (depressed). Off if power is not present.

2.3 CONFIGURATION

The Model 213 has one 8-position switch (SW1) accessible from the rear panel. This switch determines the unit's IEEE address and its operating mode. The switch is read only when the unit is powered on and should be set prior to applying power. Figure 2-2 illustrates the factory default setting for SW1.

To modify any of these defaults, disconnect the power cord from the ac line and change the switch settings using a small screwdriver. The enclosure does not need to be opened to change SW1 switch settings.

2.3.1 IEEE-488 Address Selection

The IEEE-488 bus address is set by SW1-1 through SW1-5 (located on rear of unit). The address can be set from 0 through 30 and is read only at power on. The address is selected by simple binary weighting with switch 1 being the least significant bit and switch 5 the most significant bit. The factory default is address 9. If address 31 is selected, it defaults to address 30 because the IEEE-488 standard has reserved address 31. Figure 2-3 shows the factory default IEEE address setting.

2.3.2 Mode Selection

The Model 213 can be operated in one of two modes: normal operating mode, and automatic calibration mode. The operating mode is selected by SW1-8. The switch settings for both modes are shown in Figure 2-4.

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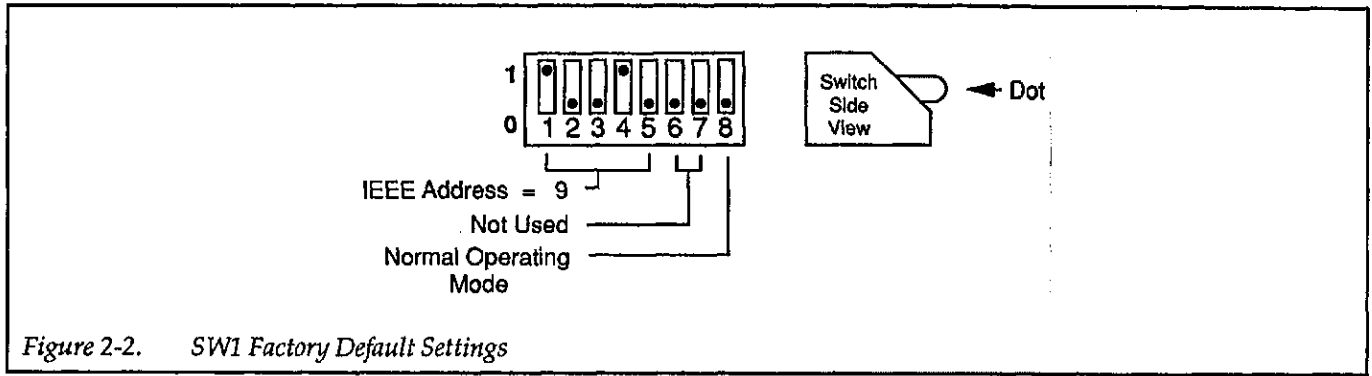


Figure 2-2. SW1 Factory Default Settings

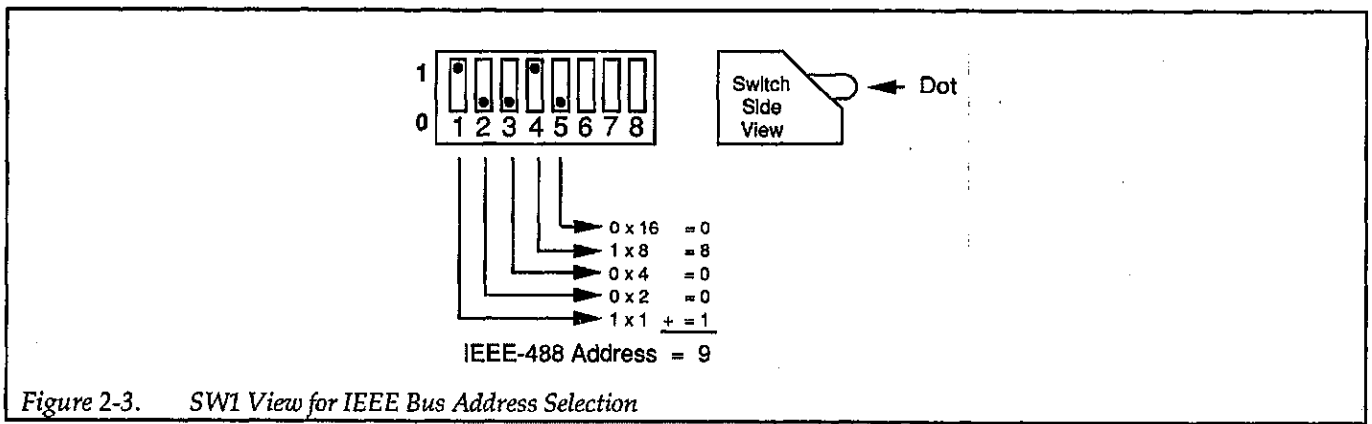


Figure 2-3. SW1 View for IEEE Bus Address Selection

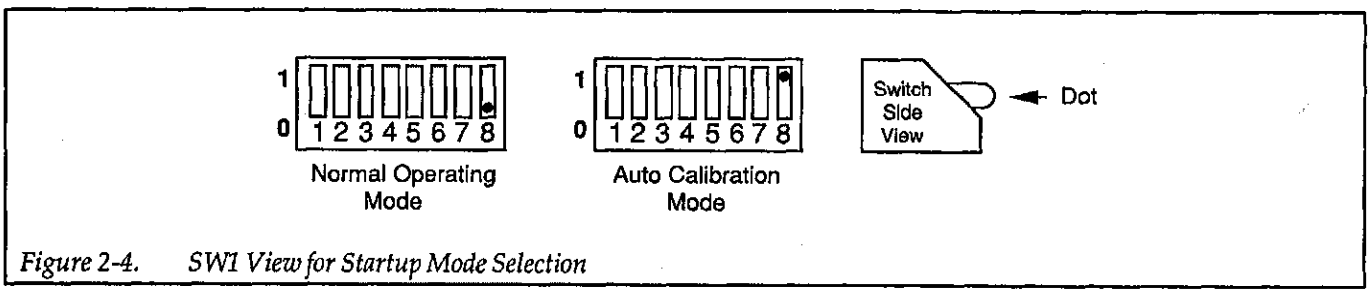


Figure 2-4. SW1 View for Startup Mode Selection



The factory setting for SW1-8 is normal operating mode. For information on the auto-calibration mode refer to Section 5.

2.4 ANALOG OUTPUT PORTS

The Model 213 can be thought of as four isolated digital to analog converters occupying one IEEE-488 bus address (see Figure 2-5). Each port has a low (L), high (H), and ground (chassis ground) line. Chassis ground may be connected to the shield of shielded cable if this type of cable is used to carry the analog signals.

CAUTION

The maximum common-mode input voltage (the voltage between output LO and chassis ground) is 500V peak. Exceeding this value may damage the interface.

The pinouts for all four analog ports are labeled on the rear panel of the unit and are shown in Figure 2-6. Each analog output is capable of sourcing and sinking a maximum current of 10mA.

The Model 213-CON Analog Output Connector is a 12-pin quick disconnect terminal block for the four analog output ports. The screw terminals accept up to #14 AWG solid or stranded wire. Before connecting wires to the terminal block, strip each end approximately 5/16". Insert the stripped ends into the terminals of the connector block and tighten the screws securely. The connector block can be installed by plugging it into the rear panel

analog output ports of the quad voltage source. To remove the connector, simply pull on the attached handle until it comes free.

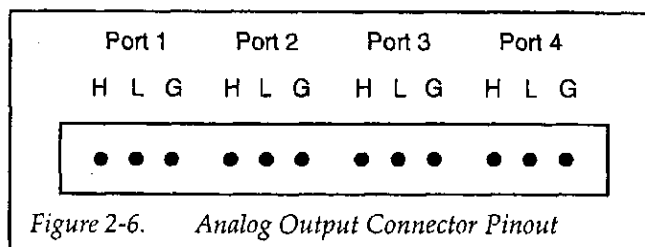


Figure 2-6. Analog Output Connector Pinout

2.5 DIGITAL INPUT/OUTPUT PORTS

The Model 213 has eight digital input lines and eight digital output lines. At power on, the configuration of digital output lines is determined by the options saved as the startup configuration. In order to set the digital output lines to a particular state upon power on, the System Defaults (Sn) command must be used after all the lines have been configured. For example, if it is desired to have digital output line 1 high and the others low at power on, the lines would be set to this configuration using the Digital Output (Dn) command and then this configuration is saved using the System Defaults (Sn) command.

Figure 2-7 illustrates the digital I/O connector as viewed from the rear of the instrument.

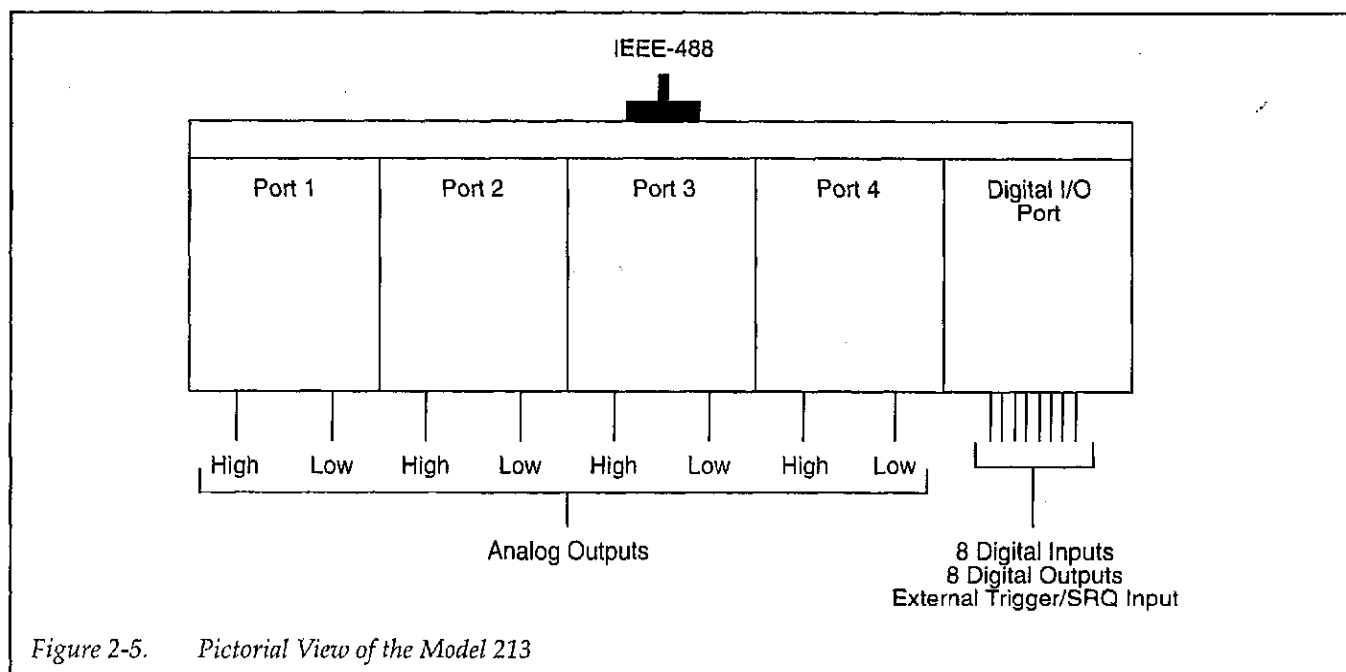


Figure 2-5. Pictorial View of the Model 213

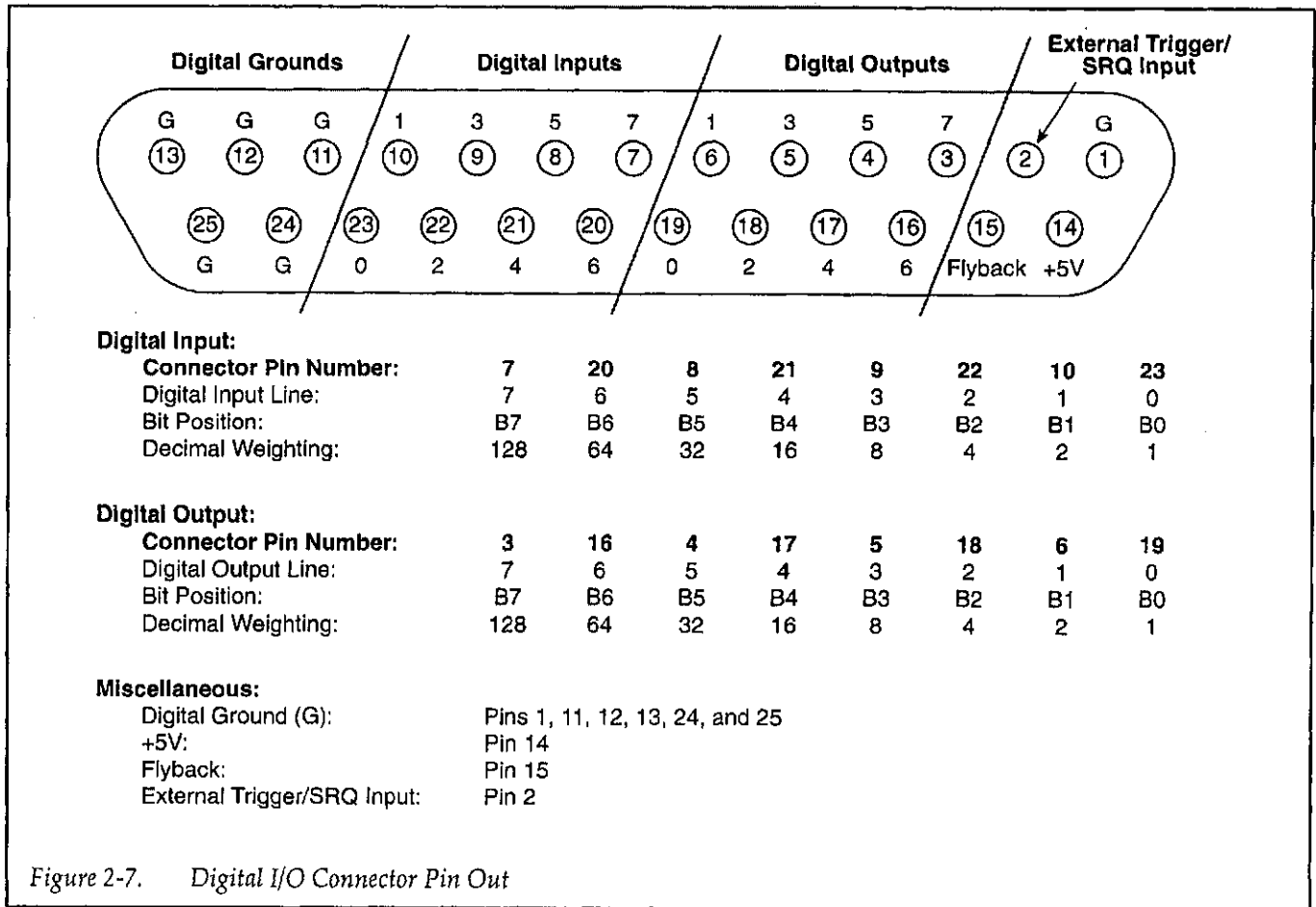


Figure 2-7. Digital I/O Connector Pin Out

2.5.1 Logic Levels

The digital output lines will drive two TTL loads. All digital input lines are less than 1.5 TTL loads. All inputs are protected against damage due to high static voltages. Normal precautions should be taken to limit the input voltages to -0.3 to +7.0 volts. All I/O lines are referenced to digital ground.

2.5.2 High Voltage/High Current Digital Outputs

In addition to interfacing with TTL logic levels, the digital output lines can be configured as high voltage/high current outputs. These outputs can sink up to 100mA at 50V dc through the use of open collector drivers with integral diodes for inductive load transient suppression. This allows for interfacing the digital outputs with relays, lamps, and solenoids.

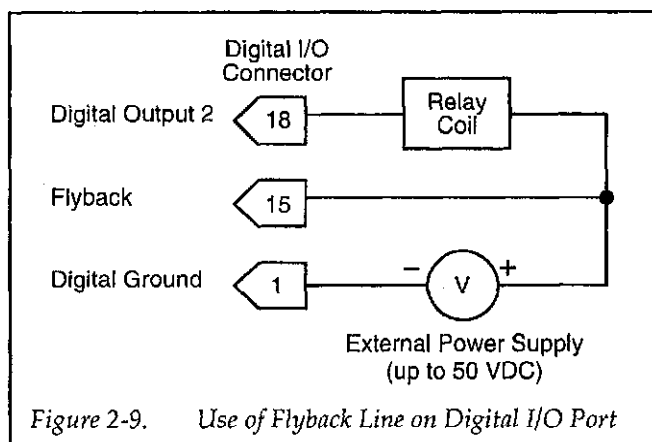
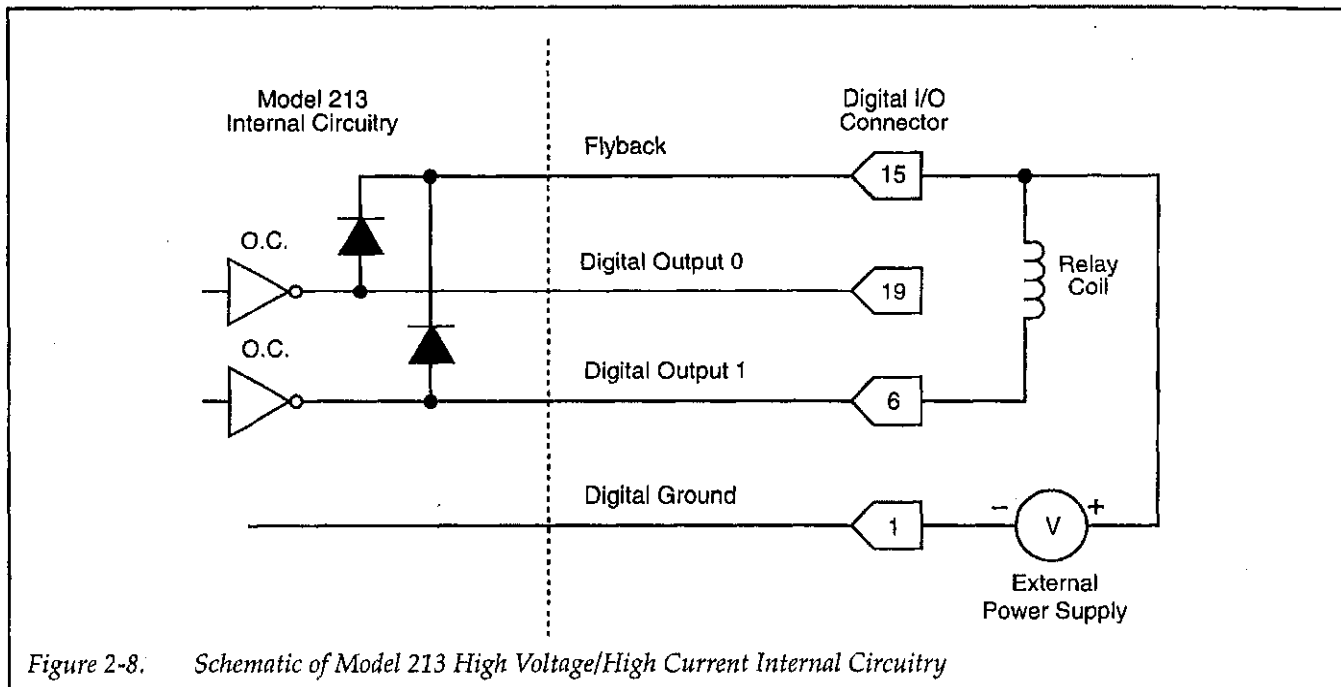
As shown in Figure 2-8, the gates driving the digital outputs (when configured for high voltage/high cur-

rent operation) contain internal diodes to suppress inductive transients. The cathodes of these diodes are tied together and connected to the flyback pin on the digital I/O port. By connecting the flyback pin to the positive end of the supply driving the relays, the internal diodes will be connected in parallel with the relay coils and thus prevent inductive spikes from damaging the internal circuitry of the Model 213.

When used with relays or solenoids, the flyback pin on the connector should be connected to the positive supply lead of the power supply used with the external devices being driven. This is shown in Figure 2-9.

To configure the digital output lines for this purpose, it is necessary to open the enclosure and reposition the configuration jumper according to the procedure in Section 6.

Once the digital output lines have been configured for high level operation, they can be used to drive devices such as relays, solenoids, and displays. For example, a

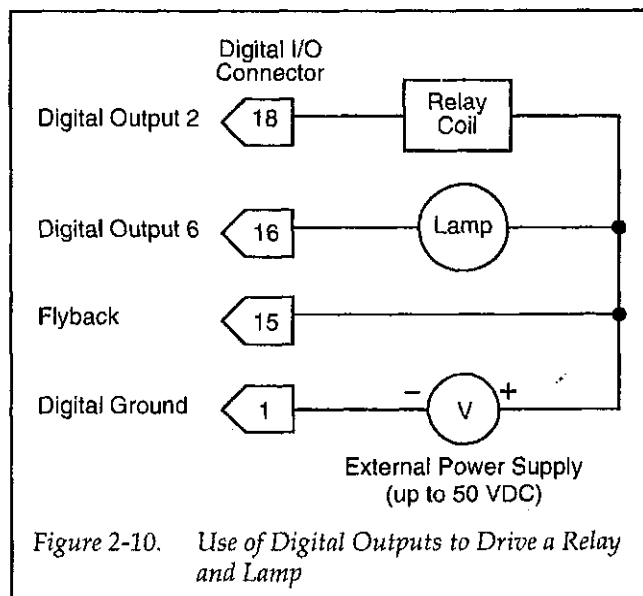


typical application may require a lamp and a relay to be driven by the Model 213. For this example, the relay is connected to digital output 2 and the lamp is connected to digital output 6. These devices would be connected as shown in Figure 2-10.

CAUTION

Never connect external high level devices to the digital output lines unless they have first been configured for this purpose. Failure to do so may result in damage to the Model 213.

Since a relay is used for this application, the flyback terminal is connected to the positive terminal of the external power supply. Note also that the ground lead of the power supply should be connected to a digital ground on the connector.



2.5.3 External Trigger/ SRQ Input (Pin 2)

The External Trigger/SRQ input can be used to trigger the Model 213 once it has been properly armed. The Model 213 can be programmed to trigger on a positive-going or negative-going edge by using the External Trigger Mask (Qn) command. Any TTL level signal may be used as a trigger pulse. A trigger pulse may also be used to generate an SRQ by using the Service Request Mask (Mn) command. The maximum rate at which the instrument can be triggered is one trigger pulse every 1msec.



2.6 IEEE-488 BUS IMPLEMENTATION

The Model 213 implements many of the capabilities defined by the IEEE-488 specification. These are discussed in the following sections. The bus uniline and multiline commands that the Model 213 does not support or respond to include:

- Remote Enable (REN)
- Go to Local (GTL)
- Local Lockout (LLO)
- Take Control (TCT)
- Parallel Poll (PP)
- Parallel Poll Configure (PPC)
- Parallel Poll Unconfigure (PPU)
- Parallel Poll Disable (PPD)

2.6.1 My Talk Address (MTA)

When the Model 213 is addressed to talk, it returns a string specifying the selected port along with the selected range and output voltage which was programmed for that port. The unit can also return a status string for each port or the entire interface by using the Status (Un) command. Information about commands previously executed or data stored in the internal buffer may be returned by using the Query (?) command.

2.6.2 My Listen Address (MLA)

When the instrument is addressed to listen, it accepts characters from the active talker and interprets these characters as commands and command parameters. These commands are explained in Section 4.

2.6.3 Device Clear (DCL and SDC)

Device clear resets the Model 213 to its power on state. The unit will be in the listener idle and talker idle state. The power on default settings for each command will be programmed.

2.6.4 Group Execute Trigger (GET)

When the Model 213 recognizes a GET, and the GET mask command has been used to arm the instrument, it outputs the programmed voltage or voltage sequence (depending on which mode the unit is in) at the selected port(s). Refer to Section 3 Operation for further information.

2.6.5 Interface Clear (IFC)

IFC places the Model 213 in the talker/listener idle state.

2.6.6 Serial Poll Enable (SPE)

When Serial Poll Enabled, the Model 213 sets itself to respond to a serial poll with its serial poll status byte if addressed to talk. When the serial poll byte is accepted by the controller, any pending SRQs are cleared. The instrument will continue to try to output its serial poll response until its serial poll is disabled by the controller.

2.6.7 Serial Poll Disable (SPD)

SPD disables the Model 213 from responding to serial polls by the controller.

2.6.8 Unlisten (UNL)

UNL places the Model 213 in the listener idle state.

2.6.9 Untalk (UNT)

UNT places the Model 213 in the talker idle state.

2.6.10 Serial Poll Response

Whenever the Model 213 generates a service request (SRQ), a serial poll will return a serial poll status byte of at least 64 (decimal) showing that the SRQ was generated by the unit. The following BASIC program illustrates one approach for handling service requests with IOtech Driver 488 software:

```
PRINT#1,"SPOLL09"           Serial poll the Model
                             213
INPUT#2,SRQ09
IF SRQ09 <64 THEN GOTO 500   SRQs disabled
IF SRQ09 = 65 THEN GOTO 600 DAC port 1 ready
                             routine
IF SRQ09 = 66 THEN GOTO 700 DAC port 2 ready
                             routine
IF SRQ09 = 68 THEN GOTO 800 DAC port 3 ready
                             routine
```

NOTE

To allow the Model 213 to detect each of the above conditions, the Service Request Mask





(Mn) command must be enabled for each condition. More extensive tests of the Serial Poll Status Byte are needed if multiple SRQ conditions are selected.

command (@) and Query commands, which are processed immediately upon receipt.

2.6.11 IEEE 488 Bus Output Terminator Selection

The terminating characters sent on output by the Model 213 are set using the Terminator (Yn) command. Upon power on, the unit's IEEE-488 bus terminators are determined by the power-on configuration saved using the System Defaults (Sn) command. The factory default terminator selection is CR LF. The power on default terminators can be changed to any of the four available options listed under the Terminator (Yn) command in Section 4 Command Descriptions. The four available terminator options, and the commands associated with them are: Y0 - CRLF, Y1 - LF CR, Y2 - CR only, and Y3 - LF only. If it is desired to have particular power on default terminator(s), the terminator(s) may be selected using the Terminator command and then this selection saved using the System Defaults (Sn) command.

2.7 HARDWARE INSTALLATION

Included with the Model 213 are accessories for rack or bench use. If rack mount installation is required, install the two rack ears using the enclosed screws. These ears can be installed so either the front or the rear of the unit faces the front of the rack fixture (see Figure 2-11).

NOTE

The front and rear rack mount holes may contain 10-32 x 1/4" nylon screws. Remove the four appropriate nylon screws before attaching the rack ears with 10-32 x 3/8" screws.

WARNING

A potential shock hazard will exist if screws longer than those supplied (10-32 x 3/8") are used to attach the rack ears.

The unit ignores all terminators received from the bus controller. Only the Execute (X) command is used to signal the Model 213 that a command string has been completed. The only exceptions to this rule are the Trigger

If bench installation is required, the rubber feet can be installed on the underside of the unit near each corner (see Figure 2-12).

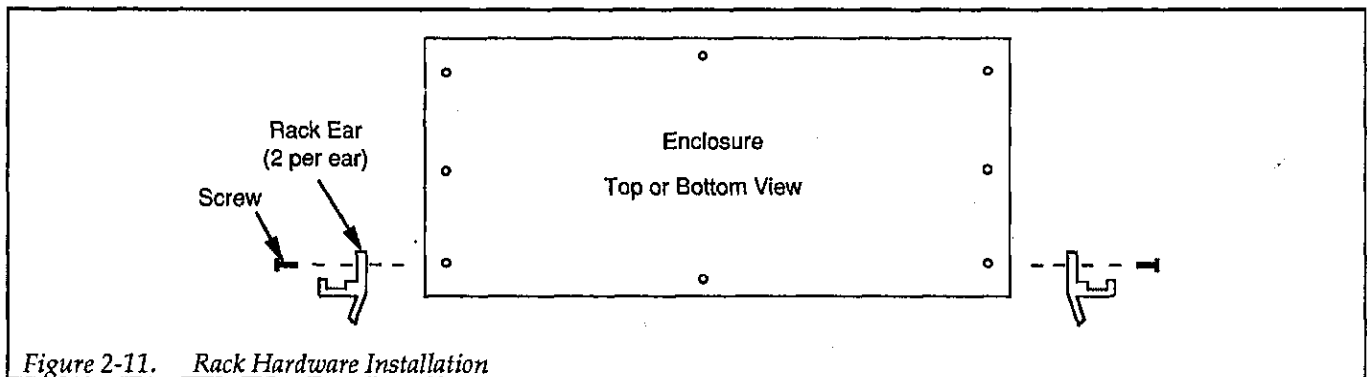


Figure 2-11. Rack Hardware Installation

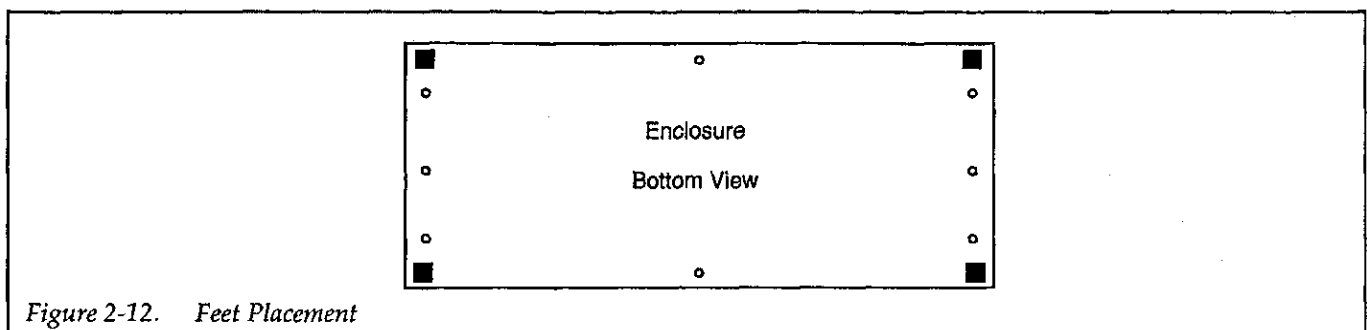


Figure 2-12. Feet Placement





2.8 POWER-UP PROCEDURE

2.8.1 Line Power

Use the following procedure to connect the Model 213 to line power and power up the instrument.

1. Check that the instrument is set to correspond to the available line power. When the instrument leaves the factory, the internally selected line voltage is marked on the rear panel near the power jack. Ranges are 90-125V or 180-250V, 50-60Hz ac. If the line voltage setting of the instrument needs to be changed, an alternate line voltage is located in Section 6.
2. Connect the female end of the power cord to the ac receptacle on the rear panel of the instrument. Connect the other end of the cord to a grounded ac outlet.

WARNING

The Model 213 is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in personal injury or death because of electric shock.

WARNING

The Model 213 is intended for **INDOOR USE ONLY**. Failure to observe this warning could result in equipment failure, personal injury, or death.

CAUTION

Be sure that the line voltage agrees with the indicated range on the rear panel of the instrument. Failure to observe this precaution may result in instrument damage.

2.8.2 Power-up Cycle

The instrument can be turned on by pressing in the rear panel POWER switch. The switch will be at the innermost position when the instrument is turned on.

All the front panel LEDs should light for approximately one second while the unit performs an internal ROM and RAM self test. At the end of this self test, all indicators should turn off except POWER.

If you obtain the above response then your Model 213 is operational. If all LEDs remain on, then a ROM error has occurred. If all LEDs (except the POWER LED) flash continuously, then a RAM error has occurred. Try cycling the power to the unit to determine that the error is repeatable.

If all LEDs except POWER and ERROR LEDs go out, there was a checksum error on non-volatile RAM and the saved configurations may be lost. The checksum error condition may be cleared by doing a save of a configuration using the System Defaults (Sn) command. (To clear possible erroneous data, first save factory default settings. Then save desired changes to the default settings.) The error condition may also be cleared by using the Error Query (E?) command.

If the LEDs do not flash and the POWER indicator does not light, there may not be any power supplied to the instrument. In this event, check to make sure ac power is supplied to the unit. If the problem persists, refer to Section 6 of this manual.

2.9 PROGRAMMING EXAMPLES

These examples use a PC/IEEE-488 DOS device driver called IOtech Driver488 in conjunction with the BASIC or GWBASIC language. Compatible IEEE-488 interface cards for an IBM PC, PS/2, or compatible include:

- IOtech GP488B or GP488/2
- National Instruments GPIB-PC, PCII, or PCIII
- Capital Equipment #01000-00300
- IBM GPIB adapter

A BASIC keyboard controller program is listed in Appendix D. The keyboard controller program allows direct communication with the Model 213 (or any IEEE-488 device on the bus) and is a convenient method of exercising the unit and becoming familiar with the commands and their actions.

First, set SW1 for bus address 9. Connect an IEEE-488 cable from the Model 213 to the IEEE-488 interface card.





Turn on the instrument by depressing the rear panel POWER switch.

Enter and run the keyboard controller program and verify that the CMD> prompt appears on the computer screen. The following is a listing of commands given to the Model 213 and the response received. Some responses are separated by extra vertical spaces for clarity although these spaces will not actually appear when using the program.

```

CMD>                                Command prompt from
                                keyboard controller pro-
                                gram
CMD>OUTPUT09;W1X                    Turn on the TEST LED
                                (TEST LED should light)
CMD>OUTPUT09;W0X                    Turn off the TEST LED
                                (TEST LED should turn off)
CMD>ENTER09

A1C0P1R0V+00.00000                 DAC default status, auto-
                                range on, direct control
                                mode, port 1 selected,
                                ground range, 0 volts.
                                Program port 1 for 5.678V.
                                A DMM connected to port 1
                                should read 5.6775V (± ac-
                                curacy specification of 10V
                                range) after this command
                                is executed.
CMD>OUTPUT09;
P1C0A0R3V5.678X

CMD>ENTER09

A0C0P1R3V+05.67750                 5.678V was rounded to
                                5.67750V
                                Program port 2 for 4.321V
CMD>OUTPUT09;
P2C0A0R3V4.321X

CMD>ENTER09

A0C0P2R2V+04.32000                 4.321V was rounded to
                                4.32000V
    
```

2.10 PERFORMANCE VERIFICATION

To verify that each DAC port is functioning within the specifications, the following procedure may be used. If

the port voltage is measured using a Model 199 System DMM/Scanner, the reading should fall between the low and high limits listed in the tables. The procedure is given for port one although each port may be tested by the Port (Pn) command. It is assumed that the port is connected to the Model 199 using the calibration cable described in Section 5 Calibration.

Command sent to the Model 213: C0 P1 A0 R3 V10 X

Direct Control Mode, Port 1, Autorange off, 10V range, output 10V.

Command sent to the Model 199: F0 R3 Z0 N1 S1 X

Dc volts, 30V range, zero disabled, scanner channel 1, 5-1/2 digit resolution.

10-Volt Range

Commanded Voltage	Low Limit	High Limit
10	9.985	10.015
5	4.99	5.01
1	0.994	1.006
0	-0.005	0.005
-1	-1.006	-0.994
-5	-5.01	-4.99
-10	-10.015	-9.985

Command sent to the Model 213: C0 P1 A0 R2 V5 X

Direct Control Mode, Port 1, Autorange off, 5V range, output 5V.

Command sent to the Model 199: F0 R3 Z0 N1 S1 X

Dc volts, 30V range, zero disabled, scanner channel 1, 5-1/2 digit resolution.





5-Volt Range

Commanded Voltage	Low Limit	High Limit
5	4.992	5.008
2.5	2.4945	2.5055
1	0.996	1.004
0	-0.003	0.003
-1	-0.996	-1.004
-2.5	-2.4945	-2.5055
-5	-4.992	-5.008

Command sent to the Model 213: C0 P1 A0 R1 V1 X

Direct Control Mode, Port 1, Autorange off, 1V range, output 1V.

Command sent to the Model 199: F0 R2 Z0 N1 S1 X

Dc volts, 3V range, zero disabled, scanner channel 1, 5-1/2 digit resolution.

1 Volt Range

Commanded Voltage	Low Limit	High Limit
1	0.998	1.002
0.5	0.4985	0.5015
0.1	0.0989	0.1011
0	-0.001	0.001
-0.1	-0.1011	-0.0989
-0.5	-0.5015	-0.4985
-1	-1.002	-0.998

2.11 DATA TRANSFER SPEEDS

The Model 213 has been measured to perform at the approximate speeds listed below. All explanations discuss only one port although the information given is valid for any port. These figures are relative to the controller used. What speeds you encounter may vary.

2.11.1 Output of Data to Analog Ports

When sending data to the analog outputs on a port of the Model 213, the outputs may be changed about once every 4msec when specifying voltages in bits, or once every 25msec when specifying voltages in volts. (The analog output settling time is listed in the specifications.)

2.11.2 Output of Data to the Digital Output Port

Data may be sent to the digital output port at an approximate rate of once every 2.5msec.

2.11.3 Input of Data from the Digital Input Port

The digital input port may be read at an approximate rate of once every 75msec.



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SECTION 3

Operation

3.1 OVERVIEW

The Model 213 provides four independently programmable 12-bit plus sign digital to analog converters (DACs). Three voltage ranges, ± 1 , ± 5 , and ± 10 , are available on a per port basis as well as an autorange feature which automatically selects the range giving the best resolution for the specified voltage. The DAC ports may be programmed in terms of volts or bits. The resolution per bit on each range is: $250\mu\text{V}/\text{bit}$ ($\pm 1\text{V}$ range), $1.25\text{mV}/\text{bit}$ ($\pm 5\text{V}$ range), and $2.5\text{mV}/\text{bit}$ ($\pm 10\text{V}$ range). Volts are programmed with decimal floating point numbers in the range of ± 10.2375 or $\pm 1.2375\text{E}+1$. Voltages may also be programmed in decimal bits (range = ± 4095) or 16-bit hexadecimal two's complement numbers (range = F001 to 0FFF).

3.2 COMMANDS

Operation of the Model 213 is accomplished using a set of commands that configure the entire unit as well as each DAC port. The commands can be divided into two groups: system commands and port commands. System commands affect the operation of the entire unit and are not specific to a given port. The system commands are listed below:

- Command Trigger (@)
- Digital Output (Dval)
- Error (E?)
- GET Trigger Mask (Gmask)
- EOI Control (Kn)
- Service Request Mask (Mmask)
- Execute (X)
- Port Select (Pn)
- External Trigger Mask (Qmask)
- System Defaults (Sn)
- Command Trigger Mask (Tmask)
- Status (Un)
- Test (Wn)
- Bus Terminator (Yn)
- Output Format (On)

Port commands only affect the operation of the selected port. The port is selected using the Port (Pn) command. The port commands are listed below:

- Autorange (An)
- Buffer Data (Brng,volts)
- Control Mode (Cn)
- Buffer Definition (Fn,m)
- Offset Calibration (Hval)
- Interval (Ival)
- Gain Calibration (Jpos,neg)
- Buffer Location (Lval)
- Number of Cycles (Nn)
- Range Select (Rn)
- Value Output (Vvolts)

3.3 DAC PORT TRIGGERING

Triggering is the process of changing a DAC output at the occurrence of a trigger event. The three trigger events which can trigger a DAC port are: a Command Trigger (@), an IEEE Group Execute Trigger (GET), or an external trigger pulse applied to the external trigger/SRQ input. Any DAC port may be configured to trigger on one or more of these trigger sources. These trigger sources and their relationship to a DAC port are shown in Figure 3-1.

As shown in the diagram, the trigger sources are routed to the ports using the trigger mask commands. The trigger mask commands are illustrated as switches. They are used to enable a trigger source to trigger the selected DAC port. All trigger signals are then combined to allow a port to be triggered upon the occurrence of any of the three trigger events.

Triggering is provided as a means of synchronizing multiple DAC ports. Voltages may be output at two or more ports simultaneously by programming each port for the desired voltages and trigger event(s). When the trigger event occurs, the programmed voltages will appear at the ports simultaneously.

For example, a typical configuration may require Port 1 to have all trigger sources disabled, Port 2 configured to

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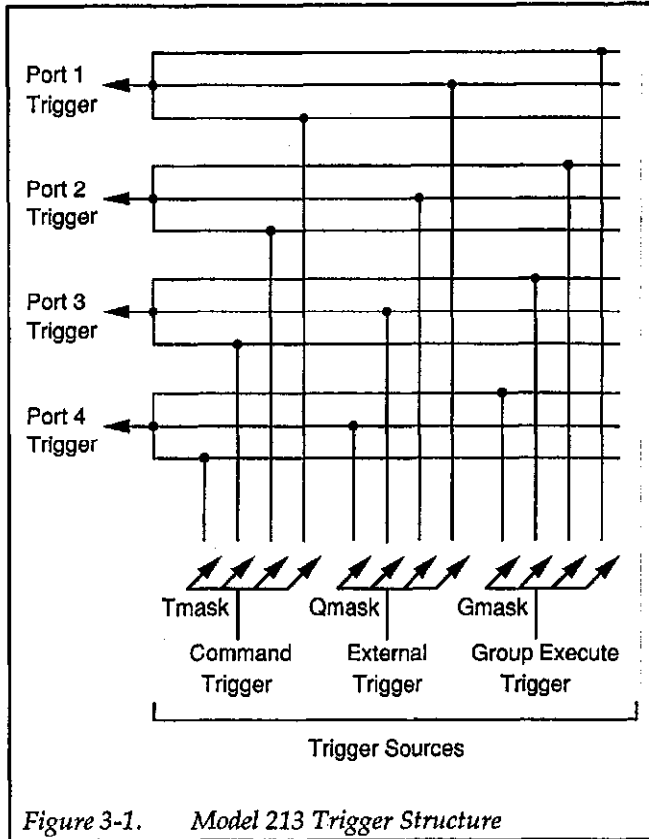


Figure 3-1. Model 213 Trigger Structure

trigger on an IEEE Group Execute Trigger, Port 3 to trigger on an external trigger, and Port 4 to trigger on any of the three trigger sources. The I/O Tech Driver488 commands to configure the ports for this configuration are shown below:

```
PRINT#1,"OUTPUT09;G0 Q0 T0 X"
PRINT#1,"OUTPUT09;G2 X"
PRINT#1,"OUTPUT09;Q4 X"
PRINT#1,"OUTPUT09;G8 Q8 T8 X"
```

Line 1: G0 disables all ports from triggering on an IEEE Group Execute Trigger, Q0 disables all ports from triggering on an external trigger, T0 disables all ports from triggering on a trigger command (@), and X executes the commands.

Line 2: G2 enables port 2 for triggering on an IEEE Group Execute Trigger and X executes the command.

Line 3: Q4 enables port 3 for triggering on an external trigger and X executes the command.

Line 4: G8 enables port 4 for triggering on an IEEE Group Execute Trigger, Q8 enables port 4 for triggering on an external trigger, T8 enables port 4 for triggering on a trigger command (@), and X executes the commands.

After these commands are executed, the trigger sources will be routed to the ports as in Figure 3-2.

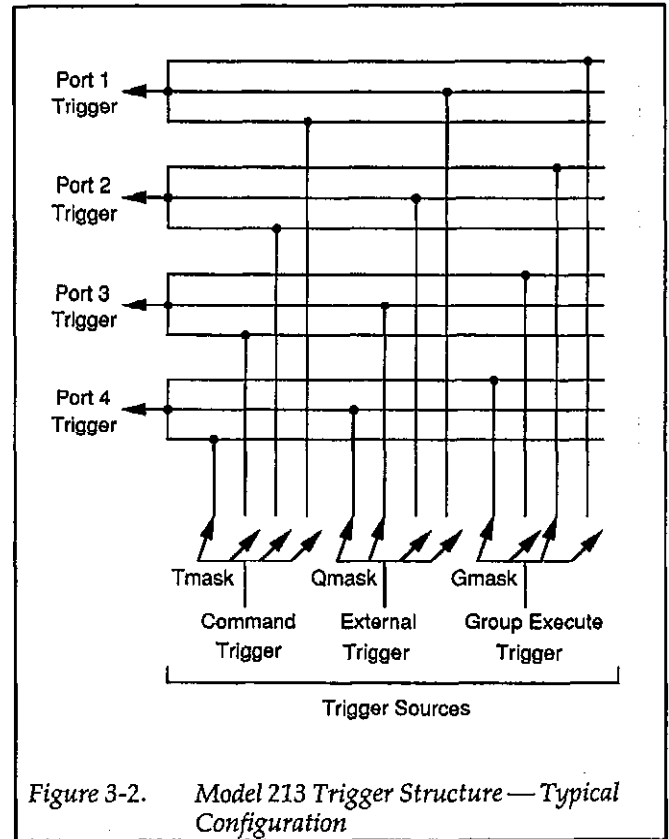


Figure 3-2. Model 213 Trigger Structure — Typical Configuration

3.3.1 DAC Trigger Processing

Operation of the Model 213 is controlled by an internal 1msec timer. Each DAC port is updated at a maximum rate of once every millisecond. When a trigger event occurs, the DAC will output the programmed voltage within 1msec of receiving the trigger. If a second trigger event occurs before the DAC has finished processing the first trigger, the second trigger will be held pending and a trigger overrun error will occur. The error condition may be cleared by issuing the Error Query command (E?) and then reading the response from the Model 213. After the first trigger is processed, the pending trigger will then be processed. Any additional triggers which may occur while a trigger is held pending will be ignored.

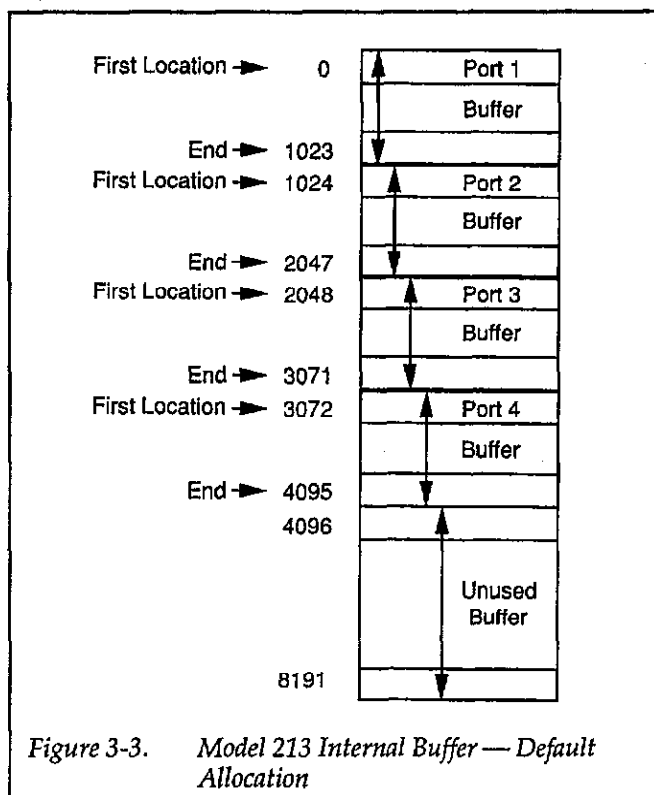


3.4 INTERNAL BUFFER

The Model 213 contains an internal buffer consisting of 8192 locations numbered 0 to 8191. The buffer is shared by all ports. Each port may be given a different section of the buffer or ports may use the same buffer locations without conflict.

This buffer may be loaded with voltage values to be output when the stepped or waveform modes are used. All data in the internal buffer is saved in non-volatile RAM. Therefore buffer data which was previously loaded will be available at power on. Examples showing the use of the internal buffer are given in the following descriptions of stepped and waveform control modes.

Figure 3-3 shows the factory default allocation of the internal buffer to each of the DAC ports on the Model 213.



Buffers are defined using the Buffer Definition command (Fstart,size). The parameters of this command specify the starting location (start) and the number of locations (size) in the defined buffer. Once the buffer has been de-

finied it may be loaded with voltage values using the Buffer Data (Brng,volts) command.

Before using the Buffer Data command, the Location Pointer (Ln) command should be used to set the location pointer to the desired value. The Location Pointer points to the location where data will be stored when the Buffer Data command is used. After each use of the Buffer Data command, the Location Pointer is incremented.

3.5 CONTROL MODES

Four modes of DAC port operation are available: direct, indirect, stepped, and waveform. Each port is independent and may be operated in a different mode. The modes of operation are described below.

3.5.1 Direct Control Mode

Each of the DAC ports may be directly controlled from the IEEE-488 bus. In the direct control mode, a DAC voltage is output upon receipt of the Execute (X) command. Direct control is accomplished by selecting the DAC port, the range or autorange, specifying the DAC output voltage, and issuing the Execute command.

One use of the direct mode is to output voltages at one or more DAC ports directly under program control from an IEEE-488 controller. To output 4V on port 1 the following command string could be used:

```
PRINT#1,"OUTPUT09;C0 P1 A0 R2 V4 X"
```

In this example, C0 selects direct control mode, P1 selects port 1, A0 disables autoranging, R2 selects the $\pm 5V$ range and V4 is the voltage to be output (4 volts). This command string causes the Model 213 to output 4V at port 1.

3.5.2 Indirect Control Mode

Indirect control implies that the DAC output will change only when a trigger event occurs. Indirect control is accomplished by selecting the DAC port, the range or autorange, specifying the DAC output voltage and the desired trigger source. When the trigger event occurs, the programmed voltage will be output.

One use of the indirect mode is to output voltages at one or more DAC ports upon the occurrence of a trigger



event. The command string shown below causes the Model 213 to output 7.5V at port 2 upon receipt of an external trigger signal.

```
PRINT#1,"OUTPUT09;C1 P1 Q1 A0 R2 V4 X"
```

In this example, C1 selects the indirect control mode, P1 selects port 1, Q1 enables port 1 to trigger on the positive edge of an external trigger sense pulse, A0 disables autoranging, R2 selects the $\pm 5V$ range and V4 is the voltage to be output (4V).

3.5.3 Stepped Mode

The stepped control mode may be used to control the DAC in a stepped manner. In this mode, a sequence of DAC voltages is loaded into the Model 213 internal buffer. After the voltages are loaded into the buffer, the DAC output can then be stepped through each of the values by using any of the three trigger sources. When the last voltage in the buffer is output, the Model 213 will automatically return to the first location defined by the Buffer Definition (F1,n) command thereby allowing the sequence to be repeated.

One application of stepped mode may be to use the Model 213 to output a series of test voltages which may control another device. The example of Figure 3-4 shows how the instrument would be configured to output the next voltage in a sequence of voltages each time an external trigger is received. In this example, the voltage at port 1 is stepped to the next value in the buffer each time an external trigger is received. Each "T" on the graph represents a trigger event. The voltage sequence is 1V, 3V, 4V.

The commands required to load the internal buffer for this example are:

```
PRINT#1,"OUTPUT09;C2 P1 F0,3L0 Q1 X"
PRINT#1,"OUTPUT09;B1,1 X B2,3 X B2,4 X"
PRINT#1,"OUTPUT09;L0 X"
```

Or, in one statement:

```
PRINT#1,"OUTPUT09;C2 P1 F0,3 L0 Q1 B1,1 X B2,3 X B2,4 X L0 X"
```

Line 1: C2 selects stepped control mode, P1 selects port 1, F0,3 defines a buffer with the first location as location 0 and the number of values in the sequence to 3. L0 sets the location pointer back to 0 (first location) and Q1 enables port 1 to trigger on an external trigger.

Line 2: B1,1X selects the $\pm 1V$ range, 1V for first point, B2,3X selects the $\pm 5V$ range, 3V for second point and B2,4X selects the $\pm 5V$ range, 4V for third point.

Line 3: L0 sets the location pointer back to location 0 before the port is triggered. If this is not done, the location pointer will start at location 3, not location 0.

The output of the sequence is controlled by the rate at which external triggers occur. In Figure 3-4, each "T" represents an external trigger event.

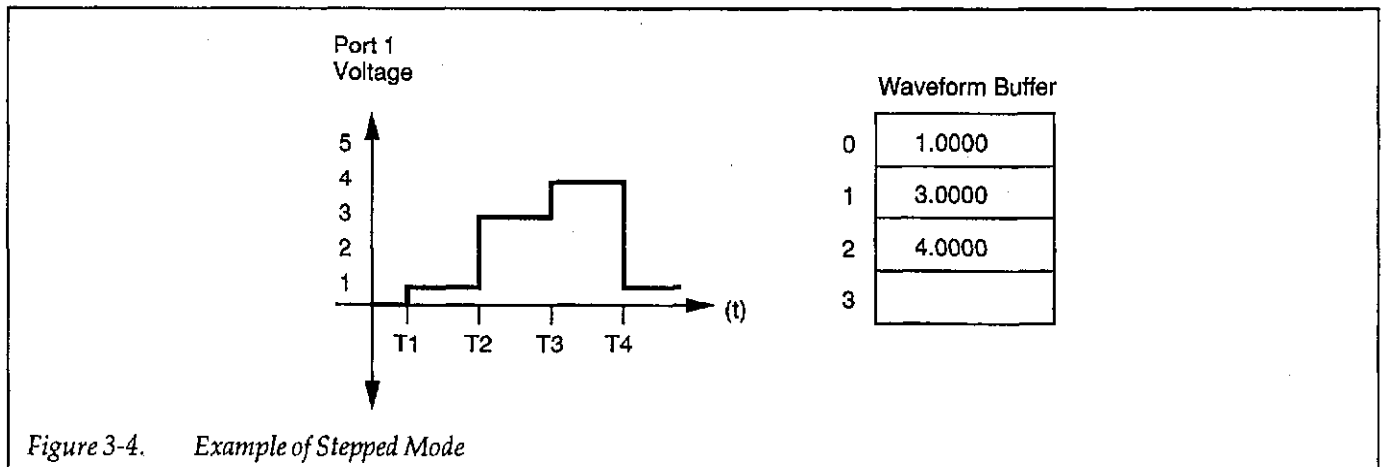


Figure 3-4. Example of Stepped Mode



3.5.4 Waveform Mode

The waveform control mode may be used to control the DAC in an automatic manner. A buffer is defined using the Buffer Definition (F1,n) command and voltage values are loaded into the buffer using the Location Pointer (Ln) command and the Buffer Data (Brng,val) command. Once the Model 213 is triggered, these preloaded voltage values are then output at a regular interval. The time interval between the output of each value is set by using the Interval (In) command. The number of cycles of the waveform is set by using the Number of Cycles (Nn) command.

When the last voltage in the buffer is output, the Model 213 will remain at that location if the number of cycles set with the Nn command has been reached. The voltage stored at this location is then output continuously. If the specified number of cycles has not been reached, the Model 213 automatically continues at the first buffer location.

One application of waveform mode may be to use the Model 213 as a precise function generator. The example of Figure 3-5 shows how the instrument would be configured to output a 6V peak to peak 500Hz square wave centered at zero. More complex waveforms may be generated by loading the buffer with values computed using a high-level language program. Sample programs which will load the buffer with voltage values to generate a sine, triangle, ramp and other waveforms are listed in Appendix E.

The 500Hz square wave shown on the left of Figure 3-5 is generated by loading the buffer with the values shown on the right of Figure 3-5.

The commands required to load the internal buffer for this example are:

```
PRINT#1,"OUTPUT09;C3 P1 F0,2 G1 L0 I1 X"
PRINT#1,"OUTPUT09;B2,3 X B2,-3 N0 X"
PRINT#1,"OUTPUT09;L0 X"
PRINT#1,"OUTPUT09;TRIGGER"
```

Line 1: C3 selects waveform control mode, P1 selects port 1, F0,2 defines a buffer with the first location as location 0 and the number of points in the sequence to 2, G1 selects trigger on GET, L0 sets the location pointer to 0 (the first location) and I1 sets the time interval between points to 1msec.

Line 2: B2,3X selects the $\pm 5V$ range, 3V for first point and B2,-3X selects the $\pm 5V$ range, -3V for second point, N0 sets the number of cycles to continuous.

Line 3: L0 sets the location pointer back to location 0 before the port is triggered. If this is not done, the location pointer will start at location 2, not location 0.

Line 4: When the IEEE-488 Group Execute Trigger is executed, the Model 213 will output the waveform at port 1 continuously.

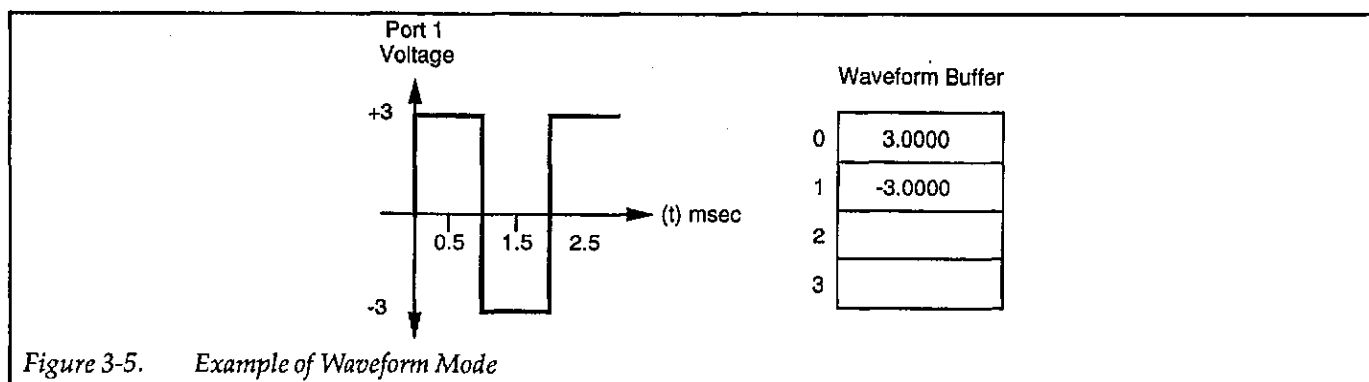


Figure 3-5. Example of Waveform Mode

3.6 MULTIPLE DAC PORT SYNCHRONIZATION

Multiple DAC port output changes may be synchronized in any of the triggered modes of operation (indirect, stepped, and waveform). This is accomplished by using the trigger mask commands to enable the ports to trigger on the same trigger event(s).

Synchronization in waveform mode is automatically accomplished by programming multiple ports with the same time interval using the Interval command (In) and the same buffer size using the Buffer Definition command (Fl,n). The Waveform Buffer Program included in Appendix E shows how multiple, synchronized waveforms may be generated.

3.7 DIGITAL I/O PORT

The digital I/O port on the Model 213 may be used to read eight TTL level inputs and control eight TTL level outputs. The digital output port may also be configured for high voltage, high current operation. Once the out-

put port is configured for high level operation, the output can control relays and other high level devices.

One use of the high level outputs may be to energize a relay under program control. Figure 3-6 shows how a digital output line can control a relay which in turn, connects the Port 4 output voltage to an external voltage controlled device. The Digital Output (Dval) command would then be used to control the relay. Sending the command D0X will energize the relay and a D8X will de-energize the relay.

3.8 USER DEFINED SYSTEM DEFAULTS

The System Defaults (Sn) command is used to save the calibration constants in the non-volatile RAM. It may also be used to save a particular configuration of the Model 213 as a power on default configuration. All system and port commands may be used to configure the instrument and then this particular configuration saved as the power on default configuration.

An application may require the unit to power on in the following configuration:

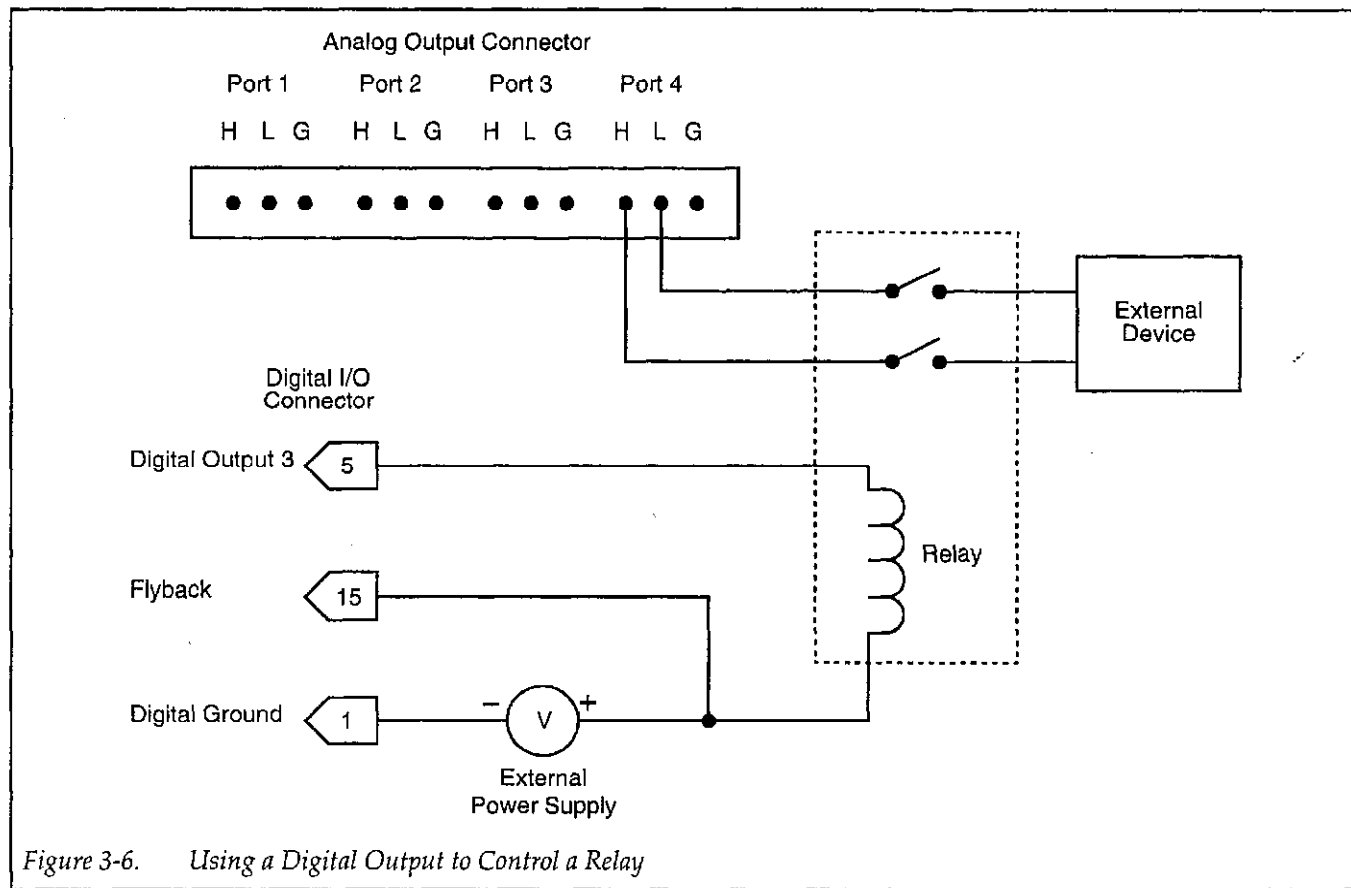


Figure 3-6. Using a Digital Output to Control a Relay

Autorange disabled
Waveform control mode
Interval = 1msec

Port 2 selected
Range = $\pm 10V$
Trigger on GET

The commands to configure the unit in the above configuration and then save this configuration as the power on default would be as follows:

```
PRINT#1,"OUTPUT09;A0 C3 I1 P2 R3 G2 X"  
PRINT#1,"OUTPUT09;S1 X"
```

A0 disables autoranging, C3 selects waveform control mode, I1 sets the interval to 1msec, P2 selects port 2, R3 sets the range to $\pm 10V$, G2 enables port 2 to trigger on GET.

S1 saves this configuration as the power on default configuration.

Another application may require the Model 213 to output a certain voltage immediately upon power-up. To do this, place a port in direct control mode and program the desired voltage. If the S1 command is now given, the Model 213 will output the programmed voltage at power-up. The command string follows:

```
PRINT #1, "OUTPUT09; A1 P1 C0 V3 X S1 X"
```

A1 enables autoranging, P1 selects port 1, C0 selects direct control mode, V3 programs a level of 3 volts, and S1 gives the settings as power-up defaults.

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SECTION 4

Command Descriptions

4.1 COMMAND DESCRIPTIONS

Control of the Model 213 is implemented with 26 bus commands, described here in detail. Examples are given for the commands using a PC functioning as an IEEE-488 controller by using an IEEE-488 board and IOtech Driver488 software. All examples are given using GWBASIC or BASICA. Commands may be given using upper or lower case letters. The Model 213 bus address should be set to 9 for all examples.

In order to establish communication with Driver488 from GWBASIC or BASICA, the following sequence must be used:

```
OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
IOCTL#1,"BREAK"
PRINT#1,"RESET"
OPEN "\DEV\IEEEIN" FOR INPUT AS #2
```

All of the command examples that follow assume that the driver has been properly opened and reset by the above sequence.

Most of the instructions offer a query (?) option. This option can be used to determine the present configuration or mode of a command previously executed. Any number of these query commands may be combined into one string to allow the user to construct a specialized status command requesting the instrument to return only that information which is of interest for a given application.

NOTE

It is necessary that the Execute command (X) follow all command strings sent to the Model 213. No commands are executed until an X is received by the unit. The only exceptions to this rule are the query commands and the Trigger (@) command. These commands do not have to be followed by an X.

Operation of the Model 213 is accomplished using a set of commands that configures the entire interface and commands that configure each DAC port. The syntax rules for using the commands are listed below.

Each command consists of one alphabetic character followed by one or two numbers. The alphabetic character is referred to as the command and the number(s) following the command are the command parameters. Multiple parameters must be separated by a comma.

Examples:

A0 "A" specifies the Autorange command, 0 is the parameter which specifies autorange disabled.
F0,20 "F" specifies the Buffer Definition command, 0 is a parameter which specifies the starting location as location 0, 20 is another parameter which specifies the size of this particular buffer as 20 (20 locations).

Commands are interpreted and processed as they are received but are not executed until the Execute (X) command is issued. (The exceptions to this rule are commands issued with the Query (?) parameter and the Trigger (@) command which do not need to be followed by the Execute (X) command.)

Examples:

A0X This command (disable autorange) will be executed immediately upon receipt of the X
A0 The command will be interpreted, but not executed
X Upon receipt of the X, the Autorange command will be executed.

Voltage values may be specified using scientific notation. (The E may be in upper or lower case.)

Examples: All the commands below specify the same voltage (5.6V)

V5.6 V0.56E1 V56E-1 V.056e+2

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If bits are used to specify a voltage, the numeric bit value is preceded by a number sign (#).

Examples:

R3V#4000 The voltage specified is $4000 \times 2.5\text{mV} = 10\text{V}$.
R3V#-3356 The voltage specified is $-3356 \times 2.5\text{mV} = -8.39\text{V}$.

Hexadecimal values are preceded by a dollar sign (\$) and followed by a Z.

R3V#\$ACDZ The voltage specified is $2765 \times 2.5\text{mV} = 6.91\text{V}$. (\$ACD = 2765)

Commands may be entered in upper or lower case.

Example:

A0 is interpreted the same as a0

Spaces between commands and parameters are ignored.

Examples:

P1 is interpreted the same as P 1
F0,20X is interpreted the same as F 0 , 2 0 X

Commands may be sent individually or in a string with other commands.

Examples:

These three commands sent in three consecutive program lines:

```
PRINT#1,"OUTPUT09;C0"  
PRINT#1,"OUTPUT09;P1"  
PRINT#1,"OUTPUT09;V2X"
```

would have the same effect as the single line below:

```
PRINT#1,"OUTPUT09;C0 P1 V2 X"
```

Due to the structure of the command interpreter, each command may be issued only once within a string. However, the same command may be issued more than once

in a string if each usage of the command is followed by the Execute (X) command.

Examples:

You can program port 1 for 3V and port 2 for 5V using one command string as shown below:

```
PRINT#1,"OUTPUT09;P1 V3 X P2 V5 X"
```

All of the Model 213 commands can be divided into two groups: system commands and port commands. System commands affect the operation of the entire interface and are not specific to a given port. The system commands are listed below:

- Trigger Command (@)
- Digital Output (Dval)
- Error (E?)
- GET Trigger Mask (Gmask)
- EOI Control (Kn)
- Service Request Mask (Mmask)
- Output Format (On)
- Port Select (Pn)
- External Trigger Mask (Qmask)
- System Defaults (Sn)
- Command Trigger Mask (Tmask)
- Status (Un)
- Test (Wn)
- Execute (X)
- Bus Terminator (Yn)

Port commands only affect the operation of the selected port. The port is selected using the Port (Pn) command. The port commands are listed below:

- Autorange (An)
- Buffer Data (Brng,volts)
- Control Mode (Cn)
- Buffer Definition (Fstart,size)
- Offset Calibration (Hval)
- Interval (It)
- Gain Calibration (Jpos,neg)
- Buffer Location (Ln)
- Number of Cycles (Nn)
- Range Select (Rn)
- Value Output (Vvolts)

All commands are summarized in Table 4-1.





Table 4-1. Command Summary

Command	Code	Description
Trigger (system command)	@	Commanded trigger. Triggers the ports specified in the command trigger mask (Tmask). This command does NOT require the Execute (X) command to operate.
Autorange (port command)	A0 A1 (default) A?	Disable autoranging for selected DAC port Enable autoranging for selected DAC port Returns current autorange setting.
Buffer Data (port command)	Brng,volts Brng,#val Brng,#\$valZ B?	Write volts value in buffer location for selected DAC port. Write decimal bit value in buffer location for selected DAC port. Write hexadecimal bit value in buffer location for selected DAC port. Returns the range and value at the location pointer for the selected DAC port in the format specified by the Output Format (On) command. <i>Notes:</i> Using this command causes the location counter to increment after the value has been written to or read from the buffer. Factory default buffer values are zero, range 0. rng=0-3, volts=number without a V prefix.
Control Mode (port command)	C0 (default) C1 C2 C3 C?	Direct mode Indirect mode Stepped mode Waveform mode Returns current control mode for selected port <i>Notes:</i> Selecting a control mode stops the prior mode activity and re-arms the port for the selected mode.
Digital Output (system command)	Dval D?	Outputs the value on the digital output port Returns the current value of the digital output port. <i>Notes:</i> The default output value is 0. val=0-255.
Error Query (port command)	E? E1 E2 E3 E4 E5	Returns error status which indicates the last error encountered Invalid command Invalid command parameter Command conflict Calibration write protected Non-volatile RAM error <i>Notes:</i> Upon reading the error status the error is cleared.
Buffer Definition (port command)	Fstart,size F?	Specifies starting location and number of locations used in the internal buffer for the selected port. $0 \leq \text{start} \leq 8191$; $1 \leq \text{size} \leq 8192$. Returns the starting buffer location and number of locations used in the defined buffer. <i>Notes:</i> The sum of loc+num must be less than or equal to 8192. The default values are 0,1024; 1024, 1024; 2048, 1024; and 3072, 1024 for ports 1 thru 4 respectively.
Get Trigger Mask (system command)	Gmask G-mask G0 G?	Sets bits in the GET trigger mask which specifies which ports will be triggered upon receipt of a bus GET command. Clears the specified bits in the GET trigger mask. Clears all bits in the GET trigger mask. Returns current GET trigger mask.





Command Summary (Cont.)

Command	Code	Description
Offset Calibration (port command)	The mask bits are as follows: Bit 0 Bit 1 Bit 2 Bit 3	Enable trigger to DAC port 1 (1). Enable trigger to DAC port 2 (2). Enable trigger to DAC port 3 (4). Enable trigger to DAC port 4 (8). <i>Notes:</i> The default mask value is 0.
	Hval H?	Specifies the offset constant for selected range and port. Range is ± 255 . Returns the offset constant for selected range and port <i>Notes:</i> Calibration constants must be programmed while using the direct control mode (C0). Autorange must be disabled to program calibration constants. The current voltage output is retriggered upon execution of this command. Default value is 0.
Interval (port command)	It I?	Specify time interval (in milliseconds) used with the waveform control mode. Range for t is 1-65535. Returns the current interval. <i>Notes:</i> The default value is 1000 (1 second).
	Jpos, neg J?	Specifies the gain constant for both polarities of the selected range and port. pos and neg = 0-255. Returns the gain constants for selected range and port. <i>Notes:</i> Calibration constants must be programmed while using the direct control mode (C0). Autorange must be disabled (A0) to program calibration constants. The current voltage output is retriggered upon execution of this command. Default values are 128,128.
EOI Control (system command)	K0 K1 (default) K?	Assert EOI on last bus terminator. Disable EOI. Returns the current EOI control setting.
	Lval L?	Specifies the current buffer location. Range for val is 0-8191. Returns the current buffer location in the format specified by the Output Format (On) command. The value returned after an L? is the first location that will be used in stepped and waveform modes.
	Mmask M-mask M0 M?	Sets bits in the service request mask which specifies which Model 213 events will generate a bus service request. Clears the specified bits in the service request mask. Clears all bits in the service request mask. Returns current service request mask.
Service Request Mask (system command)	The mask bits are as follows: Bit 0 Bit 1 Bit 2 Bit 3 Bit 4 Bit 5 Bit 7	Enable SRQ on DAC port 1 trigger ready (1). Enable SRQ on DAC port 2 trigger ready (2). Enable SRQ on DAC port 3 trigger ready (4). Enable SRQ on DAC port 4 trigger ready (8). Enable SRQ on Trigger Overrun (16). Enable SRQ on error (32). Enable SRQ on External input transition (128).





Command Summary (Cont.)

Command	Code	Description
Number of Cycles (port command)	Nval	Specifies the number of cycles through the buffer in the waveform mode. val is 0-65535, where 0 is continuous.
	N?	Returns the number of repetitions specified for use in the waveform mode. <i>Notes:</i> The default value is 1.
Output Format (system command)	O0 (default)	Sets output format to volts in ± 10.0000 (fixed).
	O1	Sets output format in volts in decimal bits.
	O2	Sets output format in volts in hexadecimal bits.
	O?	Returns current output format selected.
Port Select (system command)	P1 (default)	Select DAC port 1.
	P2	Select DAC port 2.
	P3	Select DAC port 3.
	P4	Select DAC port 4.
	P?	Returns currently selected port.
External Trigger Mask (system command)	Qmask	Sets bits in the external trigger mask which specifies the active edge of the external input line and which ports will be triggered upon a transition of that line.
	Q-mask	Clears the specified bits in the external trigger mask.
	Q0	Clears all bits in the external trigger mask.
	Q?	Returns current external trigger mask.
	The mask bits are as follows:	
Bit 0	Enable trigger to DAC port 1 (1).	
Bit 1	Enable trigger to DAC port 2 (2).	
Bit 2	Enable trigger to DAC port 3 (4).	
Bit 3	Enable trigger to DAC port 4 (8).	
Bit 7	External input line edge sense: (128) 1=negative edge triggered 0=positive edge triggered <i>Notes:</i> The bit 7 default value is 0.	
Range Select (port command)	R0	Select DAC Ground range.
	R1 (default)	Select DAC $\pm 1V$ range.
	R2	Select DAC $\pm 5V$ range.
	R3	Select DAC $\pm 10V$ range.
	R?	Returns DAC volt range. <i>Notes:</i> This command should not be used when autorange is enabled.
System Defaults (system command)	S0	Restores the factory default value to NV-RAM.
	S1	Saves the current settings as default values to NV-RAM.
	S2	Restores Gain and Offset cal constants.
	S3	Saves current calibration constants to calibration NV-RAM.
	S?	Returns the last Sn command executed.





Command Summary (Cont.)

Command	Code	Description
Command Trigger Mask (system command)	Tmask	Sets bits in the command trigger mask which specifies which ports will be triggered upon receipt of a trigger command (@).
	T-mask	Clears the specified bits in the command trigger mask.
	T0	Clears all bits in the command trigger mask.
	T?	Returns current command trigger mask.
	The mask bits are as follows: Bit 0 Bit 1 Bit 2 Bit 3	Enable trigger to DAC port 1. Enable trigger to DAC port 2. Enable trigger to DAC port 3. Enable trigger to DAC port 4. <i>Notes:</i> The default value is 0.
Status (system command)	U0	Send system status on talk.
	U1	Send DAC port 1 status on talk.
	U2	Send DAC port 2 status on talk.
	U3	Send DAC port 3 status on talk.
	U4	Send DAC port 4 status on talk.
	U5	Send digital input port status on talk.
	U6	Send overrun status on talk.
	U7	Returns actual output voltage and range.
U8 (default)	Returns programmed output voltage and range.	
U?	Returns current status select setting. <i>Notes:</i> All status commands are one shot.	
Value Output (port command)	Vvolts	Write volts value for selected DAC port.
	V#val	Write decimal bit value for selected DAC port.
	V#\$valZ	Write hexadecimal bit value for selected DAC port.
	V?	Returns current range and value for selected port in the format specified by the Output Format (On) command. <i>Notes:</i> The current autorange and range affect the value. When programming in bits, autorange must be disabled. The digital port must be programmed in bits.
Test (system command)	W0 (default)	Turn off TEST LED.
	W1	Turn on TEST LED.
	W?	Return state of TEST LED.
Execute (system command)	X	Execute command string.
Bus Terminator (system command)	Y0 (default)	Bus terminator is carriage return line feed.
	Y1	Bus terminator is line feed carriage return.
	Y2	Bus terminator is carriage return only.
	Y3	Bus terminator is line feed only.
	Y?	Returns current bus terminator setting.





4.2 @ — Trigger

Purpose	The Trigger command triggers the ports specified in the command trigger mask (Tmask).	
Type	System command	
Format	@	
Parameters	None	
Description	This command does not require the Execute (X) command and is executed immediately upon receipt. It may be used in any control mode except the direct control (CO) mode (which does not require a trigger) to trigger one or more DAC ports simultaneously.	
Programming	PRINT#1,"CLEAR09"	Reset the Model 213
Examples	PRINT#1,"OUTPUT09;A0 C1 T1 P1 R2 V3 X"	Disable autoranging, select indirect control mode, enable port 1 for triggering on @. Select port 1, select 5V range, output 3V. (The Model 213 will not output the programmed voltage until it receives the @.)
	PRINT#1,"OUTPUT09;@"	Trigger the DAC The DAC will output 3V on port 1.
	Triggering multiple ports:	
	PRINT#1,"OUTPUT09;T3 P1 R2 V3 X"	Enable ports 1 and 2 for triggering on @, select port 1, select 5V range, program port 1 for 3V.
	PRINT#1,"OUTPUT09;P2 R3 V8 X"	Select port 2, select 10V range, program port 2 for 8V.
	PRINT#1,"OUTPUT09;@"	Trigger the Model 213 The unit will output 3V on port 1 and output 8V on port 2.



4.3 A — Autorange

Purpose To enable or disable autoranging for the selected DAC port.

Type Port command

Format An

Parameters

- A0 Disable autoranging for selected DAC port
- A1 Enable autoranging for selected DAC port (default)
- A? Return current autorange setting

Description The Autorange command will enable or disable autoranging for the selected DAC port. If autoranging is enabled, the Model 213 will select the range for the best resolution for the specified output voltage. The Model 213 will select a range for the specified voltage (V) based on the table shown below:

Voltage	Range
$0 < V \leq \pm 1$	R1 ($\pm 1V$ range)
$1 < V \leq \pm 5$	R2 ($\pm 5V$ range)
$5 < V$	R3 ($\pm 10V$ range)

If autoranging is disabled, the range is set using the Range (Rn) command.

Programming Note If autoranging is enabled, the Range command should not be used. A conflict error (E3) will result if the Range command is issued while the port is in autorange.

Programming Example

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;C0 P1 A1 V3 X"	Select direct control mode, select port 1, enable auto-range output 3V. Unit will output 3V on port 1.

4.4 B — Buffer Data

Purpose To write a voltage value to the internal buffer for the selected DAC port.

Type Port command

Format Brng,volts

Parameters Brng,volts Write a voltage value in the buffer for the selected DAC port (rng selects the range and is one of the following):

rng	Range
0	Ground
1	±1V
2	±5V
3	±10V

Volts is any voltage value specified as a number without a V prefix.

Brng,#bits Write voltage value in bits to the buffer for selected DAC port.

Brng,#\$hexZ Write voltage value in hexadecimal bits to the buffer for selected DAC port. Hexadecimal values must be followed by a Z.

B? Returns the range and voltage value at the location pointer for the selected DAC port in the format specified by the Output Format (On) command.

Description

The Buffer Data command is used to write a voltage value to the internal buffer. The buffer data is written to the location pointed to by the location pointer. The location pointer can be set to any location in the buffer by using the Location Pointer (Ln) command. The range (rng) and voltage value (volts) must be specified when using the Buffer Data command.

When creating a buffer of voltage values, the buffer is first defined using the Buffer Definition (Fl,n) command, the location pointer is set to the first location in the newly defined buffer by using the Location Pointer (Ln) command, and the Buffer Data command is then used to fill the buffer.

The Execute (X) command must be used after each Buffer Data command. The location pointer will automatically increment after each Buffer Data command is executed.

Buffer data may be written to locations outside of the defined buffer area for the selected port if so desired.



**Programming
Notes**

1. Each use of this command will cause the location counter to increment after the value has been written to or read from the buffer.
2. Factory default buffer values are range 0, zero volts.
3. If the Buffer Data command is used more than once within a command string, each Buffer command must be followed by the Execute (X) command.
4. The Model 213 may be stopped while in the waveform mode by sending the Waveform Control (C3) command. This will halt the instrument but re-arm it for another trigger from the bus.

**Programming
Examples**

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;A0 C3 P1 F0,2 G1 N3 L0 I2000 X"	Disable autorange, select waveform control mode, select port 1, define a buffer with the first location=0 and the number of locations =2, select trigger on GET, number of cycles=3, set location pointer to 0 (first location in the defined buffer), set time interval between points to 2sec.
PRINT#1,"OUTPUT09;B2,3 X B2,4 X"	Set buffer location 0 to 3V, set buffer location 1 to 4V. (Note: the location pointer will increment after the B2,3 command is executed).
PRINT#1,"OUTPUT09;L0X"	Set location pointer back to 0 (first location). This is done so that when the Model 213 is triggered, it will start the sequence with the value in location 0.
PRINT#1,"@"	Trigger the Model 213. The unit will output 3V, pause 2sec, output 4V, pause 2sec then repeat the sequence two more times.



4.5 C — Control Mode

Purpose To choose the operational mode of a selected port.

Type Port command

Format Cn

Parameters C0 Direct mode trigger on Execute (X) command (default).
C1 Indirect mode, trigger on GET, external trigger or @
C2 Stepped mode, trigger on GET, external trigger or @
C3 Waveform mode, trigger on GET, external trigger or @
C? Returns current control mode for selected port

Description The Control Mode command is used to choose the operational mode of a selected port. The modes and their operation are described in the programming examples.

Programming Note Issuing any control mode command stops the prior mode activity and rearms the port for the selected mode. For example, if the Model 213 is generating a waveform, it may be halted and re-armed by issuing the C3 command.

Programming Examples

Using the direct control mode:

```
PRINT#1,"CLEAR09"  
PRINT#1,"OUTPUT09;C0 P1 A0  
R2 V4 X"
```

Reset the Model 213
Select direct control mode, select port 1, disable auto-ranging, select $\pm 5V$ range, output 4V. The unit will output 4V on port 1 after executing this command string.

Using the indirect control mode:

```
PRINT#1,"CLEAR09"  
PRINT#1,"OUTPUT09;C1 P1 T1  
A0 R2 V4 X"  
  
PRINT#1,"OUTPUT09;@"
```

Reset the Model 213
Select indirect control mode, select port 1, enable port 1 to trigger on @, disable autoranging, select $\pm 5V$ range, output 4V.
The unit will output 4V on port 1 upon receiving the @ command.

Using the stepped control mode:

```
PRINT#1,"OUTPUT09;C2 P1  
F0,3L0 Q1 X"  
  
PRINT#1,"OUTPUT09;B1,1 X"
```

C2 selects stepped control mode, P1 selects port 1, F0,3 defines a buffer with the first location as location 0 and the number of values in the sequence to 3, L0 sets the location pointer back to 0 (first location) and Q1 enables port 1 to trigger on an external trigger.
B1,1X selects the $\pm 1V$ range, 1V for first point, B2,3X



B2,3 X B2,4 X"	selects the $\pm 5V$ range, 3V for second point and B2,4X selects the $\pm 5V$ range, 4V for third point.
PRINT#1,"OUTPUT09;L0 X"	L0 sets the location pointer back to location 0 before the port is triggered. If this is not done, the location pointer will start at location 3, not location 0.

The output of the sequence is controlled by the rate at which external triggers occur.

Using the waveform control mode:

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;C3 P1 F0,2 G1 N0 L0 I2000 X"	Select waveform control mode, select port 1, define a buffer with the first location=0 and the size=2, enable port 1 to trigger on GET, set number of cycles to continuous, set location pointer to 0 (first location), set time interval between points to 2sec.
PRINT#1,"OUTPUT09;B1,1 X B2,4 X"	Select $\pm 1V$ range, 1V for first point, select $\pm 5V$ range, 4V for second point.
PRINT#1,"OUTPUT09;L0X"	Set the location pointer back to 0 (first location). This is done so that when the instrument is triggered, it will start the sequence with the value in location 0. The location pointer is automatically incremented whenever a voltage value is sent to the Model 213 internal buffer using the B command.
PRINT#1,"TRIGGER"	Trigger the unit. The Model 213 will output 1V, pause for 2sec, output 4V, pause for 2sec then repeat this sequence indefinitely or until it receives another Control Mode command.



4.6 D — Digital Output

Purpose To output up to 8 bits of data to the digital output port.

Type System command

Format Dval

Parameters

Dval Outputs the value on the digital output port where val = 0 to 255. The value is output in binary (sending a D5 command will set lines 0 and 2 to a logic high level).

D? Return the current value of the digital output port in the format specified by the "O" command.

Description The Digital Output command is used to output up to 8 bits of data to the digital output port. The data will appear at the digital output port as soon as the command is executed. There are no triggering or buffer options available when using the digital output port. The digital input port may be read using the U5 Status command.

Programming Notes

1. The default output value is 0 (all digital output lines low, 0V).
2. All bits on the digital output port will be affected when using this command. For example, if D1X is sent, line 0 will be set to a logic high level (+5V) and the other lines set to a logic low level (0V).

Programming Examples

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;D6 X"	Set lines 1 and 2 high on the digital output port (6 = 0000 0110 binary)
PRINT#1,"OUTPUT09;D?"	Read the programmed state of the digital output port
PRINT#1,"ENTER09"	
INPUT#2,A\$	
PRINT A\$	Display shows 6

4.7 E — Error Query

Purpose	To determine the present error condition on the selected port of the Model 213.
Type	System command
Format	E?
Parameter	E? Return and clear present error condition
Description	<p>The Error Query command is used to determine the present error condition on the selected port of the Model 213. After execution of the Error Query command, the present error condition is cleared. The error condition is also cleared by executing the the Status (U0) command. When an error has occurred, the ERROR light on the front panel of the Model 213 will turn on. The ERROR light will stay on until an Error Query (E?) or Status (U0) command is executed.</p>

If a calibration write protected failure (E4) occurs, this error condition may also be cleared by executing the Error Query (E?) command. This type of error occurs when an attempt is made to save calibration constants without first setting the calibration switch on the rear panel to the depressed position.

After execution of the Error Query command, the Model 213 will return one of the following error codes:

- E0 No error has occurred
- E1 Unrecognized command (example Z4X)
- E2 Invalid command parameter (example A62X, C10X)
- E3 Command conflict error (example A1R2)
- E4 Calibration switch not closed
- E5 Non-volatile RAM error, system defaults or calibration constants may be lost.

If a non-volatile RAM error (E5) occurs on power up, the S? command may be used to check the system defaults. One of the following responses will be returned:

- S0 Factory defaults are in use, user programmed defaults were lost
- S1 User programmed defaults are still valid

The calibration constants may be tested by issuing the command string A0R0XJ?. One of the following responses will be returned:

- J128,128 Factory calibration constants are in use, calibration constants which were saved from a calibration procedure have been lost. The Model 213 should be recalibrated if this response is returned
- J127,127 Calibration constants which were saved from a calibration procedure are still valid



Programming Note After execution of the Error Query command, the present error condition is cleared.

Programming PRINT#1,"CLEAR09" Reset the Model 213

Examples PRINT#1,"OUTPUT09;E?" Request error status

```
PRINT#1,"ENTER09"
INPUT#2,A$
PRINT A$
PRINT#1,"OUTPUT09;C0 P1 A0
R1 V3 X"
```

Display shows E0, no errors have occurred. Select direct control mode, select port 1, disable auto-ranging, select ±1V range, output 3V. ERROR light on Model 213 should turn on after this command string is executed.

```
PRINT#1,"OUTPUT09;E?"
```

Request error status

```
PRINT#1,"ENTER09"
INPUT#2,A$
PRINT A$
```

Display shows E2 (invalid command parameter) since an attempt was made to output 3V on the 1V range. The V3 command caused the error since valid voltage values for the 1V range must be between -1 and 1V. Send an invalid command to the Model 213.

```
PRINT#1,"OUTPUT09;Z4X"
PRINT#1,"OUTPUT09;E?"
PRINT#1,"ENTER09"
INPUT#2,A$
```

Request error status
(Note: ERROR light should be on)

```
PRINT A$
PRINT#1,"OUTPUT09;E?"
PRINT#1,"ENTER09"
INPUT#2,A$
PRINT A$
```

Display shows E1-unrecognized command. (ERROR light should be off)
Request error status

Display shows E0 since error condition has been cleared after reading error status



4.8 F — Buffer Definition

Purpose To create a buffer of voltage values to use in the stepped (C2) or waveform (C3) control modes for a selected port.

Type Port command

Format **Fstart,size**

Parameters

Fstart,size	Define the starting location and size of a buffer, where $0 \leq \text{start} \leq 8191$ and $1 \leq \text{size} \leq 8192$. (See Programming Notes.)
F?	Returns the starting location and buffer size of the most recently defined buffer

Description The Buffer Definition command is used to create a buffer of voltage values to use in the stepped (C2) or waveform (C3) control modes for a selected port. A buffer is defined by specifying the starting location and the buffer size. Any size buffer may be defined, however, the last location must be at a numerically higher location than the first location. More than one port may share the same buffer (completely or partially) if it is desired to output the same values at different ports simultaneously.

Programming Notes

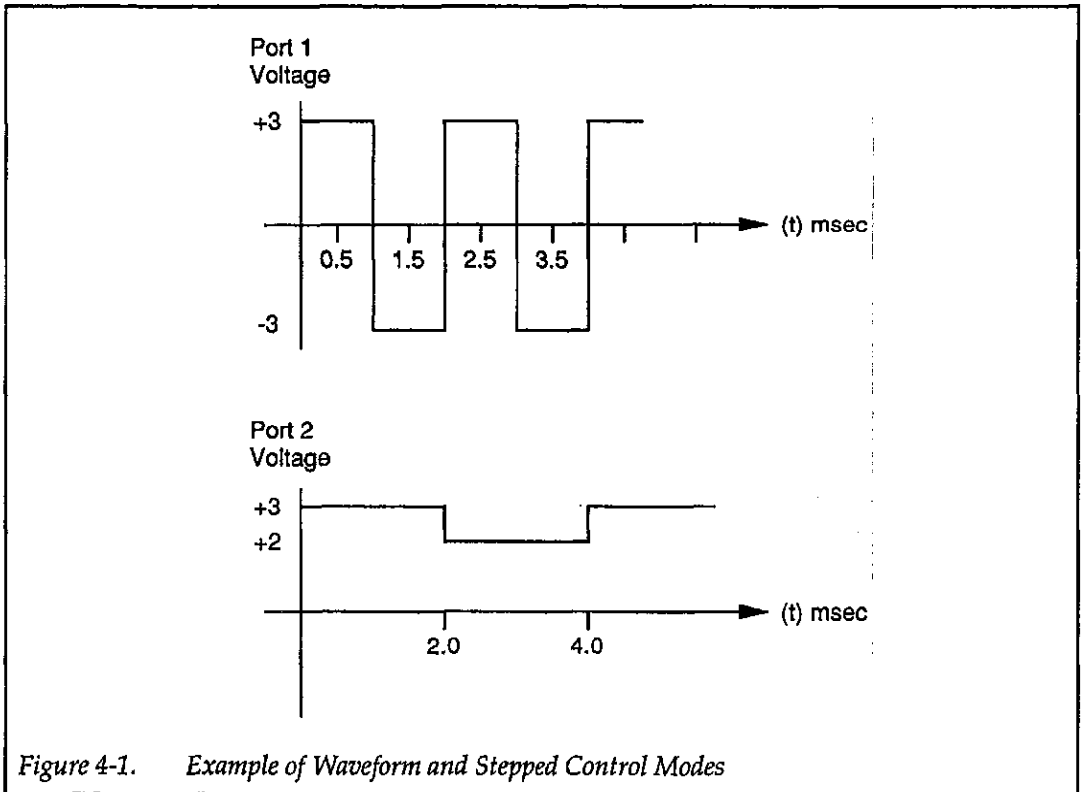
1. The sum of start and size must be less than or equal to 8192.
2. The default start and size values for each port are:

Port	Default Values (start,size)
1	0, 1024
2	1024, 1024
3	2048, 1024
4	3072, 1024

Programming Examples

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;C3 P1 F0, 2 G1 N0 L0 I1 X"	Select waveform control mode, select port 1, define a buffer with the starting location=0 and size=2, enable port 1 to trigger on GET, set number of cycles to continuous, set location pointer to 0 (first buffer location for the port 2 buffer), set time interval between points to 1msec.
PRINT#1,"OUTPUT09;B2,3 X B2,-3 X"	Set buffer location 0 to 3V, set buffer location 1 to -3V
PRINT#1,"OUTPUT09;L0 X"	Set location pointer back to 0 (first location for the port 1 buffer)
PRINT#1,"OUTPUT09;C3 P2 F10, 2 G2 N0 L10 I2 X"	Select waveform control mode, select port 2, define a buffer with the starting location=10 and size=2, enable port 2 to trigger on GET, set number of cycles to continuous, set location pointer to 10 (first location for the port 2 buffer), set time interval between points to

PRINT#1,"OUTPUT09;B2,3 X B2,2 X"	2msec. Set buffer location 10 to 3V, set buffer location 11 to 2V
PRINT#1,"OUTPUT09;L10 X"	Set location pointer to 10 (first location for the port 2 buffer)
PRINT#1,"TRIGGER"	Trigger the Model 213. The unit will output the wave- forms shown in Figure 4-1 on ports 1 and 2.



4.9 G — GET Trigger Mask

Purpose To mask or unmask the GET trigger.

Type System command

Format **Gmask**

Parameters

Gmask	Sets bits in the GET trigger mask which specifies which ports will be triggered upon receipt of a bus GET command
G-mask	Clears the specified bits in the GET trigger mask
G0	Clears all bits in the GET trigger mask
G?	Returns current GET trigger mask

Description The GET Trigger Mask command is used to mask or unmask the GET trigger to allow DAC port triggering upon receipt of an IEEE Group Execute Trigger (GET) from the IEEE-488 bus. One or more DAC ports may be masked or unmasked using this command.

The mask bits are as follows (bit values are shown in parentheses):

Bit 0 (1)	Enable GET trigger on DAC port 1
Bit 1 (2)	Enable GET trigger on DAC port 2
Bit 2 (4)	Enable GET trigger on DAC port 3
Bit 3 (8)	Enable GET trigger on DAC port 4

Programming Note The default mask value is 0.

Programming Examples

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;C1 G8 P4 A0 R2 V3 X"	Select indirect control mode, enable port 4 to trigger on a GET, select port 4, disable autoranging, select 5V range, output 3V
PRINT#1,"TRIGGER"	Trigger the DAC. The unit will output 3V on port 4

4.10 H — Offset Calibration

Purpose To program the offset calibration constant of a selected port and range.

Type Port command

Format Hval

Parameters

Hval Specifies the offset calibration constant for selected range and port. (val is between ± 255)

H? Returns the offset calibration constant for selected range and port.

Description The Offset Calibration command programs the offset calibration constant for the selected range and port. The direct control (C0) mode must be selected when using this command. The value may be any number in the range ± 255 . Changing the value parameter by one causes a zero offset of approximately $77\mu\text{V}$.

Programming Notes

1. Calibration constants must be programmed while using the direct control mode (C0).
2. Autorange must be disabled (A0) to program calibration constants.
3. The current programmed output voltage will appear at the analog output upon receipt of this command.

Programming Examples

```
PRINT#1,"OUTPUT09;C0 P1 A0      Select direct control mode, select port 1, disable auto-
R2 H125 X"                       ranging, select  $\pm 5\text{V}$  range, set offset for  $\pm 5\text{V}$  range to
                                  125.
PRINT#1,"OUTPUT09;H?"           Request current offset calibration constant for port 1
PRINT#1,"ENTER09"
INPUT#2,A$
PRINT A$                          Display shows H+00125
```



4.11 I — Interval

Purpose To specify the time interval between each voltage value in waveform control mode for the selected port.

Type Port command

Format It

Parameters It Specify time interval used with the waveform control mode (t is between 1 and 65535 where 1 count = 1 msec)
I? Returns the current interval

Description The Interval command specifies the time interval between each voltage value that is output when in the waveform (C3) control mode. The frequency of the output waveform may be controlled by selecting the proper interval based on the number of voltage points per cycle.

Programming Note The default value for t is 1000 (1 second).

Programming Examples

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;C3 P1 F0, 100 G1 N0 L0 I40 X"	Select waveform control mode, select port 1, define a buffer with the first location=0 and the number of locations=100, enable port 1 to trigger on GET, set number of cycles to continuous, set location pointer back to 0 (first location in the buffer), set the time interval between points to 40msec.
PRINT#1,"TRIGGER"	Trigger the Model 213. Voltage value will be output at port 1 every 40msec.





4.12 J — Gain Calibration

Purpose To set the positive and negative gain calibration constants of a selected port and range.

Type Port command

Format Jpos,neg

Parameters Jpos,neg Specifies the gain constant for both polarities of the selected range and port. Values for positive and negative are between 0 and 255
J? Returns the positive and negative gain constants for the selected range and port

Description The Gain Calibration command is used to set the positive and negative gain calibration constants for the selected range and port. The range for each constant is 0 to 255. The larger the gain constant, the larger the absolute output voltage.

Programming Note

1. The DAC port must be in direct control mode (C0) and autorange must be disabled (A0) to program the calibration constants.
2. The current voltage output is retriggered upon execution of this command.
3. The default value for the pos and neg parameters is 128.
4. Changing the positive or negative value by one changes the gain by approximately 46ppm.

Programming Examples

<pre>PRINT#1,"OUTPUT09;C0 P1 A0 R2 J50,60 X"</pre>	<p>Select direct control mode, select port 1, disable auto-ranging, select $\pm 5V$ range, set gain for the positive polarity to 50, set gain for negative polarity to 60.</p>
<pre>PRINT#1,"OUTPUT09;J?" PRINT#1,"ENTER09" INPUT#2,A\$ PRINT A\$</pre>	<p>Request current gain calibration constants for port 1</p> <p>Display shows J050,J060</p>





4.13 K — End or Identify (EOI)

Purpose To indicate the end of a multiple byte transfer sequence.

Type System command

Format Kn

Parameters

K0	Assert EOI on last bus terminator
K1 (default)	Do not assert EOI on last bus terminator
K?	Returns current EOI selection

Description The EOI line is one of five interface management lines on the IEEE-488 bus. It is used by a talker to indicate the end of a multiple byte transfer sequence. The controller can change the EOI mode by programming the Model 213 from the bus. In the K0 mode, the EOI line is asserted by the Model 213 on the last byte of every bus output string. In the K1 mode the EOI function is disabled.

Programming Examples

PRINT#1,"OUTPUT09;K1 X"	Disables EOI assertion on last byte
PRINT#1,"OUTPUT09;K?"	Request EOI selection from Model 213
PRINT#1,"ENTER09"	
INPUT#2,A\$	
PRINT A\$	Display shows K1



4.14 L — Location Pointer

Purpose To set the location pointer to a specified location in the internal buffer for a selected port.

Type Port command

Format Ln

Parameters Ln Sets the location pointer to location n . n is between 0 and 8191
L? Returns current buffer location. The L? command may be used even when the Model 213 is running in stepped or waveform mode.

Description The Location Pointer command is used to set the location pointer to a specified location in the internal buffer for a selected port. (There are four separate location pointers.) This command is used in conjunction with the Buffer Data (Brng,volts) command. After a data value is put in the buffer by using the Buffer Data (Brng,volts) command, the location pointer is automatically incremented.

The location pointer points to the first voltage value which will be output when the stepped (C2) or waveform (C3) control modes are used. Once a DAC port is triggered in the stepped (C2) or waveform (C3) control modes, the location pointer will always point to the next location containing the voltage value to be output. Each port has its own location pointer, therefore, the location pointer may be set to a different location for each port.

Before triggering a DAC port, the location pointer should be set to the desired starting point in the internal buffer.

CAUTION

Do not use the Ln command to change the location pointer while the DAC is generating a waveform in waveform control mode (C3). Unpredictable operation may occur.

Programming Examples

```
PRINT#1,"CLEAR09"
```

```
PRINT#1,"OUTPUT09;C3 P1  
F200,400 G1 N30 I2000 X"
```

Reset the Model 213

Select waveform control mode, select port 1, define a buffer with the first location=200 and the size=400, enable port 1 to trigger on GET, set the number of cycles to 30, set location pointer back to 0 (first location), set time interval between points to 2sec.

Note: Assume that we are using a buffer that has already been loaded with voltage values. Using the Buffer Definition (Fstart,size) command above defines what segment of the buffer we will be using when in waveform mode.

```
PRINT#1,"OUTPUT09;L200X"
```

Set location pointer to 200 (start of the buffer which was previously defined)



PRINT#1,"TRIGGER"

Trigger the Model 213. The unit will output the values in the buffer starting at location 200. (The buffer we have defined starts at location 200 and ends at location 600.)



4.15 M — Service Request Mask (SRQ)

Purpose To program which conditions generate an SRQ (service request).

Type System command

Format Mmask

Parameters

Mmask	Set bit(s) in the service request mask to specify which events will generate a bus service request (SRQ)
M-mask	Clears the specified bits in the service request mask
M0	Clears all bits in the service request mask
M?	Returns current service request mask

Description The Service Request (SRQ) Mask command is used by the Model 213 to alert the controller to one of several conditions described below. Multiple service request conditions can be enabled simultaneously by issuing them separately or by combining them in one command string. If multiple Service Request Mask commands are contained within the same command string, each Mmask command must be followed by an Execute (X) command. The programmed SRQ modes will remain enabled until the M0 (SRQ disabled) command is sent, or the controller sends a Device Clear (DCL) or Selected Device Clear (SDC).

The mask bits are as follows (bit values are shown in parentheses):

Bit 0 (1)	Enable SRQ when DAC port 1 is ready for trigger
Bit 1 (2)	Enable SRQ when DAC port 2 is ready for trigger
Bit 2 (4)	Enable SRQ when DAC port 3 is ready for trigger
Bit 3 (8)	Enable SRQ when DAC port 4 is ready for trigger
Bit 4 (16)	Enable SRQ on trigger overrun
Bit 5 (32)	Enable SRQ on error
Bit 7 (128)	Enable SRQ on External input transition

Programming Note

1. The Service Request Mask bits are logically ORed together as received. To delete any one bit, it is necessary to use the M-mask option.
2. The ports and edge sense are selected for triggering by the External Trigger Mask (Q) command.

Programming Examples

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;M32 X"	Select SRQ on error
PRINT#1,"OUTPUT09;Z6 X"	Send an invalid command.
	Note: ERROR and SRQ LEDs should illuminate
PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;M2 X M4 X"	Select SRQ on DAC port 2 ready and SRQ on DAC port 3 ready
PRINT#1,"OUTPUT09;M6 X"	This command string would have the same effect as the command string sent in the line above where M2X plus



PRINT#1,"OUTPUT09;M-1 X"

M4X equals M6X.

The above command string will disable port 1 from generating an SRQ when ready.



4.16 N — Number of Cycles

Purpose	To specify how many times the values in a specified buffer will be output.	
Type	Port command	
Format	Nn	
Parameters	<p>Nn Specifies the number of cycles that will be output when a DAC port is in the waveform mode. n is between 0 and 65535, where n=0 will cause the DAC port to output the buffer values continuously</p> <p>N? Returns the number of cycles specified for use in the waveform mode</p>	
Description	<p>The Number of Cycles command specifies how many times the values in a specified buffer will be output. For example, if it is desired to output a waveform three times, the number of cycles would be three.</p>	
Programming Note	The default value for n is 1 (1 cycle).	
Programming Examples	<pre>PRINT#1,"CLEAR09" PRINT#1,"OUTPUT09;C3 P1 F0, 2 G1 N30 L0 I2000 X"</pre> <pre>PRINT#1,"TRIGGER"</pre>	<p>Reset the Model 213</p> <p>Select waveform control mode, select port 1, define a buffer with the first location=0 and a size=2, enable port 1 to trigger on GET, set number of cycles=30, set location pointer to 0 (first location), set time interval between points to 2sec.</p> <p>Trigger the Model 213. The unit will output the waveform 30 times then halt.</p>



4.17 O — Output Format

Purpose To select the output format used when sending a voltage value to the controller.

Type System command

Format On

Parameters
 O0 (default) Sets output format to volts in ± 10.0000 (fixed)
 O1 Sets output format to volts in decimal bits
 O2 Sets output format to volts in hexadecimal bits
 O? Returns current output format selected

Description The Output Format command selects the output format that the Model 213 uses when sending a voltage value to the controller. The available output formats are: 0 to $\pm 10.0000V$ (fixed point), 0 to ± 4000 (decimal bits), or 0 to \$0FFF (positive hexadecimal values) and \$F001 to \$FFFF (negative hexadecimal values). When using the hexadecimal format, negative voltages are specified using two's complement form.

The bit resolution is: $250\mu V/\text{bit}$, $1.25mV/\text{bit}$ and $2.5mV/\text{bit}$ for the $\pm 1V$, $\pm 5V$ and $\pm 10V$ ranges respectively.

Programming Examples

<pre>PRINT#1,"CLEAR09" PRINT#1,"OUTPUT09;C0 P1 A0 R2 X" PRINT#1,"OUTPUT09;O0 V4 X" PRINT#1,"OUTPUT09;V?" PRINT#1,"ENTER09" INPUT#2,A\$ PRINT A\$ PRINT#1,"OUTPUT09;O1X" PRINT#1,"OUTPUT09;V?" PRINT#1,"ENTER09" INPUT#2,A\$ PRINT A\$ PRINT#1,"OUTPUT09;O2X" PRINT#1,"OUTPUT09;V?" PRINT#1,"ENTER09" INPUT#2,A\$ PRINT A\$</pre>	<p>Reset the Model 213 Select direct control mode, port 1, disable autoranging, select $\pm 5V$ range Select output format in $+10.0000$ (fixed), output 4V Request the present voltage value</p> <p>Display shows V+04.00000 Set output format to decimal bits Request the present voltage value</p> <p>Display shows V#+03200 ($3200 \times 1.25mV = 4V$) Set output format in hexadecimal bits Request the present voltage value</p> <p>Display shows V#\$0C80 ($\\$C80 = 3200$)</p>
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4.18 P — Port

Purpose To determine which port is selected for use with subsequent commands.

Type System command

Format Pn

Parameters

- P1 Select port 1
- P2 Select port 2
- P3 Select port 3
- P4 Select port 4
- P? Return present port selection

Description The Port command determines which port is selected for use with subsequent commands. Only one port at a time may be selected. However, commands may be sent to all ports within one command string if each set of port commands is followed by the Execute (X) command.

Programming Examples

```
PRINT#1,"CLEAR09"           Reset the Model 213
PRINT#1,"OUTPUT09;C0 P1 A1  Select direct control mode, select port 1, en-
V7 X"                       able autoranging, output 7V
```

The unit will output 7 volts on port 1.

Sending multiple Port commands in one string:

```
PRINT#1,"CLEAR09"           Reset the Model 213
PRINT#1,"OUTPUT09; P1 C0 A0  Select port 1, select direct control mode, disable auto-
R3 V7 X P2 C0 A0 R3 V6 X"   ranging, select ±10V range, output 7V. Select port 2, se-
                             lect direct control mode, disable autoranging, select
                             ±10V range, output 6V
```

Port 1 will output 7V and port 2 will output 6V.

4.19 Q — External Trigger Mask

Purpose To enable or disable the specified DAC port for triggering by an external trigger.

Type System command

Format Qmask

Parameters

- Qmask Set bit(s) in the external trigger mask to specify which ports will be triggered by an external trigger event
- Q-mask Clears the specified bits in the external trigger mask
- Q0 Clears all bits in the external trigger mask
- Q? Returns current external trigger mask

Description The External Trigger Mask command enables or disables the specified DAC port for triggering by an external trigger signal. The external trigger signal is applied to the External Trigger/SRQ input on the Digital I/O port.

The mask bits are as follows (bit values are shown in parentheses):

Bit	Function
Bit 0 (1)	Enable trigger to DAC port 1
Bit 1 (2)	Enable trigger to DAC port 2
Bit 2 (4)	Enable trigger to DAC port 3
Bit 3 (8)	Enable trigger to DAC port 4
Bit 7 (128)	External input edge sense: 1 = negative edge triggered 0 = positive edge triggered

Programming Note The default value for all bits is 0.

Programming Examples

```
PRINT#1,"CLEAR09"
PRINT#1,"OUTPUT09;C1 Q129
P1 A0 R2 V2 X"
```

Reset the Model 213
Select indirect control mode, enable port 1 for triggering by an external trigger signal, trigger on negative edge of external trigger signal, select port 1, disable auto-ranging, select 5V range, output 2V. Port 1 will output 2V when an external trigger pulse is applied. (Port 1 will trigger on the negative edge of the external trigger pulse)

```
PRINT#1,"OUTPUT09;Q-12 X"
```

Clear bits 2 and 3 of external trigger mask to disable triggering of ports 3 and 4 when an external trigger pulse is received.

4.20 R — Range

Purpose	To specify which output voltage range is used on the selected port.	
Type	Port command	
Format	Rn	
Parameters	R0 Select DAC Ground range (DAC will output 0V only) R1 Select DAC $\pm 1V$ range (default) R2 Select DAC $\pm 5V$ range R3 Select DAC $\pm 10V$ range R? Returns DAC voltage range selection for selected port	
Description	<p>The Range command specifies which output voltage range is used on the selected port. Autoranging must be disabled (A0) when using the Range command, otherwise a command conflict error (E3) will occur.</p> <p>The bit resolution is: 250μV/bit, 1.25mV/bit and 2.5mV/bit for the $\pm 1V$, $\pm 5V$ and $\pm 10V$ ranges, respectively.</p>	
Programming Note	This command may not be used when autoranging is enabled (A1) for the selected port.	
Programming Examples	<pre>PRINT#1,"CLEAR09" PRINT#1,"OUTPUT09;C0 P1 A0 R2 V4 X"</pre>	Reset the Model 213 Select direct control mode, select port 1, disable auto-ranging, select $\pm 5V$ range, output 4V. The unit will output 4V on port 1

4.21 S — System Defaults

Purpose To save or restore a default setting for each command.

Type System command

Format Sn

Parameters

- S0 Restore the factory default command settings as the power on defaults
- S1 Save the current command settings as the power on defaults
- S2 Restore factory default calibration constants to NV-RAM
- S3 Save current calibration constants in NV-RAM
- S? Return the last System Defaults command executed

Description The System Defaults command may be used to save or restore a default setting for each command. The System Defaults command is also used to save or restore the calibration constants.

All calibration constants and a power on default setting for each command are saved in an internal non-volatile RAM (NV-RAM). Once calibration constants have been saved in the NV-RAM, they will be used whenever the DAC is commanded to output a voltage. The command options saved in NV-RAM will be the default settings when the unit is powered on.

Programming Note

Issuing an S2 or S3 command without the calibration enable switch in the depressed position will cause an calibration write protected (E4) error. After calibration, the S3 command would be used to save the new calibration constants in the NV-RAM.

Programming Example

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;A0 C1 O1 P2 Y1 X"	Configure port 2 as follows: autorange disabled, indirect control mode, output format in decimal bits, line feed (LF) terminator
PRINT#1,"OUTPUT09;S1X"	Save this configuration as the power on default configuration for port 2

4.22 T — Command Trigger Mask

Purpose To enable or disable the specified DAC port for triggering by the Trigger (@) command.

Type System command

Format Tmask

Parameters

Tmask	Set bit(s) in the command trigger mask to specify which ports will be triggered by the trigger command (@)
T-mask	Clears the specified bits in the command trigger mask
T0	Clears all bits in the command trigger mask
T?	Returns current command trigger mask

Description The Command Trigger Mask enables or disables the specified DAC port for triggering by the Trigger command (@).

The mask bits are as follows (bit values are shown in parentheses):

Bit	Function
Bit 0 (1)	Enable DAC port 1 to trigger on @
Bit 1 (2)	Enable DAC port 2 to trigger on @
Bit 2 (4)	Enable DAC port 3 to trigger on @
Bit 3 (8)	Enable DAC port 4 to trigger on @

Programming Note The default bit value for each port is 0.

Programming Example

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;C1 T1 P1 A0 R2 V4 X"	Select indirect control mode, enable port 1 to trigger on @, select port 1, disable autoranging, select ±5V range, output 4V.
PRINT#1,"OUTPUT09;@"	Trigger DAC port 2

The unit will output 4V on port 1.



4.23 U — Status

Purpose To cause the Model 213 to send a status message when next addressed to talk.

Type System command

Format Un

Parameters

U0	Send system status on talk
U1	Send DAC port 1 status on talk
U2	Send DAC port 2 status on talk
U3	Send DAC port 3 status on talk
U4	Send DAC port 4 status on talk
U5	Send digital input port status on talk
U6	Send overrun status on talk
U7	Send actual output voltage and range on talk
U8 (default)	Send programmed output voltage and range on talk
U?	Returns current status select setting

Description The Status (U0) command will cause the Model 213 to send a status message when next addressed to talk. The U5 is used to read the digital input port. (The Dval command is used to write to the digital output port.) The status of the unit may be read at any time without interfering with normal operation. Any error conditions are cleared after the status string is read by the controller.

The format of the status string returned by the Model 213 after receiving a Status command is as follows:

```

U0          *.*D###E#G###K#M###O#P#Q###S#T###U#W#Y#
U1, U2, U3, U4 A#C#F#####I#####L#####N#####P#R#V#.#####
U5          ###          ### is the decimal value of the input lines
U6          nnn          nnn specifies the port which was overrun:
                        001 = port 1, 002 = port 2, 004 = port 3,
                        008 = port 4, 006 = ports 2 and 3, etc.
U7          C#P#R#V±##.#####' where V is the actual output voltage
U8          A#C#P#R#V±##.##### where V is the programmed output voltage
    
```

where each # equals the parameter(s) corresponding to that command. The leading information *.* in the U0 status string is the revision level of the Model 213 firmware.

Programming Example

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;U0 X"	Request the system status of the unit
PRINT#1,"ENTER09"	
INPUT#2,A\$	Read the status string
PRINT A\$	Display = *.*D###E#G###K#M###O#P#Q###S#T###U#W#Y#



Where each # would show the current option in use for each command.

PRINT#1,"OUTPUT09;S0 X"	Restore the factory defaults as the power on defaults
PRINT#1,"CLEAR09"	Reset the Model 213. Issuing an IEEE-488 Interface Clear (IFC) will set the unit to its power on state.
PRINT#1,"OUTPUT09;U2 X"	Request the status of port 2
PRINT#1,"ENTER09"	Read the status
INPUT#2,A\$	
PRINT A\$	

Status string returned will be:

A1C0F01024,01024I01000L01024N00001P2R0V+00.00000

Autorange on, direct control mode, first buffer location = 1024, buffer size = 1024 locations, interval = 1000 milliseconds, location pointer = 1024, number of cycles = 1, port 2 is the selected port, range = R0 (the range will be R0, ground range, if autoranging is disabled), programmed output voltage is 0 volts.

Summary of the System Status (U0) information.

A#	Autorange
A0	Autorange disabled for selected DAC port
A1	Autorange enabled for selected DAC port
C#	Control mode
C0	Direct mode, trigger on Value (V) command
C1	Indirect mode, trigger on GET, external trigger or @
C2	Stepped mode, trigger on GET, external trigger or @
C3	Waveform mode, trigger on GET, external trigger or @
D###	Digital output
###	A number between 0 and 255 showing the programmed state of the digital output port
E#	Error message
E0	No error
E1	Unrecognized command
E2	Invalid command parameter
E3	Command conflict (e.g. attempting to select a range when in autorange)
E4	Calibration write protected
E5	Non-volatile RAM error

Note: Upon reading the error status the error condition is cleared.

Fstart,size	Buffer definition
start	starting location of the defined buffer (0 to 8191)
size	size of the defined buffer (1 to 8192)
Gn	GET trigger mask



G0	Clears all bits in the GET trigger mask
G1	Enable DAC port 1 to trigger on GET
G2	Enable DAC port 2 to trigger on GET
G4	Enable DAC port 3 to trigger on GET
G8	Enable DAC port 4 to trigger on GET

Note: The status indication reflects the sum of all received GET Trigger Mask commands.

It	Interval
t	Time interval in milliseconds (t = 1 – 65,535 milliseconds)

Note: The default interval is t = 1000 (1 second).

Kn	End or identify
K0	EOI asserted on last bus terminator
K1	EOI disabled

Ln	Buffer pointer n = present buffer pointer location (0 to 8191)
----	----------------------------------------------------------------

Mn	Service request mask
M0	SRQ is disabled
M1	SRQ on port 1 trigger ready
M2	SRQ on port 2 trigger ready
M4	SRQ on port 3 trigger ready
M8	SRQ on port 4 trigger ready
M16	SRQ on trigger overrun
M32	SRQ on error
M128	SRQ on external input transition

Note: The status indication reflects the sum of all received Service Request Mask commands.

Nn	Number of cycles (n = 1 to 65,535)
N0	Continuous

On	Output format
O0	Output format in volts (± 10.0000)
O1	Output format in decimal bits
O2	Output format in hexadecimal bits

Pn	Port
P1	Port 1 selected
P2	Port 2 selected
P3	Port 3 selected
P4	Port 4 selected

Qmask	External trigger mask
Q0	All bits are cleared in external trigger mask
Q1	Enable external trigger on port 1
Q2	Enable external trigger on port 2
Q4	Enable external trigger on port 3
Q8	Enable external trigger on port 4
Q128	External input is negative edge triggered

Note: The status indication reflects the sum of all received External Trigger Mask



commands.

Rn	Range
R0	DAC ground range selected (output 0V only)
R1	DAC $\pm 1V$ range selected
R2	DAC $\pm 5V$ range selected
R3	DAC $\pm 10V$ range selected
Sn	System defaults
S0	Restores the factory default values to NV-RAM
S1	Saves the current settings as default values to NV-RAM
S2	Restore calibration constants to calibration NV-RAM
S3	Save calibration constants to calibration NV-RAM
Tmask	Command trigger mask
T0	All bits are cleared in command trigger mask
T1	Enable command trigger on port 1
T2	Enable command trigger on port 2
T4	Enable command trigger on port 3
T8	Enable command trigger on port 4
	Note: The status indication reflects the sum of all received External Trigger Mask commands.
Un	Status
U0	System status sent on talk
Wn	Test
W0	TEST LED is off
W1	TEST LED is on
Yn	Terminator
Y0	CR LF
Y1	LF CR
Y2	CR only
Y3	LF only

4.24 V — Value Output

Purpose To program a voltage value to the selected DAC port.

Type Port command

Format Vval

Parameters

Vval	Write volts value for selected DAC port (val = 0 to ± 10)
V#val	Write bit value for selected DAC port (val = 0 to ± 4095)
V#\$valZ	Write hexadecimal bit value for selected DAC port, val = F001 to $\pm 0FFF$ (-095 to +4095)
V?	Returns current range and value for selected port in the format specified by the Output Format (On) command.

Description The Value Output command is used to program a voltage value to the selected DAC port. A voltage may be specified in any of three formats:

Volts:	V7.5 or V0.75E+1 (7.5V)
Decimal bits:	V#3000 ($3000 \times 2.5\text{mV} = 7.5\text{V}$)
Hexadecimal bits:	V#\$BB8Z (\$BB8 = 3000, which is also 7.5V)

The bit resolution is: $250\mu\text{V}/\text{bit}$, $1.25\text{mV}/\text{bit}$ and $2.5\text{mV}/\text{bit}$ for the $\pm 1\text{V}$, $\pm 5\text{V}$ and $\pm 10\text{V}$ ranges respectively.

Programming Notes

1. When programming in bits, autorange must be disabled (A0). The voltage output when programming in bits will depend on the range selected. Factory default value is zero volts (V+00.00000), ground range (R0).
2. When programming in hexadecimal bits, the hexadecimal number must be preceded by a "\$" and followed by the letter "Z".

Programming Examples

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;C0 P1 A0 R2 V4 X"	Select direct control mode, select port 1, disable autoranging, select $\pm 5\text{V}$ range, output 4V. The unit will output 4V on port 1.
PRINT#1,"OUTPUT09;C0 P1 A0 R1 V#3200 X"	Select direct control mode, port 1, disable autoranging, select $\pm 1\text{V}$ range, output 0.8V (voltage specified in decimal bits). The unit will output 0.8V on port 1. ($3200 \times 250\mu\text{V} = 0.8\text{V}$)
PRINT#1,"OUTPUT09;C0 P1 A0 R2 V#3200 X"	Select direct control mode, port 1, disable autoranging, select $\pm 5\text{V}$ range, output 4V (voltage specified in decimal bits). The unit will output 4V on port 1. ($3200 \times 1.25\text{mV} = 4\text{V}$)
PRINT#1,"OUTPUT09;C0 P1 A0 R3 V#3200 X"	Select direct control mode, port 1, disable autoranging, select $\pm 10\text{V}$ range, output 8V (voltage specified in deci-

+

mal bits). The unit will output 8V on port 1.
($3200 \times 2.5\text{mV} = 8\text{V}$)

+



4.25 W — Test

Purpose To verify that communication has been established with the Model 213.

Type System command

Format Wn

Parameters
W0 Turn off TEST LED
W1 Turn on TEST LED
W? Return the state of the TEST LED

Description The Test command is used to verify that communication has been established with the Model 213. If the W1 command is executed, the front panel TEST LED should light. If the W0 command is then executed, the TEST LED should turn off. This command can be used to test the connection between the IEEE-488 controller and the Model 213.

Programming Example

PRINT#1,"CLEAR09"	Reset the Model 213.
PRINT#1,"OUTPUT09;W1X"	Turn on the TEST LED. TEST LED on front panel should light
PRINT#1,"OUTPUT09;W0X"	Turn off the TEST LED. TEST LED on front panel should turn off



4.26 X — Execute

Purpose To direct the Model 213 to execute commands received since the last X.

Type System command

Format <command> X

Parameters None

Description Commands sent to the Model 213 will result in no action until the unit is instructed to execute these commands. This is done by issuing the Execute (X) command, usually as the last character of a command string. Commands sent without an X are stored in an internal buffer and are not executed until an X is received.

Any number of Execute commands may be inserted into the same command string. If a command is used more than once in a command string, the Execute command must be used before that command is used again.

Programming Example

```
PRINT#1,"CLEAR09"  
PRINT#1,"OUTPUT09;V4"  
PRINT#1,"OUTPUT09;X"
```

```
PRINT#1,"OUTPUT09;P1 V4 X  
P2 V3 X"
```

Reset the Model 213

Send "V4" to the unit command input buffer
Instruct the unit to execute its command input buffer.
The unit will output 4V on the selected port upon receipt of the X.

Two port (Pn) commands issued within the same string require an X after each usage.



4.27 Y — Terminator

Purpose To select the terminator sequence that marks the end of the instrument's data string.

Type System command

Format Yn

Parameters Y0 CR LF
Y1 LF CR
Y2 CR only
Y3 LF only
Y? Return present terminator selection

Description The IEEE-488 bus terminator(s) at power-on default to the terminator setting saved in the non-volatile RAM. The terminators may be programmed for any combination of carriage return (CR) and line feed (LF). The Y0 setting is the most commonly accepted terminator, CR-LF. Y1 reverses the sequence to send LF-CR. Y2 sends CR only and Y3 sends LF only. The terminator selection may be saved as the power on default setting by using the System Defaults (S1) command.

Programming Example PRINT#1,"OUTPUT09;Y3X" Select line feed terminator



4.28 Query Option

Purpose To determine the present configuration or mode of a previously executed command.

Type System command

Format <command>?

Parameters None

Description All Model 213 commands offer a Query (?) option which may be used to determine the present configuration or mode of a command previously executed. To use this option, the first letter of the command is used followed by a question mark (?). Any number of these query commands may be combined into one string to allow the user to construct a specialized status command requesting the Model 213 to return only that information which is of interest for a given application. The Execute (X) command is not needed when using the Query option of a command.

Programming Examples

PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;M32 X"	Select SRQ on error
PRINT#1,"OUTPUT09;M?"	Determine last M command executed
PRINT#1,"ENTER09"	Read data from the Model 213
INPUT#2,A\$	Display shows M032
PRINT A\$	
PRINT#1,"OUTPUT09;A0 C0 P1 R3 V8.12345 X"	Autoranging off, direct control mode, select port 1, ±100V range, output 8.12345V.
PRINT#1,"OUTPUT09;U8 X"	Request actual output voltage and range
PRINT#1,"ENTER09"	Read data from the Model 213
INPUT#2,A\$	
PRINT A\$	Display shows the status message A0C0P1R3V+08.1225 Note: the programmed voltage was rounded to the nearest value

Using the Query option to return the same status message:

PRINT#1,"OUTPUT09;A?C?P? R?V?"	Request the status of Channel 1
PRINT#1,"ENTER09"	Read data from the Model 213
INPUT#2,A\$	Display shows the status message A0C0P1R3V+08.12250
PRINT A\$	



4.29 Serial Poll Status Byte

The serial poll status byte is sent upon receiving the serial poll (SPOLL) command from the controller. Refer to the Service Request Mask (Mn) command description for details on how the serial poll byte is affected. To enable each bit to reflect the true status of the device, the appropriate Mn command must be executed. Below is a description of the significance of each bit in the serial poll status byte.

Bit Location	Value (SRQ bit value if set to logic 1)	
Bit 0 (LSB)	1	DAC port 1 ready for trigger
Bit 1	2	DAC port 2 ready for trigger
Bit 2	4	DAC port 3 ready for trigger
Bit 3	8	DAC port 4 ready for trigger
Bit 4	16	Trigger overrun
Bit 5	32	Error
Bit 6	64	Service request bit
Bit 7 (MSB)	128	External trigger input transition

Serial Poll Byte Description

- Bit 0 Set when DAC port 1 can accept a trigger. Cleared if the port is not ready or is generating a waveform in the waveform (C3) mode.
- Bit 1 Set when DAC port 2 can accept a trigger. Cleared if the port is not ready or is generating a waveform in the waveform (C3) mode.
- Bit 2 Set when DAC port 3 can accept a trigger. Cleared if the port is not ready or is generating a waveform in the waveform (C3) mode.
- Bit 3 Set when DAC port 4 can accept a trigger. Cleared if the port is not ready or is generating a waveform in the waveform (C3) mode.
- Bit 4 Set when the Model 213 receives a trigger while processing a previous trigger. Cleared by executing the Overrun Status (U6) or the Error Query (E?) commands and then reading the response.
- Bit 5 Set when one of the error conditions (listed under the Error command) occurs. Cleared by executing an Error Query (E?) or Status (U0) command.
- Bit 6 When the Model 213 generates a service request, this bit is set. This is used by the controller to determine that the service request was generated by the Model 213. This bit is cleared when the unit is serial polled.
- Bit 7 Set when an external trigger pulse is received on the external trigger/SRQ input and the Model 213 is properly armed. Cleared when the unit is serial polled.





**Programming
Example**

PRINT#1,"OUTPUT09;S0 X"	Restore the factory power on defaults
PRINT#1,"CLEAR09"	Reset the Model 213
PRINT#1,"OUTPUT09;M32 X"	Select SRQ on error
PRINT#1,"OUTPUT09;P7 X"	Send an invalid bus command. ERROR and SRQ LEDs should illuminate
PRINT#1,"SPOLL09"	Serial poll status byte returned will be 111 (64 + 32 + 8 + 4 + 2 + 1)

The interpretation of this serial poll status byte is as follows:

- 64 The Model 213 was the source of the SRQ.
- 32 There was an error
- 8 Port 4 is ready for a trigger
- 4 Port 3 is ready for a trigger
- 2 Port 2 is ready for a trigger
- 1 Port 1 is ready for a trigger

When the unit is serial polled, the SRQ LED will turn off.



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SECTION 5

Calibration

5.1 CALIBRATION OVERVIEW

Each port of the Model 213 should be calibrated every 12 months or if the calibration report (described in paragraph 5.4) shows that the unit is not operating within the specifications. Calibration involves computing the correct calibration constants for the offset and gain for each range and polarity. These constants are then stored in the non-volatile RAM for subsequent use. When a DAC port is commanded to output a voltage, the calibration constants are sent to internal D/A converters, which set the offset and gain for the given range and polarity.

The Model 213 may be calibrated by the following two methods:

1. Calibration may be performed manually.
2. Calibration may be performed automatically with the Model 213 acting as a bus controller connected to a Model 199 DMM. A calibration report will then be printed if the Model 213 is connected to an IEEE-488 printer.

The CAL ENABLE switch on the rear panel must be in the closed (depressed) position to allow the new calibration constants to be saved in the non-volatile RAM. If the switch is not in this position, the calibration constants may be changed but they will not be saved. If the unit is then turned off, the calibration constants will revert to their last saved values. After calibration is completed, the CAL ENABLE switch should be set to the open position (switch cap flush with the rear panel) to prevent accidental changing of the calibration constants.

5.2 CALIBRATION PROCEDURE

The calibration procedures used to compute the gain and offset calibration constants are explained below. The example below shows how to compute the positive gain, negative gain, and offset calibration constants for the $\pm 10V$ range of port 1. The equipment needed to calibrate the Model 213 manually is listed below:

1. Voltmeter with a full scale error of 0.01% or better

2. IEEE-488 controller or a PC with an IEEE-488 interface
3. IEEE-488 cable
4. Test leads
5. The analog output connector included with the Model 213

Commands that must be sent are listed after each step. If you are using a PC with an IEEE-488 interface, IOtech Driver488 software, and GWBASIC or BASICA, you can send commands to the Model 213 directly by using the Keyboard Controller program listed in Appendix D. For example, to send the command W1X (this will turn on the TEST light on the front panel of the Model 213) you would type the following after the CMD> prompt: OUTPUT 09;W1X then press the Return key.

5.3 MANUAL CALIBRATION PROCEDURE

1. Connect the Model 213 to the IEEE-488 controller using an IEEE-488 cable.
2. Connect the negative input of the voltmeter to the Port 1 L (Low) output and connect the positive input of the voltmeter to the Port 1 H (High) output. Set the IEEE-488 bus address of the Model 213 to 9. Turn the unit on and allow it to warm up for at least one hour before beginning the calibration procedure.
3. Initialize the Model 213 by sending an IEEE-488 Selective Device Clear (SDC).

Command sent to the Model 213:
CLEAR 09

4. Select port 1, direct control mode, autoranging disabled, select the $\pm 10V$ range, set the offset to 0, set the positive and negative gain constants to 128, program the port to output 0V.

Command sent to the Model 213:
OUTPUT 09; P1 C0 A0 R3 H0 J128,128 V0 X

NOTE

This procedure will calibrate the $\pm 10V$ range on port 1. To calibrate all ranges on all ports, you must repeat the procedure 11 times (first by changing ranges, then by changing ports).

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5. Measure and record the port 1 output voltage. Call this voltage ZVAL.
6. Program the Model 213 port 1 to output 10V.

Command sent to the Model 213:
OUTPUT 09; V10 X

7. Measure and record the port 1 output voltage. Call this voltage PVAL.
8. Program the Model 213 port 1 to output -10V.

Command sent to the Model 213:
OUTPUT 09; V-10X

9. Measure and record the port 1 output voltage. Call this voltage NVAL.
10. Set the positive and negative gain constants to maximum (255) and program the port to output 10V.

Command sent to the Model 213:
OUTPUT 09; J255,255 V10 X

11. Measure and record the port 1 output voltage. Call this voltage MVAL.
12. Set the positive and negative gain constants to minimum (0) and program the port to output 10V.

Command sent to the Model 213:
OUTPUT 09; J0,0 V10 X

13. Measure and record the port 1 output voltage. Call this voltage NOVAL.

The gain calibration constant is then computed using the following formulas:

$$\text{Gain adjustment per bit} = (\text{MVAL} - \text{NOVAL}) / 255$$

$$\text{Positive error in volts} = \text{PVAL} - \text{ZVAL} - 10$$

$$\text{Positive gain calibration constant} = 128 - \text{positive error} / \text{gain adjust per bit}$$

$$\text{Negative error in volts} = \text{NVAL} - \text{ZVAL} + 10$$

$$\text{Negative gain calibration constant} = 128 + \text{negative error} / \text{gain adjust per bit}$$

14. Once the gain calibration constants have been computed, the positive and negative gains should be set to these new values. This can be done using the Gain Calibration (Jpos,neg) command. For example, if the positive and negative gain calibration constants are 131 and 148 respectively, the command J131,148 X should be sent to the Model 213.

The offset calibration constant should be computed after setting the gain calibration constant to its new value. (The offset calibration constant is affected by the gain calibration constant.) The procedure for computing the offset calibration constant is shown below.

1. Set the offset of port 1 to minimum (-255) and program port 1 to output 0 volts. Command sent to the Model 213:
OUTPUT 09; H-255 V0 X
2. Measure and record the port 1 output voltage. Call this voltage NOFFVAL.
3. Set the offset of port 1 to maximum (+255) and program port 1 to output 0 volts. Command sent to the Model 213:
OUTPUT 09; H255 V0 X
4. Measure and record the port 1 output voltage. Call this voltage POFFVAL.
5. Set the offset of port 1 to 0 and program port 1 to output 0V. Command sent to the Model 213:
OUTPUT 09; H0 V0 X
6. Measure and record the port 1 output voltage. Call this voltage ZERR.

The offset calibration constant is computed using the following formulas:

$$\text{Offset adjustment per bit} = (\text{POFFVAL} - \text{NOFFVAL}) / 510$$

$$\text{Offset calibration constant} = -(\text{ZERR} / \text{offset adjustment per bit})$$

7. The offset calibration constant should now be set to the newly computed value by using the Hn command. For example, if the offset calibration constant is 18, the command H18 X should be sent to the Model 213.

5.4 STAND-ALONE CALIBRATION

Fully automatic calibration of the Model 213 may be performed by connecting the unit to a Model 199 System DMM/Scanner. In the automatic calibration mode, the Model 213 acts as a bus controller. Automatic calibration requires the unit to be connected to a Model 199 on the IEEE-488 bus and with the DAC ports connected to the scanner inputs using a calibration cable. An optional IEEE-488 printer may also be connected on the bus and when calibration is finished, the Model 213 will print a calibration report. Any other device which functions as a bus controller must be disconnected from the bus during the auto-calibration. The IEEE-488 address of the Model 199 must be set to 26 and the address of the printer must be 5. The address of the Model 213 is internally set to 0 regardless of the rear panel address switch settings.





With the unit off, set SW1-8 on the rear panel in the up position to enable the stand-alone calibration mode. This is shown in Figure 5-1.

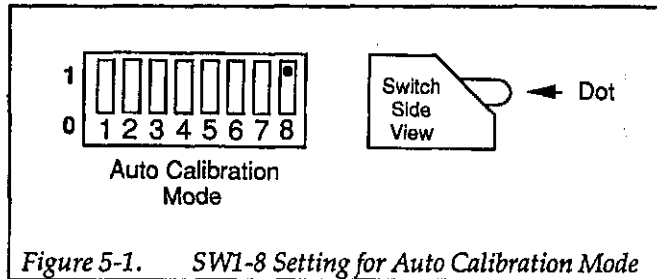


Figure 5-1. SW1-8 Setting for Auto Calibration Mode

controllers should be disconnected from the IEEE-488 bus.

You will then need to make a calibration cable using the analog connectors for the Model 213 and the Model 199. Both connectors have screw terminals, therefore no soldering is required. The wiring for this cable is shown in Figure 5-3.

Once the calibration cable has been made, the analog output of all Model 213 ports can then be connected to the Model 199 as shown in Figure 5-4.

The Model 199 and optional printer must then be connected to the IEEE-488 connector on the rear panel of the Model 213 as shown in Figure 5-2. Any other IEEE-488

When power is applied to the Model 213 its TEST LED will flash indicating that auto-calibration is taking place then turn off when the calibration has finished. If any er-

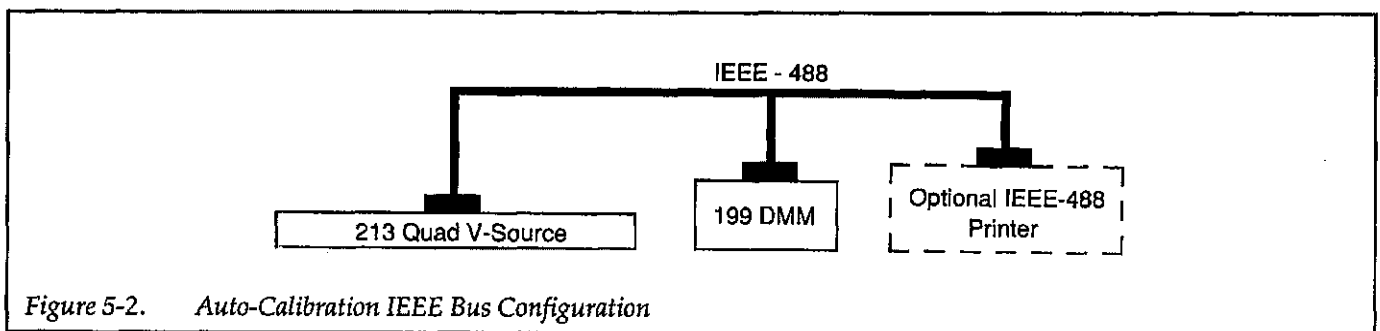


Figure 5-2. Auto-Calibration IEEE Bus Configuration

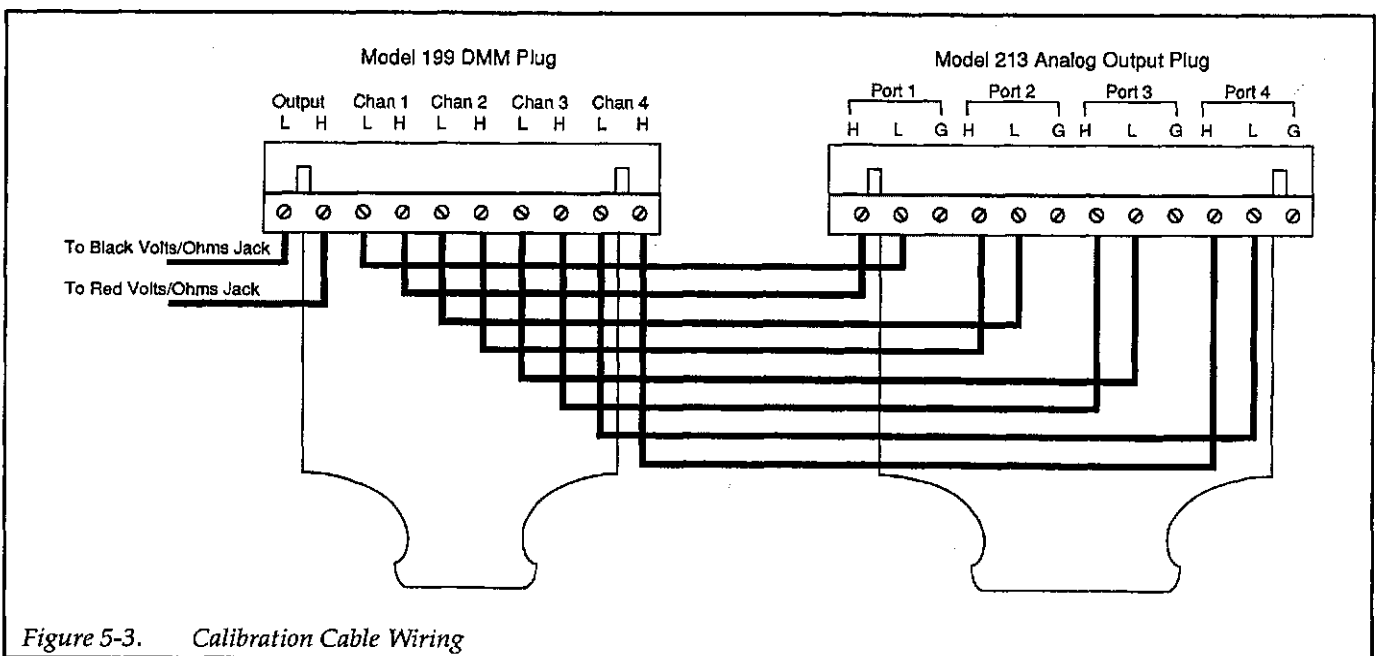


Figure 5-3. Calibration Cable Wiring



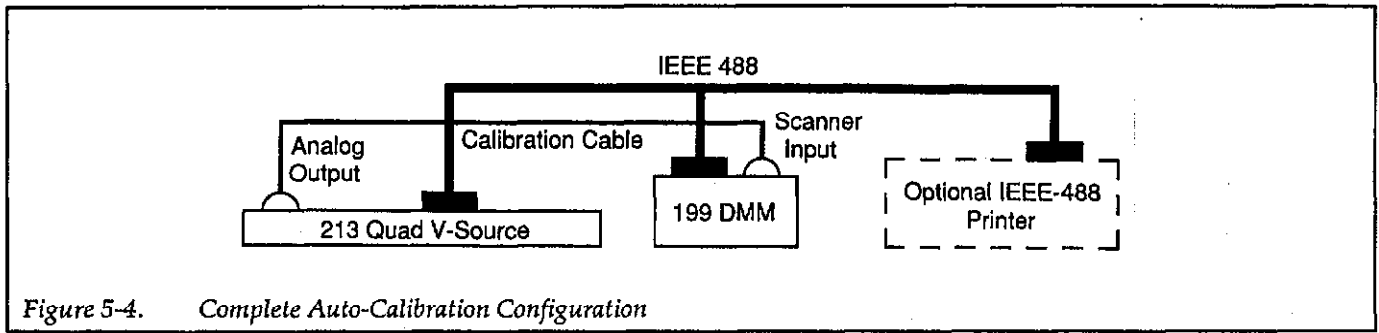


Figure 5-4. Complete Auto-Calibration Configuration

rors occur during calibration the ERROR LED will flash and the calibration procedure will be aborted.

During auto-calibration, several messages will be displayed on the Model 199 in upper-case characters. Each message will be displayed for two seconds. The messages will be displayed in the same order as listed below. The meanings of the messages are described below.

DAC488/4 — This message is displayed if the Model 213 is properly connected to the Model 199.

AUTO_CAL — This message is displayed after message 1 to show that the Model 213 is in auto-calibration mode.

NO_SCANNER — This message is displayed if the Model 199 does not have a scanner installed.

NO_CONNECT — This message is displayed if the calibration cable is not connected or the wiring is incorrect.

CALIBRATE — This message is displayed if the CAL ENABLE switch is in the depressed position, which will allow the new calibration constants to be saved in the non-volatile RAM.

CAL_OFF — This message is displayed if the calibration enable switch is not in the depressed position. The Model 213 will not perform the auto-calibration. However, the present calibration constants will be used in the verify procedure. This approach may be used to verify the calibration of the unit without recalibrating it.

VERIFY — This message is displayed when the Model 213 has finished calibrating all ports and is ready to print

a calibration verification report. If a printer is connected, a verification report is printed listing all voltages tested. Any failures are noted on the report. A summary report is also printed which lists the calibration constants for each port and range.

NO_PRINTER — This message is displayed if the Model 213 does not find a printer connected at bus address 5.

CAL_PASSED — This message is displayed if no errors occur during the verification tests.

CAL_FAILED — This message is displayed if any errors occur during the verification tests.

Note: All lines sent to the printer are terminated with a carriage return (CR)

5.5 CALIBRATION REPORT

After stand-alone calibration finishes, a calibration report will be printed if the Model 213 is connected to an IEEE printer. The report will appear as shown in Table 5-1.

A report similar to the one shown will be printed for all ports. The Nominal voltage is the voltage the DAC was programmed to output. The Actual voltage is the actual voltage measured by the Model 199 DMM. Error is the difference between the nominal and the actual values. Result will show Pass if the port is functioning within the stated specifications.

After the last port is tested, a summary report will be printed similar to the one shown in Table 5-2.



Table 5-1. Calibration Report Format

IOtech		DAC488/4		Performance Verification			Port #1
Nominal	Actual	Error	Result	Nominal	Actual	Error	Result
+10.000	+10.000	+0.0003	Pass	-10.000	-10.000	-0.0004	Pass
+9.0000	+9.0005	+0.0005	Pass	-9.0000	-9.0006	-0.0006	Pass
+8.0000	+8.0007	+0.0007	Pass	-8.0000	-8.0008	-0.0007	Pass
+7.0000	+7.0003	+0.0003	Pass	-7.0000	-7.0006	-0.0006	Pass
+6.0000	+6.0006	+0.0007	Pass	-6.0000	-6.0010	-0.0010	Pass
+5.0000	+5.0000	-0.0000	Pass	-5.0000	-5.0003	-0.0003	Pass
+4.0000	+4.0004	+0.0004	Pass	-4.0000	-4.0007	-0.0007	Pass
+3.0000	+3.0000	-0.0000	Pass	-3.0000	-3.0006	-0.0006	Pass
+2.0000	+2.0002	+0.0002	Pass	-2.0000	-2.0008	-0.0008	Pass
+1.0000	+0.9999	-0.0001	Pass	-1.0000	-1.0004	-0.0004	Pass
+0.0000	-0.0000	-0.0000	Pass				
+5.0000	+5.0000	-0.0000	Pass	-5.0000	-4.9998	-0.0002	Pass
+4.5000	+4.5001	+0.0001	Pass	-4.5000	-4.4999	+0.0001	Pass
+4.0000	+4.0001	+0.0001	Pass	-4.0000	-4.0000	+0.0000	Pass
+3.5000	+3.5002	+0.0002	Pass	-3.5000	-3.4999	+0.0001	Pass
+3.0000	+3.0003	+0.0003	Pass	-3.0000	-2.9999	+0.0001	Pass
+2.5000	+2.5003	+0.0003	Pass	-2.5000	-2.5000	+0.0000	Pass
+2.0000	+2.0004	+0.0004	Pass	-2.0000	-2.0000	+0.0000	Pass
+1.5000	+1.5003	+0.0003	Pass	-1.5000	-1.4997	+0.0002	Pass
+1.0000	+1.0004	+0.0004	Pass	-1.0000	-0.9999	+0.0001	Pass
+0.5000	+0.5003	+0.0003	Pass	-0.5000	-0.4997	+0.0003	Pass
+0.0000	-0.0000	-0.0000	Pass				
+1.0000	+1.0000	+0.0000	Pass	-1.0000	-0.9999	+0.0001	Pass
+0.9000	+0.9001	+0.0001	Pass	-0.9000	-0.9000	+0.0000	Pass
+0.8000	+0.8000	+0.0000	Pass	-0.8000	-0.7999	+0.0001	Pass
+0.7000	+0.7001	+0.0001	Pass	-0.7000	-0.6999	+0.0001	Pass
+0.6000	+0.6001	+0.0001	Pass	-0.6000	-0.5999	+0.0001	Pass
+0.5000	+0.5001	+0.0001	Pass	-0.5000	-0.4999	+0.0001	Pass
+0.4000	+0.4001	+0.0001	Pass	-0.4000	-0.3999	+0.0001	Pass
+0.3000	+0.3001	+0.0001	Pass	-0.3000	-0.2999	+0.0001	Pass
+0.2000	+0.2001	+0.0001	Pass	-0.2000	-0.1999	+0.0001	Pass
+0.1000	+0.1001	+0.0001	Pass	-0.1000	-0.0999	+0.0001	Pass
+0.0000	+0.0000	+0.0000	Pass				



Table 5-2. Calibration Report

Calibration Report						
Manufacturer: IOtech		Model: DAC488/4			Serial #	
Port	Range	%Err + FS	%Err - FS	Offset	J Vals	H Val
1	1	+0.0044	-0.0002	+0.0000	130, 126	-10
1	2	+0.0046	+0.0024	-0.0000	132, 127	18
1	3	+0.0033	+0.0038	-0.0000	131, 126	20
2	1	+0.0021	-0.0066	-0.0000	120, 137	12
2	2	-0.0013	-0.0036	-0.0000	123, 139	-8
2	3	-0.0003	-0.0028	-0.0001	121, 138	5
3	1	+0.0024	+0.0004	-0.0000	140, 148	-4
3	2	-0.0027	+0.0003	-0.0000	123, 122	7
3	3	+0.0018	-0.0012	-0.0000	130, 133	12
4	1	-0.0015	+0.0008	-0.0000	121, 130	5
4	2	+0.0036	-0.0011	-0.0000	142, 156	-10
4	3	+0.0013	+0.0010	-0.0000	123, 138	1

A description of each item in the summary calibration report is given below:

Port: This column shows the port being tested.

Range: 1: ±1V range, 2: ±5V range, 3: ±10V range

%Err +FS: Percent of error at positive full scale reading. This is computed using the following formula:

$$\frac{(\text{Full Scale Reading} - \text{Full Scale Voltage})}{(\text{Full Scale Voltage})} \times 100\% = \% \text{Err} + \text{FS}$$

For example, if a DAC port is programmed for 10V on the 10V scale and the voltmeter reads 10.0001V, then the percent of error would be:

$$\frac{(10.0001 - 10.0000)}{(10.0000)} \times 100\% = +0.001\%$$

%Err - FS: Percent of error at negative full scale reading. This is computed using the following formula:

$$\frac{(\text{Full Scale Reading} - \text{Full Scale Voltage})}{(\text{Full Scale Voltage})} \times 100\% = \% \text{Err} - \text{FS}$$

For example, if a DAC port is programmed for -5V on the 5V scale and the voltmeter reads -5.0002V, then the percent of error would be:

$$\frac{(-5.0002 - -5.0000)}{(-5.0000)} \times 100\% = -0.004\%$$

Offset: This is the measured output voltage when the port is programmed to output 0 volts.

J Vals: These number are the gain calibrations constants for the range and port. The positive gain calibration constant is printed first.

H Val: This number is the offset calibration constant for the range and port.





SECTION 6

Service Information

6.1 ORDERING INFORMATION

To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover for addresses. When ordering, include the following information:

1. Instrument model number
2. Instrument serial number
3. Parts description
4. Circuit designation (if applicable)

6.2 FACTORY SERVICE

If the instrument is to be returned to the factory for service, please complete the service form, which follows this section, and return it with the instrument.

WARNING

The procedures included in this section are for used by qualified service personnel only. Do not perform these procedures unless qualified to do so. Never open the Model 213 case while it is connected to the ac line. Internal voltage potentials exist which could cause personal injury or death.

6.3 LINE VOLTAGE SELECTION

The Model 213 may be operated from 90-125V or 180-250V, 50-60Hz ac. The operational voltage is set by an internal switch (S104). The interface was shipped from the factory set for the operating voltage marked on the rear panel. To change the operating voltage, it is necessary to open the enclosure and change the setting of S104 according to the following instructions:

WARNING

Disconnect the power cord from the ac line and from the Model 213. Disconnect any cables prior to disassembly. Never open the case while it is connected to the ac line. In-

ternal voltage potentials exist which could cause personal injury or death.

1. Place the quad voltage source on a flat surface. Remove the eight screws on top of the case and remove the top cover. Located next to the main power supply transformer is the line voltage selection switch S104. Using a small screwdriver, insert the tip of the screwdriver into the slot of the switch and move the switch to the left or right so that the desired line voltage selection appears on the switch.
2. Install a power line fuse appropriate for the line voltage. See the following paragraph for the fuse replacement procedure.
3. Make note of the new voltage setting for later reference and carefully re-assemble the unit.

6.4 FUSE REPLACEMENT

The Model 213 contains an internal ac line fuse. The fuse is located next to the internal line voltage switch (S104). This fuse may be replaced by using the procedures found in the following paragraphs.

WARNING

Disconnect the power cord from the ac line and from the Model 213. Disconnect any cables prior to disassembly.

1. Turn off the power and disconnect the line cord and all other test cables from the interface.
2. Place the interface on a flat surface. Remove the eight screws on top of the case and remove the top cover.
3. The fuse is located next to the line voltage selection switch (S104). Gently pull upward on the plastic fuse housing. The entire housing with the fuse inside should be removed.
4. Open the fuse housing by pushing up on the tab on the bottom of the housing.
5. Remove the fuse, and replace it with the proper type using Table 6-1 as a guide.

CAUTION

Do not use a fuse with a rating higher than specified or instrument damage may occur.



If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

Table 6-1. Line Fuse Values

Line Voltage	Fuse Type	Keithley Part No.
90-125V	3/4A, 250V, Slo Blo, 3AG	FU-19
180-250V	3/8A, 250V, Slo Blo, 3AG	FU-18

- Close the housing and insert it into the fuse holder.
- Make note of the fuse rating for later reference and carefully re-assemble the unit.

6.5 HIGH VOLTAGE/HIGH CURRENT DIGITAL OUTPUTS

In addition to interfacing with TTL logic levels, the digital output lines can be configured as high voltage/high current outputs. These outputs can sink up to 100mA at 50V dc through the use of open collector drivers with integral diodes for inductive load transient suppression. This allows for interfacing the digital outputs relays, lamps, and solenoids.

To configure the digital output lines for this purpose, it is necessary to open the enclosure and reposition the configuration jumper according to the following instructions. Disconnect the power cord from the ac line and from the interface. Disconnect any IEEE-488 analog or digital I/O cables prior to disassembly.

WARNING

Disconnect the power cord from the ac line and from the Model 213. Disconnect any cables prior to disassembly. Never open the case while it is connected to the ac line. Internal voltage potentials exist which could cause personal injury or death.

Place the interface on a flat surface. Remove the eight screws on top of the case and remove the top cover. Located in front of the internal DIP switch (S102) are three sockets and a configuration jumper. This jumper is factory set to configure the digital output lines for low level TTL logic levels as shown below in Figure 6-1.

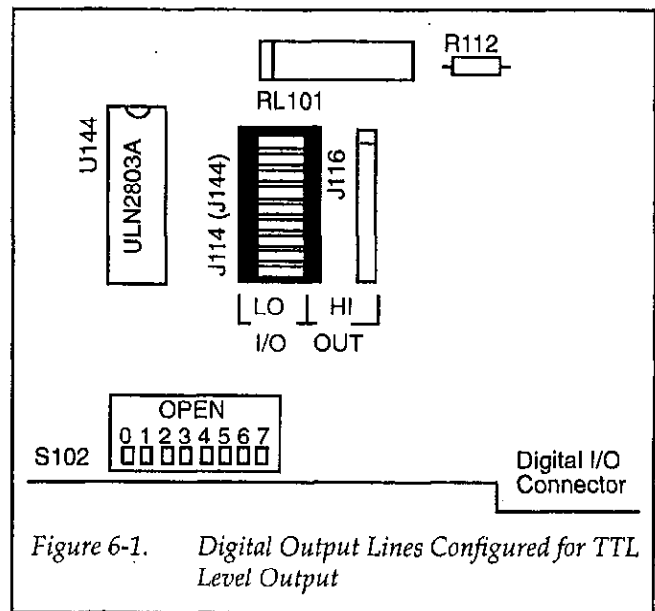


Figure 6-1. Digital Output Lines Configured for TTL Level Output

To configure the digital output lines as high voltage high current outputs, remove the configuration jumper and reinsert it so that the center socket is now connected to the right socket as shown in Figure 6-2.

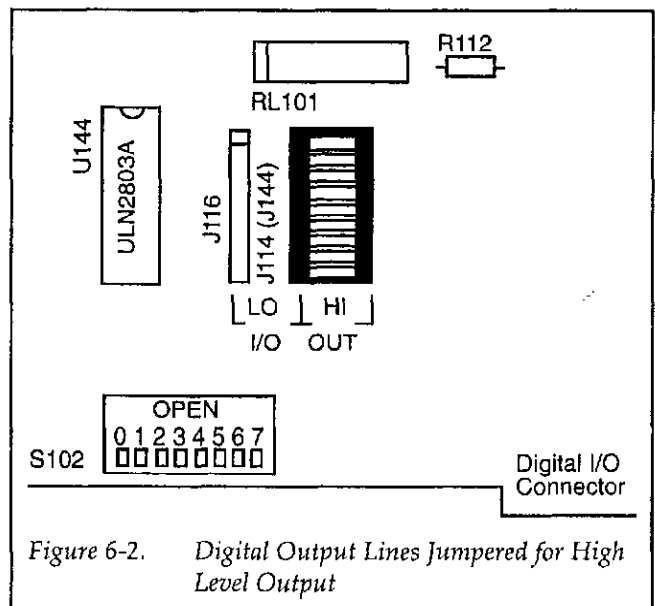


Figure 6-2. Digital Output Lines Jumpered for High Level Output

Once the jumper has been repositioned for your particular application, make note of the new setting for later reference and carefully reassemble the unit.

6.6 THEORY OF OPERATION

The heart of the Model 213 is a 6809 microprocessor (U101) supported by 16K bytes of firmware EPROM (U102) and 32K bytes of battery-backed-up RAM (U103). Interface to the IEEE-488 bus is accomplished by a 9914



interface chip (U105). A 65C22 (U109) generates real-time interrupts for the firmware operating system and also drives the front panel LEDs.

Isolation of the analog ports is accomplished using separate bipolar power supplies for each port. Opto-isolators are used to isolate the digital and analog circuitry. High-voltage, high-current output capability is available on the digital output port through a 74HCTLS240 and a ULN2803A peripheral driver (U144).

Calibration of the analog ports is accomplished by the use of two 8-bit D/A converters on each analog circuit. One converter is used to adjust the gain and the other the offset.

6.7 COMPONENT LAYOUTS AND REPLACEABLE PARTS LIST

Component layouts for the mother board and analog board are shown in Figures 6-3 and 6-4. Tables 6-2, 6-3 and 6-4 contain replaceable parts information.



Table 6-2. Model 213 Mother Board, Parts List

CIRCUIT DESIGNATION	DESCRIPTION
C101-C129	0.1uF 25V Ceramic
C131-C142	0.1uF 25V Ceramic
C168-C170	0.1uF 25V Ceramic
C130	0.01uF 25V Ceramic
C143,C144	15pF 25V Ceramic
C146	10,000uF 25V Electrolytic
C151,C152	220uF 25V Electrolytic
C156,C157	220uF 25V Electrolytic
C161,C162	220uF 25V Electrolytic
C166,C167	220uF 25V Electrolytic
C145,C147	10uF 25V Electrolytic
C148,C149	10uF 25V Electrolytic
C150,C153	10uF 25V Electrolytic
C154,C155	10uF 25V Electrolytic
C158,C159	10uF 25V Electrolytic
C160,C163	10uF 25V Electrolytic
C164,C165	10uF 25V Electrolytic
D107,D108	Diode 1N5400
D110,D111	Diode 1N5400
D113,D114	Diode 1N5400
D116,D117	Diode 1N5400
D119,D120	Diode 1N5400
D109,D112	1N914 Diode
D115,D118	1N914 Diode
D101-D106	Green PC Mount LED
D121-D124	Bridge Rectifier RB151
J101	IEEE Connector
J102	DB25 Female Connector
J103	12 Pin Jack
J114-J116	8 pin SIP socket 0.1" centers
R101	10k Ω 1/4 Watt
R102	7 \times 4.7K Ω Network
R103	10K Ω Resistor 1/4 Watt
R104	7 \times 470 Ω Network
R105	9 \times 10K Ω Network
R106-R108	470 Ω Resistor 1/4 Watt
R113-R115	470 Ω Resistor 1/4 Watt
R120-R122	470 Ω Resistor 1/4 Watt
R127-R129	470 Ω Resistor 1/4 Watt
R109-R111	4.7K Ω Resistor 1/4 Watt
R116-R118	4.7K Ω Resistor 1/4 Watt
R123-R125	4.7K Ω Resistor 1/4 Watt
R130-R132	4.7K Ω Resistor 1/4 Watt
R112,R119	20K Ω Metal Film 1 % 100ppm/deg C, 1/4 Watt
R126,R133	20K Ω Metal Film 1 % 100ppm/deg C, 1/4 Watt

RL101-RL104	Relay SPST
S101	Switch for Calibration
S102	8 Pole Piano DIP Switch
S103	Power Switch
S104	110/220V Switch
T101	Transformer
T102-T105	Transformer
U101	68B09
U103	M51257L-10 (in DS1213C socket)
U105	9914A
U106	75160
U107	75162
U108	LT7705
U109	65B22
U110,U112	74LS04
U111	74LS155
U113	74LS08
U114	74HCT244
U115	74LS244
U116	74LS373
U117-U122	6N137 Opto Isolator
U124-U129	6N137 Opto Isolator
U123	7416
U130	LM309 Regulator
U131,U134	78L05 Regulator
U137,U140	78L05 Regulator
U132,U135	78L15 Regulator
U138,U141	78L15 Regulator
U133,U136	79L15 Regulator
U139,U142	79L15 Regulator
U143	74HCT240
U144	ULN2803A
Y101	8MHz Crystal

Table 6-3. Model 213 Analog Board, Parts List

CIRCUIT DESIGNATION	DESCRIPTION
C201-C218	0.1 μ F Ceramic 25V
C219,C220	100pF Ceramic
C221	220pF Ceramic
C222	0.1 μ F Polyester Film 50V
C223,C224,C235	0.001 μ F Polyester Film 50V
D202	1N914 Diode
R201,R219	1K Ω Metal Film 1% 100ppm/deg C 1/4 Watt
R202	562 Ω Metal Film 1% 100ppm/deg C 1/4 Watt
R203	47.5K Ω Metal Film 1% 100ppm/deg C 1/4 Watt
R204,R208,R209	20K Ω Metal Film 0.1% 25ppm/deg C 1/4 Watt
R213,R216,R217	20K Ω Metal Film 1% 100ppm/deg C 1/4 Watt
R205	33.2K Ω Metal Film 0.1% 25ppm/deg C 1/4 Watt
R206	2K Ω Trimpot
R210	10K Ω Metal Film 0.1% 25ppm/deg C 1/4 Watt
R211	8K Ω Metal Film 0.1% 25ppm/deg C 1/4 Watt
R212	2K Ω Metal Film 0.1% 25ppm/deg C 1/4 Watt
R214	10.2K Ω Metal Film 1% 100ppm/deg C 1/4 Watt
R215	18.2K Ω Metal Film 1% 100ppm/deg C 1/4 Watt
R218	499K Ω Metal Film 1% 100ppm/deg C 1/4 Watt
R221	100 Ω Metal Film 1% 100ppm/deg C 1/4 Watt
U201-U205	CD4094B 8-Bit CMOS Shift Register
U208	AD7541AKN 12-Bit D/A
U206,U207	AD7523JN 8-Bit D/A
U211-U213	LF442N Dual Op Amp
U214	LF412N Dual Op Amp
U209,U210	DG211AN Quad Analog Switch

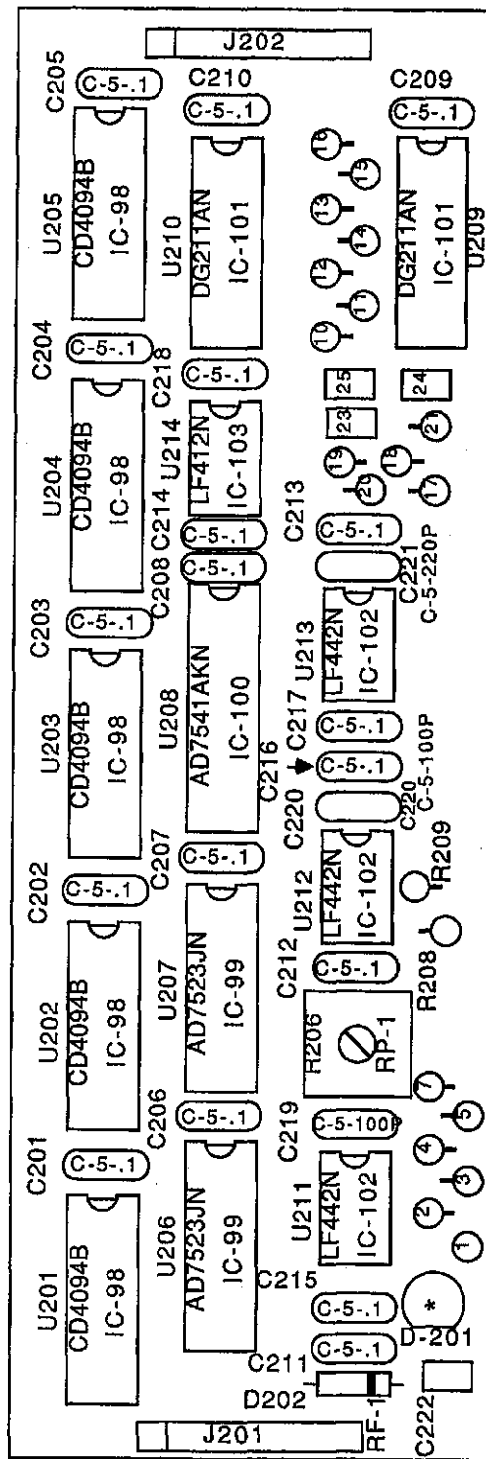


Figure 6-4. Analog Board, Component Location Drawing

Table 6-4. Model 213 Miscellaneous, Parts List

DESCRIPTION	KEITHLEY PART NO.
Feet (4)	FE-24-1
Front Panel Overlay	C213-303
Fuse, 3/4A	FU-19
Fuse, 3/8A	FU-18
Instruction Manual	213-901-00
Line Cord	CO-19
Rack Ears (2)	B2361-311
Screws (4), for rack ears	10-32 × 3/8PFHBLKOX
Screws (8), nylon	10-32 × 1/4PBHBLKNY
12-pin Analog Output Connector	231-CON
25-pin Digital I/O Connector	CS-400

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APPENDIX A

Command Summary

Command	Code	Description
Trigger (system command)	@	Commanded trigger. Triggers the ports specified in the command trigger mask (Tmask). This command does NOT require the Execute (X) command to operate.
Autorange (port command)	A0 A1 (default) A?	Disable autoranging for selected DAC port Enable autoranging for selected DAC port Returns current autorange setting.
Buffer Data (port command)	Brng,volts Brng,#val Brng,#\$valZ B?	Write volts value in buffer location for selected DAC port. Write decimal bit value in buffer location for selected DAC port. Write hexadecimal bit value in buffer location for selected DAC port. Returns the range and value at the location pointer for the selected DAC port in the format specified by the Output Format (On) command. <i>Notes:</i> Using this command causes the location counter to increment after the value has been written to or read from the buffer. Factory default buffer values are zero, range 0. rng=0-3, volts=number without a V prefix.
Control Mode (port command)	C0 (default) C1 C2 C3 C?	Direct mode Indirect mode Stepped mode Waveform mode Returns current control mode for selected port <i>Notes:</i> Selecting a control mode stops the prior mode activity and re-arms the port for the selected mode.
Digital Output (system command)	Dval D?	Outputs the value on the digital output port Returns the current value of the digital output port. <i>Notes:</i> The default output value is 0. val=0-255.
Error Query (port command)	E? E1 E2 E3 E4 E5	Returns error status which indicates the last error encountered Invalid command Invalid command parameter Command conflict Calibration write protected Non-volatile RAM error <i>Notes:</i> Upon reading the error status the error is cleared.
Buffer Definition (port command)	Fstart,size F?	Specifies starting location and number of locations used in the internal buffer for the selected port. $0 \leq \text{start} \leq 8191$; $1 \leq \text{size} \leq 8192$. Returns the starting buffer location and number of locations used in the defined buffer. <i>Notes:</i> The sum of loc+num must be less than or equal to 8192. The default values are 0,1024; 1024, 1024; 2048, 1024; and 3072, 1024 for ports 1 thru 4 respectively.

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Command	Code	Description
Get Trigger Mask (system command)	Gmask	Sets bits in the GET trigger mask which specifies which ports will be triggered upon receipt of a bus GET command.
	G-mask	Clears the specified bits in the GET trigger mask.
	G0	Clears all bits in the GET trigger mask.
	G?	Returns current GET trigger mask.
	The mask bits are as follows: Bit 0 Bit 1 Bit 2 Bit 3	Enable trigger to DAC port 1 (1). Enable trigger to DAC port 2 (2). Enable trigger to DAC port 3 (4). Enable trigger to DAC port 4 (8). <i>Notes:</i> The default mask value is 0.
Offset Calibration (port command)	Hval	Specifies the offset constant for selected range and port. Range is ± 255 .
	H?	Returns the offset constant for selected range and port <i>Notes:</i> Calibration constants must be programmed while using the direct control mode (C0). Autorange must be disabled to program calibration constants. The current voltage output is retriggered upon execution of this command. Default value is 0.
Interval (port command)	It	Specify time interval (in milliseconds) used with the waveform control mode. Range for t is 1-65535.
	I?	Returns the current interval. <i>Notes:</i> The default value is 1000 (1 second).
Gain Calibration (port command)	Jpos, neg	Specifies the gain constant for both polarities of the selected range and port. pos and neg = 0-255.
	J?	Returns the gain constants for selected range and port. <i>Notes:</i> Calibration constants must be programmed while using the direct control mode (C0). Autorange must be disabled (A0) to program calibration constants. The current voltage output is retriggered upon execution of this command. Default values are 128,128.
EOI Control (system command)	K0	Assert EOI on last bus terminator.
	K1 (default)	Disable EOI.
	K?	Returns the current EOI control setting.
Location Pointer (port command)	Lval	Specifies the current buffer location. Range for val is 0-8191.
	L?	Returns the current buffer location in the format specified by the Output Format (On) command. The value returned after an L? is the first location that will be used in stepped and waveform modes.
Service Request Mask (system command)	Mmask	Sets bits in the service request mask which specifies which Model 213 events will generate a bus service request.
	M-mask	Clears the specified bits in the service request mask.
	M0	Clears all bits in the service request mask.
	M?	Returns current service request mask.



Command	Code	Description
Service Request Mask (cont.)	The mask bits are as follows:	
	Bit 0	Enable SRQ on DAC port 1 trigger ready (1).
	Bit 1	Enable SRQ on DAC port 2 trigger ready (2).
	Bit 2	Enable SRQ on DAC port 3 trigger ready (4).
	Bit 3	Enable SRQ on DAC port 4 trigger ready (8).
	Bit 4	Enable SRQ on Trigger Overrun (16).
	Bit 5	Enable SRQ on error (32).
	Bit 7	Enable SRQ on External input transition (128).
Number of Cycles (port command)	Nval	Specifies the number of cycles through the buffer in the waveform mode. val is 0-65535, where 0 is continuous.
	N?	Returns the number of repetitions specified for use in the waveform mode. <i>Notes:</i> The default value is 1.
Output Format (system command)	O0 (default)	Sets output format to volts in ± 10.0000 (fixed).
	O1	Sets output format in volts in decimal bits.
	O2	Sets output format in volts in hexadecimal bits.
	O?	Returns current output format selected.
Port Select (system command)	P1 (default)	Select DAC port 1.
	P2	Select DAC port 2.
	P3	Select DAC port 3.
	P4	Select DAC port 4.
	P?	Returns currently selected port.
External Trigger Mask (system command)	Qmask	Sets bits in the external trigger mask which specifies the active edge of the external input line and which ports will be triggered upon a transition of that line.
	Q-mask	Clears the specified bits in the external trigger mask.
	Q0	Clears all bits in the external trigger mask.
	Q?	Returns current external trigger mask.
	The mask bits are as follows:	
	Bit 0	Enable trigger to DAC port 1 (1).
	Bit 1	Enable trigger to DAC port 2 (2).
Bit 2	Enable trigger to DAC port 3 (4).	
Bit 3	Enable trigger to DAC port 4 (8).	
Bit 7	External input line edge sense (128): 1=negative edge triggered 0=positive edge triggered <i>Notes:</i> The bit 7 default value is 0.	
Range Select (port command)	R0	Select DAC Ground range.
	R1 (default)	Select DAC $\pm 1V$ range.
	R2	Select DAC $\pm 5V$ range.
	R3	Select DAC $\pm 10V$ range.
	R?	Returns DAC volt range. <i>Notes:</i> This command should not be used when autorange is enabled.



Command	Code	Description	
System Defaults (system command)	S0	Restores the factory default value to NV-RAM.	
	S1	Saves the current settings as default values to NV-RAM.	
	S2	Restores Gain and Offset cal constants.	
	S3	Saves current calibration constants to calibration NV-RAM.	
	S?	Returns the last Sn command executed.	
Command Trigger Mask (system command)	Tmask	Sets bits in the command trigger mask which specifies which ports will be triggered upon receipt of a trigger command (@).	
	T-mask	Clears the specified bits in the command trigger mask.	
	T0	Clears all bits in the command trigger mask.	
	T?	Returns current command trigger mask.	
	The mask bits are as follows:		
	Bit 0	Enable trigger to DAC port 1.	
	Bit 1	Enable trigger to DAC port 2.	
Bit 2	Enable trigger to DAC port 3.		
Bit 3	Enable trigger to DAC port 4.		
		Notes: The default value is 0.	
Status (system command)	U0	Send system status on talk.	
	U1	Send DAC port 1 status on talk.	
	U2	Send DAC port 2 status on talk.	
	U3	Send DAC port 3 status on talk.	
	U4	Send DAC port 4 status on talk.	
	U5	Send digital input port status on talk.	
	U6	Send overrun status on talk.	
	U7	Returns actual output voltage and range.	
	U8 (default)	Returns programmed output voltage and range.	
U?	Returns current status select setting.		
		Notes: All status commands are one shot.	
Value Output (port command)	Vvolts	Write volts value for selected DAC port.	
	V#val	Write decimal bit value for selected DAC port.	
	V#\$valZ	Write hexadecimal bit value for selected DAC port.	
	V?	Returns current range and value for selected port in the format specified by the Output Format (On) command.	
		Notes: The current autorange and range affect the value. When programming in bits, autorange must be disabled. The digital port must be programmed in bits.	
Test (system command)	W0 (default)	Turn off TEST LED.	
	W1	Turn on TEST LED.	
	W?	Return state of TEST LED.	
Execute (system command)	X	Execute command string.	
Bus Terminator (system command)	Y0 (default)	Bus terminator is carriage return line feed.	
	Y1	Bus terminator is line feed carriage return.	
	Y2	Bus terminator is carriage return only.	
	Y3	Bus terminator is line feed only.	
	Y?	Returns current bus terminator setting.	



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APPENDIX B

IEEE-488 Primer

HISTORY

The IEEE-488 bus is an instrumentation communication bus adopted by the Institute of Electrical and Electronic Engineers in 1975 and revised in 1978.

Prior to the adoption of this standard, most instrumentation manufacturers offered their own versions of computer interfaces. This placed the burden of system hardware design on the end user. If his application required the products of several different manufacturers, then he might need to design several different hardware and software interfaces. The popularity of the IEEE-488 interface (sometimes called the General Purpose Interface Bus or GPIB) is due to the total specification of the electrical and mechanical interface as well as the data transfer and control protocols. The use of the IEEE-488 standard has moved the responsibility of the user from design of the interface to design of the high level software that is specific to the measurement application.

GENERAL STRUCTURE

The main purpose of the IEEE-488 is to transfer information between two or more devices (see Figure B-1). A device can either be an instrument or a computer. Before any information transfer can take place, it is first necessary to specify which will do the talking (send data) and which devices will be allowed to listen (receive data). The decision of who will talk and who will listen usually falls on the system controller which is, at power on, the active controller.

The system controller is similar to a committee chairman. On a well run committee, only one person may speak at a time and the chairman is responsible for recognizing members and allowing them to have their say. On the bus, the device which is recognized to speak is the active talker. There can only be one talker at a time if the information transferred is to be clearly understood by all. The act of "giving the floor" to that device is called Addressing to Talk. If the committee chairman can not attend the meeting, or if other matters require his attention, he can appoint an acting chairman to take control of the pro-

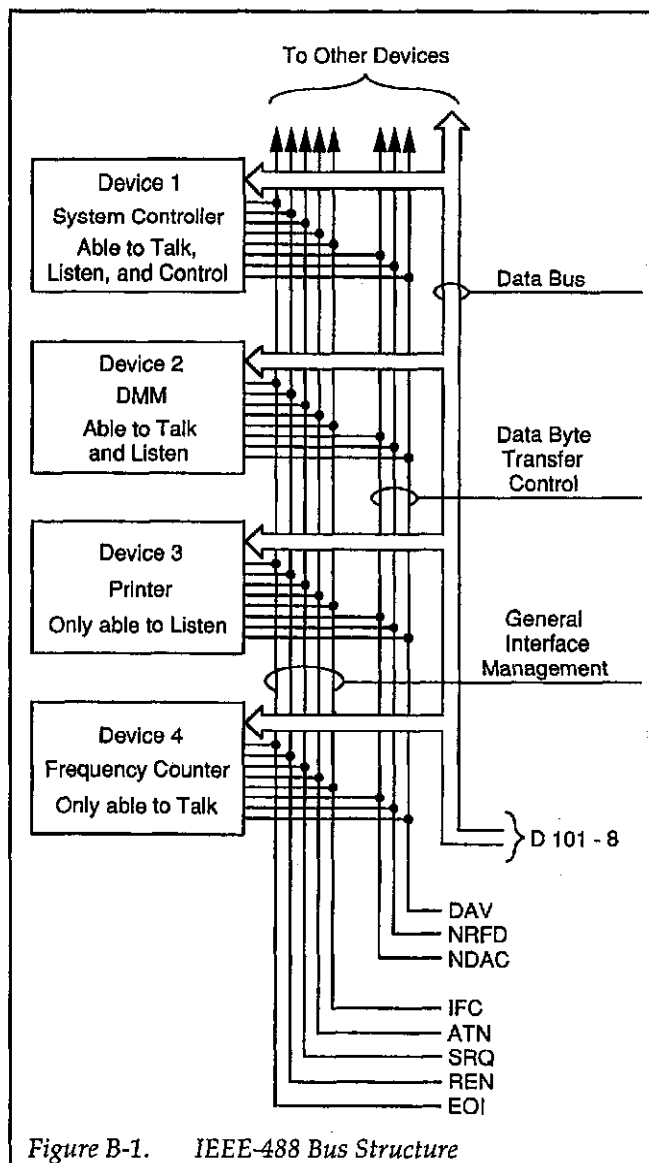


Figure B-1. IEEE-488 Bus Structure

ceedings. For the IEEE-488, this device becomes the active controller.

At a committee meeting, everyone present usually listens. This is not the case with the IEEE-488. The active controller selects which devices will listen and commands all other devices to ignore what is being transmitted. A device is instructed to listen by being Addressed to

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Listen. This device is then referred to as an active listener. Devices which are to ignore the data message are instructed to Unlisten.

The reason some devices are instructed to Unlisten is quite simple. Suppose a college instructor is presenting the day's lesson. Each student is told to raise their hand if the instructor has exceeded their ability to keep up while taking notes. If a hand is raised, the instructor stops his discussion to allow the slower students the time to catch up. In this way, the instructor is certain that each and every student receives all the information he is trying to present. Since there are a lot of students in the classroom, this exchange of information can be very slow. In fact, the rate of information transfer is no faster than the rate at which the slowest note-taker can keep up. The instructor, though, may have a message for one particular student. The instructor tells the rest of the class to ignore this message (Unlisten) and tells it to that one student at a rate which he can understand. This information transfer can then happen much quicker, because it need not wait for the slowest student.

The IEEE-488 transfers information in a similar way. This method of data transfer is called handshaking. More on this later.

For data transfer on the IEEE-488, the active controller must:

1. Unlisten all devices to protect against eavesdroppers.
2. Designate who will talk by addressing a device to talk.
3. Designate all the devices who are to listen by addressing those devices to listen.
4. Indicate to all devices that the data transfer can take place.

SEND IT TO MY ADDRESS

In the previous discussion, the terms Addressed to Talk and Addressed to Listen were used. These terms require some clarification.

The IEEE-488 standard permits up to 15 devices to be configured within one system. Each of these devices

must have a unique address to avoid confusion. In a similar fashion, every building in town has a unique address to prevent one home from receiving another home's mail. Exactly how each device's address is set is specific to the product's manufacturer. Some are set by DIP switches in hardware, others by software. Consult the manufacturer's instructions to determine how to set the address.

Addresses are sent with universal (multiline) commands from the Active Controller. These commands include My Listen Address (MLA), My Talk Address (MTA), Talk Address Group (TAG), and Listen Address Group (LAG).

BUS MANAGEMENT LINES

Five hardware lines on the IEEE-488 are used for bus management. Signals on these lines are often referred to as uniline (single line) commands. The signals are active low, i.e. a low voltage represents a logic "1" (asserted), and a high voltage represents a logic "0" (unasserted).

Attention (ATN)

ATN is one of the most important lines for bus management. If Attention is asserted, then the information contained on the data lines is to be interpreted as a multiline command. If it is not, then that information is to be interpreted as data for the active listeners. The active controller is the only bus device that has control of this line.

Interface Clear (IFC)

The IFC line is used only by the system controller. It is used to place all bus devices in a known state. Although device configurations vary, the IFC command usually places the devices in the talk and listen idle states (neither active talker nor active listener).

Remote Enable (REN)

When the system controller sends the REN command, bus devices will respond to remote operation. Generally, the REN command should be issued before any bus programming is attempted. Only the system controller has control of the Remote Enable line.





End or Identify (EOI)

The EOI line is used to signal the last byte of a multibyte data transfer. The device that is sending the data asserts EOI during the transfer of the last data byte. The EOI signal is not always necessary as the end of the data may be indicated by some special character such as carriage return.

The active controller also uses EOI to perform a Parallel Poll by simultaneously asserting EOI and ATN.

Service Request (SRQ)

When a device desires the immediate attention of the active controller it asserts SRQ. It is then the controller's responsibility to determine which device requested service. This is accomplished with a Serial Poll or a Parallel Poll.

HANDSHAKE LINES

The IEEE-488 uses three handshake lines in an "I'm ready - Here's the data - I've got it" sequence. This handshake protocol assures reliable data transfer, at the rate determined by the slowest listener. One line is controlled by the talker, while the other two are shared by all active listeners. The handshake lines, like the other IEEE-488 lines, are active low. A timing diagram for hardware lines is shown in Figure B-2.

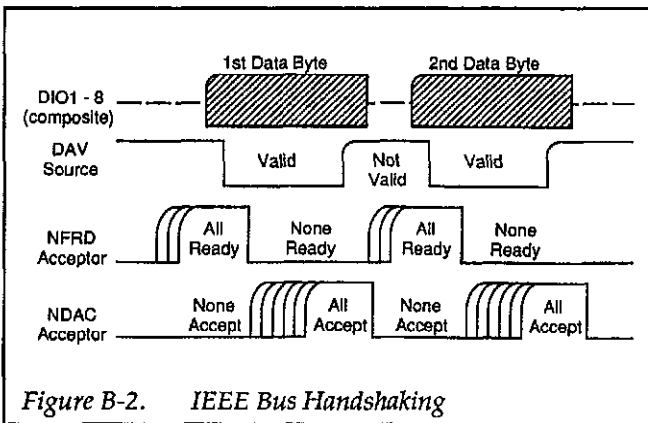


Figure B-2. IEEE Bus Handshaking

Data Valid (DAV)

The DAV line is controlled by the talker. The talker verifies that NDAC is asserted (active low) which indicates that all listeners have accepted the previous data byte transferred. The talker then outputs data on the bus and waits until NFRD is unasserted (high) which indicates that all Addressed listeners are ready to accept the information. When NFRD and NDAC are in the proper state, the talker asserts DAV (active low) to indicate that the data on the bus is valid.

Not Ready for Data (NFRD)

This line is used by the listeners to inform the talker when they are ready to accept new data. The talker must wait for each listener to unassert this line (high) which they will do at their own rate when they are ready for more data. This assures that all devices that are to accept the information are ready to receive it.

Not Data Accepted (NDAC)

The NDAC line is also controlled by the listeners. This line indicates to the talker that each device addressed to listen has accepted the information. Each device releases NDAC (high) at its own rate, but the NDAC will not go high until the slowest listener has accepted the data byte.

DATA LINES

The IEEE-488 provides eight data lines for a bit parallel/byte serial data transfer. These eight data lines use the convention of DIO1 through DIO8 instead of the binary designation of D0 to D7. The data lines are bidirectional and are active low.

MULTILINE COMMANDS

Multiline (bus) commands are sent by the active controller over the data bus with ATN asserted. These commands include addressing commands for talk, listen, Un-talk and Unlisten.

Go To Local (GTL)

This command allows the selected devices to be manually controlled. (\$01)



Listen Address Group (LAG)

There are 31 (0 to 30) listen addresses associated with this group. The three most significant bits of the data bus are set to 001 while the five least significant bits are the address of the device being told to listen.

Unlisten (UNL)

This command tells all bus devices to Unlisten. The same as Unaddressed to Listen. (\$3F)

Talk Address Group (TAG)

There are 31 (0 to 30) talk addresses associated with this group. The three most significant bits of the data bus are set to 010 while the five least significant bits are the address of the device being told to talk.

Untalk (UNT)

This command tells bus devices to Untalk. The same as Unaddressed to Talk. (\$5F)

Local Lockout (LLO)

Issuing the LLO command prevents manual control of the instrument's functions. (\$11)

Device Clear (DCL)

This command causes all bus devices to be initialized to a pre-defined or power up state. (\$14)

Selected Device Clear (SDC)

This causes a single device to be initialized to a pre-defined or power up state. (\$04)

Serial Poll Disable (SPD)

The SPD command disables all devices from sending their Serial Poll status byte. (\$19)

Serial Poll Enable (SPE)

A device which is Addressed to Talk will output its Serial Poll status byte after SPE is sent and ATN is unasserted. (\$18)

Group Execute Trigger (GET)

This command usually signals a group of devices to begin executing a triggered action. This allows actions of different devices to begin simultaneously. (\$08)

Take Control (TCT)

This command passes bus control responsibilities from the current controller to another device which has the ability to control. (\$09)

Secondary Command Group (SCG)

These are any one of the 32 possible commands (0 to 31) in this group. They must immediately follow a talk or listen address. (\$60 to \$7F)

Parallel Poll Configure (PPC)

This configures devices capable of performing a Parallel Poll as to which data bit they are to assert in response to a Parallel Poll. (\$05)

Parallel Poll Unconfigure (PPU)

This disables all devices from responding to a Parallel Poll. (\$15)

MORE ON SERVICE REQUESTS

Most of the commands covered, both uniline and multiline, are the responsibility of the active controller to send and the bus devices to recognize. Most of these happen routinely by the interface and are totally transparent to the system programmer. Other commands are used directly by the user to provide optimum system control. Of the uniline commands, SRQ is very important to the test system and the software designer has easy access to this line by most devices. Service Request is the method by which a bus device can signal to the controller that an



event has occurred. It is similar to an interrupt in a micro-processor based system.

Most intelligent bus peripherals have the ability to assert SRQ. A DMM might assert it when its measurement is complete, if its input is overloaded or for any of an assortment of reasons. A power supply might SRQ if its output has current limited. This is a powerful bus feature that removes the burden from the system controller to periodically inquire, "Are you done yet?". Instead, the controller says, "Do what I told you to do and let me know when you're done" or "Tell me when something is wrong."

Since SRQ is a single line command, there is no way for the Controller to determine which device requested the service without additional information. This information is provided by the multiline commands for Serial Poll and Parallel Poll.

Serial Poll

Suppose the controller receives a service request. For this example, let's assume there are several devices which could assert SRQ. The controller issues an SPE (Serial

Poll enable) command to each device sequentially. If any device responds with DIO7 asserted it indicates to the controller that it was the device that asserted SRQ. Often times the other bits will indicate why the device wanted service. This Serial Polling sequence, and any resulting action, is under control of the software designer.

Parallel Poll

The Parallel Poll is another way the controller can determine which device requested service. It provides the who but not necessarily the why. When bus devices are configured for Parallel Poll, they are assigned one bit on the data bus for their response. By using the Status bit, the logic level of the response can be programmed to allow logical OR/AND conditions on one data line by more than one device. When SRQ is asserted, the controller (under user's software) conducts a Parallel Poll. The Controller must then analyze the eight bits of data received to determine the source of the request. Once the source is determined, a Serial Poll might be used to determine the why.

Of the two polling types, the Serial Poll is the most popular due to its ability to determine the who and why. In addition, most devices support Serial Poll only.



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APPENDIX C

Character Codes and IEEE-488

Multiline Messages

\$00	0	\$10	16	\$20	32	\$30	48	\$40	64	\$50	80	\$60	96	\$70	112
NUL		DLE		SP		0		@		P		SCG		p	
\$01	1	\$11	17	\$21	33	\$31	49	\$41	65	\$51	81	\$61	97	\$71	113
SOH		DC1		!		1		A		Q		a		q	
GTL		LLO										SCG		SCG	
\$02	2	\$12	18	\$22	34	\$32	50	\$42	66	\$52	82	\$62	98	\$72	114
STX		DC2		"		2		B		R		b		r	
												SCG		SCG	
\$03	3	\$13	19	\$23	35	\$33	51	\$43	67	\$53	83	\$63	99	\$73	115
ETX		DC3		#		3		C		S		c		s	
												SCG		SCG	
\$04	4	\$14	20	\$24	36	\$34	52	\$44	68	\$54	84	\$64	100	\$74	116
EOT		DC4		\$		4		D		T		d		t	
SDC		DCL										SCG		SCG	
\$05	5	\$15	21	\$25	37	\$35	53	\$45	69	\$55	85	\$65	101	\$75	117
ENQ		NAK		%		5		E		U		e		u	
PPC		PPU										SCG		SCG	
\$06	6	\$16	22	\$26	38	\$36	54	\$46	70	\$56	86	\$66	102	\$76	118
ACK		SYN		&		6		F		V		f		v	
												SCG		SCG	
\$07	7	\$17	23	\$27	39	\$37	55	\$47	71	\$57	87	\$67	103	\$77	119
BEL		ETB		'		7		G		W		g		w	
												SCG		SCG	
\$08	8	\$18	24	\$28	40	\$38	56	\$48	72	\$58	88	\$68	104	\$78	120
BS		CAN		(		8		H		X		h		x	
GET		SPE										SCG		SCG	
\$09	9	\$19	25	\$29	41	\$39	57	\$49	73	\$59	89	\$69	105	\$79	121
HT		EM		)		9		I		Y		i		y	
TCT		SPD										SCG		SCG	
\$0A	10	\$1A	26	\$2A	42	\$3A	58	\$4A	74	\$5A	90	\$6A	106	\$7A	122
LF		SUB		*		:		J		Z		j		z	
												SCG		SCG	
\$0B	11	\$1B	27	\$2B	43	\$3B	59	\$4B	75	\$5B	91	\$6B	107	\$7B	123
VT		ESC		+		;		K		[		k		{	
												SCG		SCG	
\$0C	12	\$1C	28	\$2C	44	\$3C	60	\$4C	76	\$5C	92	\$6C	108	\$7C	124
FF		FS		,		<		L		\		l		|	
												SCG		SCG	
\$0D	13	\$1D	29	\$2D	45	\$3D	61	\$4D	77	\$5D	93	\$6D	109	\$7D	125
CR		GS		-		=		M		]		m		}	
												SCG		SCG	
\$0E	14	\$1E	30	\$2E	46	\$3E	62	\$4E	78	\$5E	94	\$6E	110	\$7E	126
SO		RS		.		>		N		^		n		~	
												SCG		SCG	
\$0F	15	\$1F	31	\$2F	47	\$3F	63	\$4F	79	\$5F	95	\$6F	111	\$7F	127
SI		US		/		?		O		_		o		DEL	
												SCG		SCG	

ACG = Addressed Command Group
 UCG = Universal Command Group
 LAG = Listen Address Group

TAG = Talk Address Group
 SCG = Secondary Command Group

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APPENDIX D

Keyboard Controller Program

The keyboard controller program is a simple BASIC program that accepts commands from the PC keyboard and sends them to an IEEE-488 interface with the IOtech Driver488 software. It then displays any responses on the PC screen. The keyboard controller program is a convenient method of exercising the Model 213 and becoming familiar with the commands and their actions.

```
10 ' Keyboard Controller Program
20 '
30 ' For use with the IOtech Driver488 and an
40 ' IEEE-488 interface
50 '
100 OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
110 IOCTL#1,"BREAK"
120 PRINT#1,"RESET"
130 OPEN "\DEV\IEEEIN" FOR INPUT AS #2
140 '
150 ON ERROR GOTO 300
160 PRINT#1,"ERROR OFF"
170 '
180 LINE INPUT "CMD> ",CMD$
190 PRINT#1,CMD$
200 '
210 IF IOCTL$(2) <> "1" THEN 180
220 PRINT INPUT$(1,2);
230 GOTO 210
290 '
300 ' Error Handler
310 '
320 IOCTL#1,"BREAK"
330 PRINT#1,"STATUS"
340 INPUT#2,ST$
350 PRINT CHR$(7);"Error #";MID$(ST$,15,2);": ";MID$(ST$,27)
360 RESUME NEXT
```

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APPENDIX E

Program Listings

Waveform Buffer Program

The following program is used to generate a waveform at a user selectable frequency and 20V peak-to-peak centered at 0V using the Model 213 with an IEEE-488 address of 09.

```

10  REM Basic program to load the Model 213 buffer with a multiple waveforms
20  REM Initialize the IOtech IEEE488 Driver
30  OPEN "\dev\ieeeeout" FOR OUTPUT AS #1
40  IOCTL #1, "BREAK"
50  PRINT #1, "RESET"
60  OPEN "\dev\ieeeein" FOR INPUT AS #2
70  PRINT #1, "output 09;c310x"
80  PRINT "Model 213 Waveform Demonstration Program"
90  PRINT "Initializing the Model 213"
100 REM First a 256 point sinewave
110 POINTS = 256: REM number of points in the sine wave
120 PI = 3.1415926535#
130 INC = (2! * PI) / POINTS
140 FOR LOOP = 1 TO POINTS
150 PVAL = 4095*SIN(LOOP * INC)
160 PRINT #1, "output 09;b3,#";CINT(PVAL);"x":NEXT
200 REM Now a triangle wave
210 INC = 4096 / 64
220 FOR LOOP = 0 TO 4095 STEP INC
230 PRINT #1,"output 09;b3,#";LOOP;"x":NEXT
240 FOR LOOP = 4095 TO -4095 STEP -INC
250 PRINT #1,"output 09;b3,#";LOOP;"x":NEXT
260 FOR LOOP = -4095 TO 0 STEP INC
270 PRINT #1,"output 09;b3,#";LOOP;"x":NEXT
300 REM Now a square wave
310 PRINT #1,"output 09;b3,#4095xb3,#-4095x"
400 REM Main Loop
410 CLS
420 INPUT "Select a port (1-4) ";PORT
430 IF PORT <1 OR PORT > 4 GOTO 420
440 PRINT
450 INPUT "Select an interval in milliseconds (1-255) ";INTRVL
460 IF (INTRVL <=0) OR (INTRVL >255) GOTO 450
470 PRINT "Select a waveform (1-6) ";WAVE
480 PRINT " 1 - Sinewave "
490 PRINT " 2 - Rectified Sine Wave"
500 PRINT " 3 - Triangle "
510 PRINT " 4 - Ramp "
520 PRINT " 5 - Inverted Ramp "
530 PRINT " 6 - Square Wave "
540 INPUT WAVE
550 IF WAVE <1 WAVE >6 GOTO 470
560 IF WAVE = 1 GOTO 700

```

+



```
570 IF WAVE = 2 GOTO 750
580 IF WAVE = 3 GOTO 800
590 IF WAVE = 4 GOTO 850
600 IF WAVE = 5 GOTO 900
610 IF WAVE = 6 GOTO 950
620 PRINT: PRINT: GOTO 420
700 REM sinewave output routine
710 PRINT #1,"output 09;p";PORT"c3f0,25610i";INTRVL;"n0t0x"
720 PRINT #1,"output 09;t"; (2^(PORT-1));"x@"
730 GOTO 620
750 REM rectified sinewave output routine
760 PRINT #1,"output 09;p";PORT"c3f0,12810i";INTRVL;"n0t0x"
770 PRINT #1,"output 09;t"; (2^(PORT-1));"x@"
780 GOTO 620
800 REM triangle wave output routine
810 PRINT #1,"output 09;p";PORT"c3f256,2561256i";INTRVL;"n0t0x"
820 PRINT #1,"output 09;t"; (2^(PORT-1));"x@"
830 GOTO 620
850 REM ramp wave output routine
860 PRINT #1,"output 09;p";PORT"c3f256,641256i";INTRVL;"n0t0x"
870 PRINT #1,"output 09;t"; (2^(PORT-1));"x@"
880 GOTO 620
900 REM inverted ramp wave output routine
910 PRINT #1,"output 09;p";PORT"c3f384,641384i";INTRVL;"n0t0x"
920 PRINT #1,"output 09;t"; (2^(PORT-1));"x@"
930 GOTO 620
950 REM square wave output routine
960 PRINT #1,"output 09;p";PORT"c3f512,21512i";INTRVL;"n0t0x"
970 PRINT #1,"output 09;t"; (2^(PORT-1));"x@"
980 GOTO 620
```



Buffer Save and Restore Program

This program may be used to save the contents of the Model 213 internal buffer to disk. It can also be used to load the saved values from disk into the internal buffer.

```
10 'BASIC program to save and restore the Model 213 buffer contents
20 '
30 'Initialize the IOtech IEEE488 Driver
40 OPEN "\dev\ieeout" FOR OUTPUT AS #1
50 IOCTL #1, "BREAK"
60 PRINT #1, "RESET"
70 OPEN "\dev\ieein" FOR INPUT AS #2
75 ON TIMER(5) GOSUB 2000
80 CLS
90 PRINT "Model 213 Waveform Buffer Save and Restore Program"
100 PRINT : PRINT " 1 - Save the Waveform Buffer "
110 PRINT " 2 - Restore the Waveform Buffer "
120 PRINT " 3 - Exit the program"
130 PRINT : INPUT "Select the desired function "; FUN
140 IF FUN <1 OR > 3 THEN PRINT "Invalid selection": GOTO 100
150 IF FUN = 3 THEN END
160 IF FUN = 1 THEN GOSUB 500 ELSE GOSUB 1000
170 GOTO 80
500 ' Save Model 213 waveform buffer
510 '
515 WCNT = 0: TIMER ON
520 OPEN "buffer.sav" FOR OUTPUT AS #3
530 PRINT #1, "output 09;p1c0l0x"
540 PRINT "Saving the Model 213 waveform buffer"
550 FOR LOP = 1 TO 2048
560 PRINT #1, "output 09;b?b?b?b?"
570 PRINT #1, "enter 09"
580 LINE INPUT #2, SS$
590 PRINT #3, SS$
600 NEXT LOP
610 CLOSE #3
620 TIMER OFF
630 RETURN
1000 ' Restore Model 213 waveform buffer
1010 '
1020 OPEN "buffer.sav" FOR INPUT AS #3
1030 PRINT #1, "output 09;p1c0l0x"
1040 PRINT "Restoring the Model 213 waveform buffer"
1045 WCNT = 0: TIMER ON
1050 FOR LOP = 1 TO 2048
1060 LINE INPUT #3, SS$
1070 RS$ = MID$(SS$, 1, 12) + "x" + MID$(SS$, 13, 12) + "x" + MID$(SS$, 25, 12) + "x" + MID$(SS$, 37, 12) + "x"
1080 PRINT #1, "output 09;"; RS$
1090 NEXT LOP
1100 CLOSE #3
1110 TIMER OFF
1120 RETURN
2000 PRINT "Working - "; : WCNT = WCNT + 1
2010 IF WCNT > 6 THEN PRINT : WCNT = 0
2020 RETURN
```


Service Form

Model No. _____ Serial No. _____ Date _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

- | | | |
|--------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------------------|
| <input type="checkbox"/> Intermittent | <input type="checkbox"/> Analog output follows display | <input type="checkbox"/> Particular range or function bad; specify |
| <input type="checkbox"/> IEEE failure | <input type="checkbox"/> Obvious problem on power-up | <input type="checkbox"/> Batteries and fuses are OK |
| <input type="checkbox"/> Front panel operational | <input type="checkbox"/> All ranges or functions are bad | <input type="checkbox"/> Checked all cables |

Display or output (check one)

- | | |
|-----------------------------------|------------------------------------------------------|
| <input type="checkbox"/> Drifts | <input type="checkbox"/> Unable to zero |
| <input type="checkbox"/> Unstable | <input type="checkbox"/> Will not read applied input |
| <input type="checkbox"/> Overload | |

- | | |
|-------------------------------------------|--------------------------------------------------------------|
| <input type="checkbox"/> Calibration only | <input type="checkbox"/> Certificate of calibration required |
|-------------------------------------------|--------------------------------------------------------------|

-
- Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

Be sure to include your name and phone number on this service form.

Specifications are subject to change without notice.

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