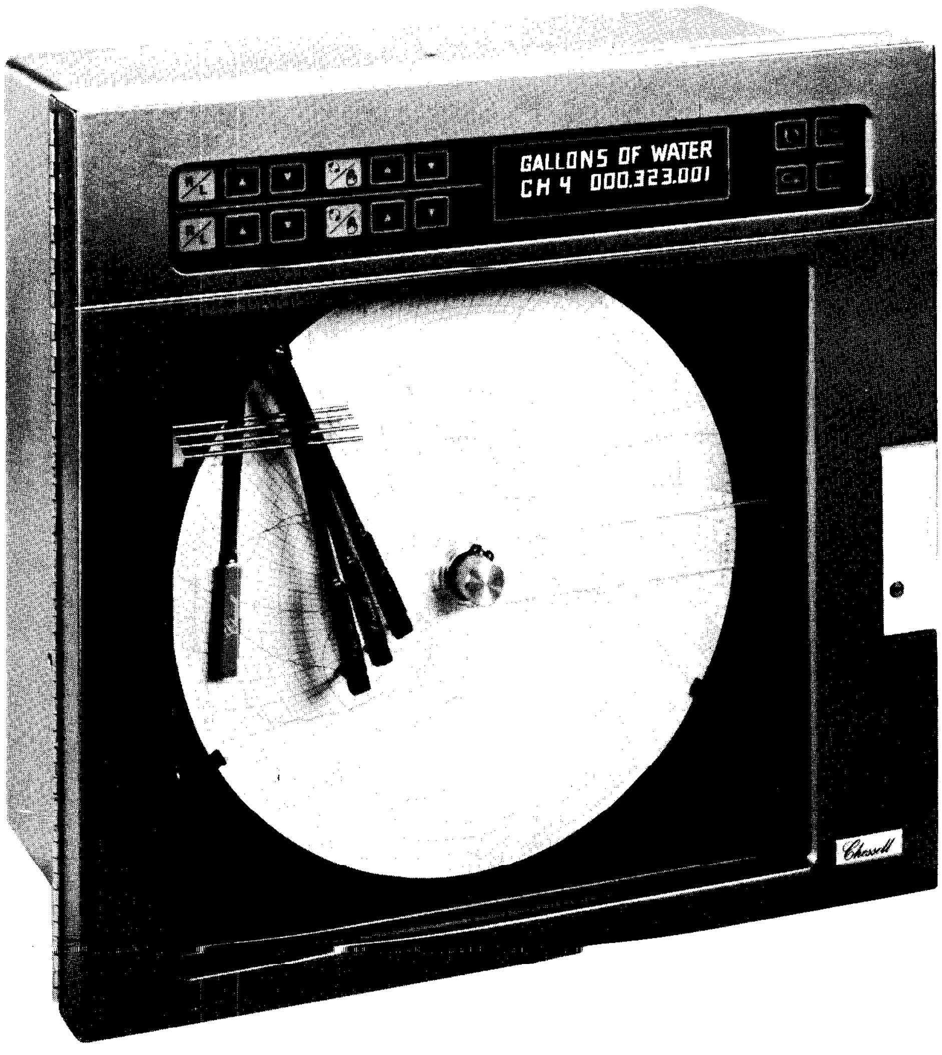
MODEL 390

CONTROLLERS, SETPOINT GENERATOR, RETRANSMISSION OPTIONS
CONFIGURATION, OPERATION & MAINTENANCE MANUAL



Part No. HA203391

Chessell

Table of Contents

Table of Contents

List of Figures

1. Warranty Statement

This Chessell product is warranted against defects in materials and workmanship for twelve months from the date of shipment. During the warranty period Chessell Corporation will, at its option, either repair or replace products which prove to be defective.

Within areas designated for service travel by Chessell or its representatives, warranty service will be provided at the buyer's facility at no charge. Outside the service areas warranty service at the buyer's facility can be provided only upon prior agreement by Chessell or its representative, and the buyer may be required to pay round-trip travel expenses.

In all cases the buyer has the option of returning the product for warranty service to a facility designated by Chessell or its representatives. The buyer shall prepay shipping charges for products returned to a service facility, and Chessell or its representatives shall pay for return of the products to the buyer.

Limitation of Warranty

The foregoing warranty shall not apply to defects arising from:

Improper or inadequate maintenance by the user

Improper or inadequate site preparation

Unauthorized modification or misuse

Operation of the product in unfavorable environments, especially high temperature, high humidity, corrosive or other damaging atmospheres

Disclaimer

No other warranty is expressed or implied. Chessell Corporation specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

Exclusive remedies

The remedies provided above are the buyer's sole and exclusive remedies. Chessell Corporation shall not be liable for any direct, indirect, special incidental, or consequential damages.

Calibration Accuracy

This Chessell product was thoroughly tested to ensure compliance with published specifications. All instruments used in production and final test are regularly inspected to maintain accuracy of calibration, traceable to the National Bureau of Standards. The user should be satisfied that the performance of the product as received meets expectations and, as part of a program of planned maintenance, should periodically check calibration accuracy against reliable standards.

CAUTION

The product cover(s) should not be removed by other than qualified service personnel. High or lethal voltages may be present at exposed points on the chassis if power is applied. Chessell Corporation shall not be liable for personal injury or property damage suffered in servicing the product. The product should not be modified or repaired in a manner at variance with procedures established by Chessell.

2. Use of This Manual

This manual applies to optional functions available for the Circular Chart Recorder. The reader should be familiar with the specifications, operation, and maintenance of the basic recorder before attempting to use this manual.

The optional functions described in this manual are:

Retransmitted Signals

PID Controllers

Setpoint Generator

3. Installation

See figure 1.

3.1. Loop Installation

Use the following procedure to install a control loop:

1. Install loop inputs

   loop 1 process variable - channel 1
   loop 2 process variable - channel 2

   loop 1 remote setpoint - channel 3
   loop 2 remote setpoint - channel 4

   loop 1 feedforward signal - channel 3 or 4
   loop 2 feedforward signal - channel 3 or 4

   configure channels as outlined in main manual

2. Install contact closure loop controls (A/M, R/L)

3. Install loop output(s)

   loop 1 primary output (heat if duplex) - output 1 A
   loop 2 primary output (heat if duplex) - output 2 A

   loop 1 cool output (if duplex) - output 1 B
   loop 2 cool output (if duplex) - output 2 B

   CAUTION - it is not advised that the outputs be connected to live end-elements until completion of installation and checkout.

4. Configure loop output(s) (see section 8.1)

5. Test loop output(s) using manual adjustment

   NOTE: - Duration adjusting type outputs need no calibration. Current adjusting type outputs are calibrated at the factory, and should need no calibration. If, however, the 4 - 20 mA. signal is out of specification, use the procedure outlined in section 3.3.

6. Configure loop (see section 8.1)

7. Connect loop output(s) to process end elements

8. Tune loop (see section 9)

3.2. Retransmitted Signal Installation

Use the following procedure to install a retransmitted signal:

1. Configure source of retransmission signal for each output to be used. Any source can be assigned to any output.

   NOTE: - If control loops are installed, the loops will take control of any outputs needed per their configuration. Retransmission can only be done on unused installed outputs.

   ex: 1 dual CAT output card in position 1.
   1 single CAT output card in position 2.

   1 loop is installed, and is configured as a single output.

   2 retransmitted signals have been installed.

   output 1A will be taken over by the loop.
   outputs 1B and 2A are available for retransmission.

   if the loop is subsequently configured as duplex, output 1B will also be taken over by the loop, and will not be available for retransmission use.

2. Configure span of retransmitted output (see section 8.3)

3. Test output against retransmitted signal source (ex. chan 1)

   NOTE: Outputs are calibrated at the factory. If output is not in specification, use calibration procedure in section 3.3.

3.3. Calibration

The only calibration points which might be necessary for the option configuration are the CAT (4 - 20 mA.) outputs used for retransmission and control. These are calibrated at the factory, but can be recalibrated in the field. Use the following procedure for each output:

1. Move link LK17 to the bottom & middle posts position. LK17 is at the bottom of the main board.
2. Connect the output concerned to J21 on the main board, using a 0.1%, 250 ohm shunt resistor. Polarities are marked on output and J21.
3. In configuration mode, scroll to "CALIBRATE INST.". (see recorder manual)
4. Press up arrow to enter calibration mode. GO SLOWLY! AVOID RECALIBRATING INPUT CHANNELS!
5. Scroll to "CALIBRATE OUTPUT".
6. Press enter. Scroll to desired output.
7. Press enter and wait until calibration completed.
8. Clear out of calibration mode, and restore LK17 to middle & top posts position.

NOTE: This calibration depends upon the accuracy of the cold junction voltage calibration done on J21. If all instrument calibration has been lost, keep in mind that CJ must be calibrated before this procedure can be performed.

4. Technical Specifications

4.1. Input Specifications

4.1.1. Analog Inputs

The process variables, remote setpoints, and feedforward signals used by the loops are acquired by the recorder input channels. These inputs are specified in the main circular chart recorder manual.

4.1.2. Contact Inputs

The following contact closure inputs are available:

AM1 - force manual on loop 1
RL1 - force local on loop 1

AM2 - force manual on loop 2
RL2 - force local on loop 2

RESET - reset the setpoint generator
HOLD - hold the setpoint generator
EXT - not used at this time

The reset contact input is edge sensitive. Reset will occur if a contact closure exists for T > 5 mSec. The setpoint generator will remain in reset until the contact is opened.

4.2. Output Specifications

4.2.1. Current Adjusting Type

Output Resolution: 0.1 % of full scale

Output Range: 4 mA. - 20 mA.

Compliance Voltage: 12 Vdc. (600 ohms)

4.2.2. Duration Adjusting Type

Output Resolution: 0.1 % of cycle rate

Cycle Rate Range: 2 sec. - 250 sec.

Output Types: Relay (2 A. @ 115 V RMS)

Triac (2 A., zero-crossing fired, 264 VAC)

4.3. Explanation of Operation

The controllers, setpoint generator, and retransmitted signals are managed by an independent microprocessor located on the option card. This processor obtains measurements and operator changes via an interface to the basic recorder processor located on the main card. Configuration and operating data for the controllers, setpoint generator, and retransmission is kept mostly in the option card, with the main card storing some information related to operator entries.

The basic operation of the system occurs at a frequency of 2 Hz. The main card initiates the cycle by transferring a block of data to the option card every half second. The option card reacts to this transfer by processing the data to produce new retransmitted outputs, PID control outputs, and incrementing the setpoint generator timebase. The option card then transfers to the main card a block of data for the main card to display on the operator interface. This complete cycle occurs in less than 250 mSec.

The interim period of time, (background), is used by the option card to service items such as serial communications.

For purposes of examining control sampling rates, it should be noted that the time from sensing the value of the process variable until the production of a new control output is one half second. The reading on the operator interface representing output may lag the physical output by one half second. If the two loops are cascaded, it should be noted that the output of loop 1 is produced before processing loop 2.

The setpoint generator output values are updated every 2 seconds. Duration entries of 0 seconds, (step changes), cannot occur in succession faster than every 2 seconds.

The time from sensing the value of an input, until producing a new retransmitted output is one half second.

Separation of data between the main card and the option card is as follows. The main card maintains the values of manual output, local setpoint, ratio, and bias. These are items which change frequently and quickly via operator entries. The option card passes back to the main card the values of controller output, actual setpoint (the option card must choose setpoint from several sources based on various conditions), and setpoint generator outputs, both event and trace. The main card chooses to display either automatic or manual output. Control of the loops (auto/manual, remote/local), is managed in concert by both cards. For instance, the main card scans the keys and sets the states but the option card executes bumpless transfers.

When replacing the option card assembly or the main card assembly, it is important to keep in mind that each card keeps a battery backed up set of data. It is possible for the option card, or main card, to default its data due to a memory fault, without the other card changing any data.

When the instrument is turned on, the main card checks to see if an option card should be installed, based upon which options have been installed. If an option card should be installed, the main card will attempt to synchronize execution with the option card. If there is no response from the option card, the main card will remain in the synchronization loop. Therfore, if the option card is not present, or faulty, the display will remain blank, and the instrument will appear to be off.

4.4. Electronic Assemblies

4.4.1. Option Card

The option card is mounted to the case of the recorder adjacent to the Main CPU card assembly. This microprocessor based printed circuit card subassembly contains the circuitry required to support the following options:

2 Loops of PID Control

Serial Communications (RS232 or RS422)

Setpoint Generation

Retransmission

Refer to figure 2 for the following discussion.

Power Supply:

The power supply circuit on the option card converts the unregulated motor voltage into the following voltages:

+5.0 V which supplies the microprocessor and support logic.

Two unregulated power supplies of +15V and -15V for the controller output cards.

Isolated +5.0V for the serial communications circuitry.

The power supply circuit is a square wave DC to DC converter design. The unregulated motor supply voltage is used to drive transformer T1 with a square wave via transistors TR3 and TR4. Regulation of the output voltages is performed by pulse width modulation via switching regulator controller U1. The feedback control is performed by monitoring the 5.0 V output from transformer T1 at the junction of L1 and C5.

Microprocessor and Digital Logic:

The option card uses a standard microprocessor system architecture consisting of an eight bit 6303 CMOS processor with 32k bytes of program memory and 4k bytes of battery backed up CMOS RAM memory. The microprocessor uses a multiplexed address and data bus to control all the I/O operations and memory transfers. The address data is demultiplexed by latch U14. The output of U14 supplies the lower order portion of the address bus to the system memory. The high order address decoding logic is decoded by U13 which generates the strobes for the peripherial interface circuits.

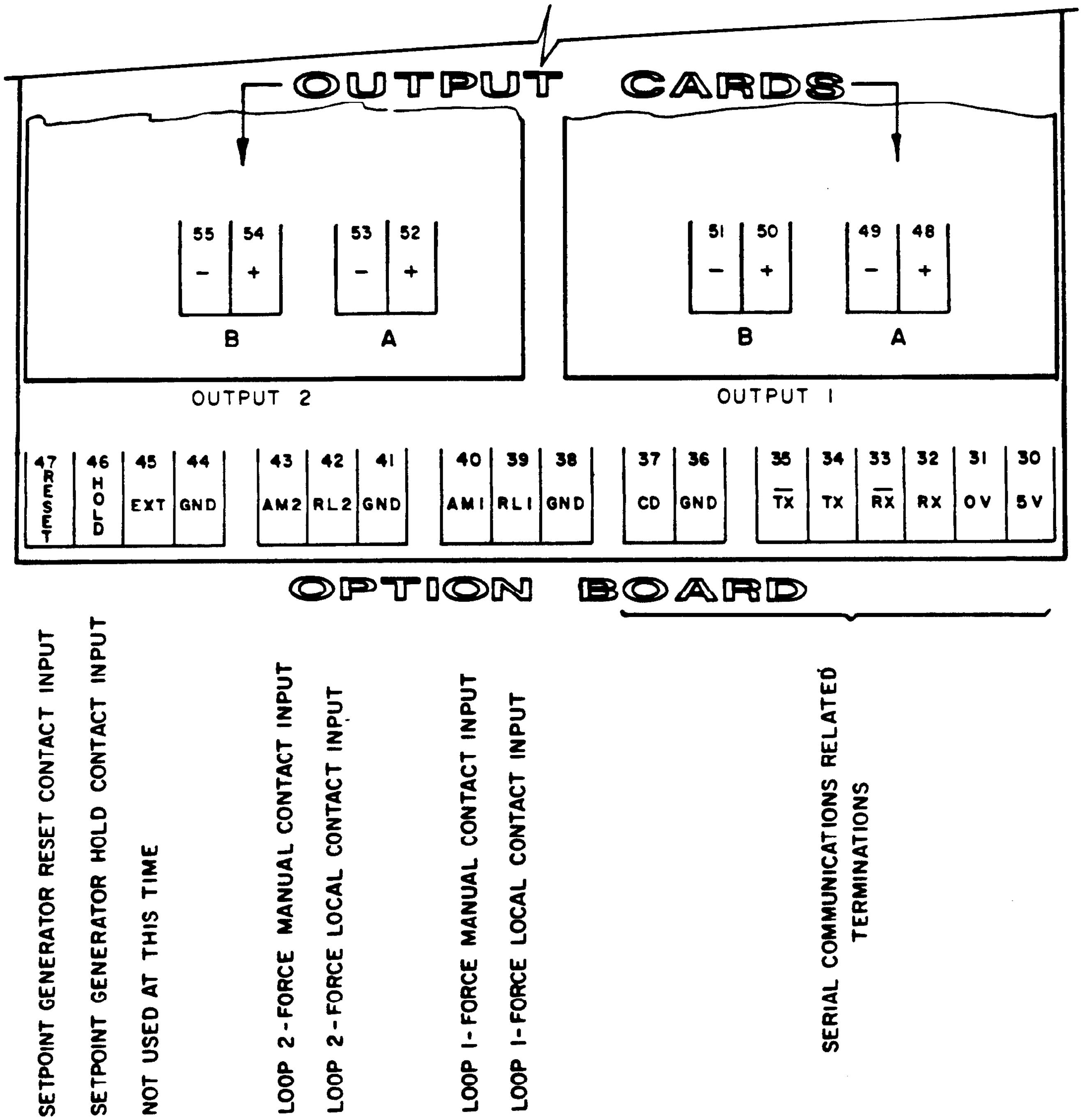


Figure 1 - Option Card Terminations

The option card microprocessor communicates with the main CPU card assembly via tri-state latches U6 and U7. These two latches provide an eight bit data path between the two assemblies.

The contact inputs are optically isolated and interfaced to the microprocessor data bus via tri-state buffer U17.

The interface to the two output cards is controlled directly from the microprocessor by means of the 6303 parallel port. The transfer of data to the output cards is performed in a bit serial mode via a data signal, clock signal and load signal.

Serial Communications:

The serial communications interface circuit consists of U21 and U23 that provide the level shifting required for RS-232 or RS-422. The serial communications signal inputs and outputs are optically isolated by isolators U20 and U24.

The baud rate clock generation is performed by U9 which divides the microprocessor clock frequency to the required baud rate frequency.

Watchdog Timer:

A watchdog timer circuit U27 and TR5 is used to insure automatic restart if a fault occurs. To prevent the time out period from expiring and resetting the microprocessor TR5 must be strobed every 60 milliseconds by the operating system software.

4.4.2. DAT Output Card

The Time Proportioning Output card mounts on the option card and is connected to the option card via an eight pin connection cable. This assembly is available in two output forms, single output or dual output and two output types, TRIAC or relay. Refer to figure 3 for the following discussion.

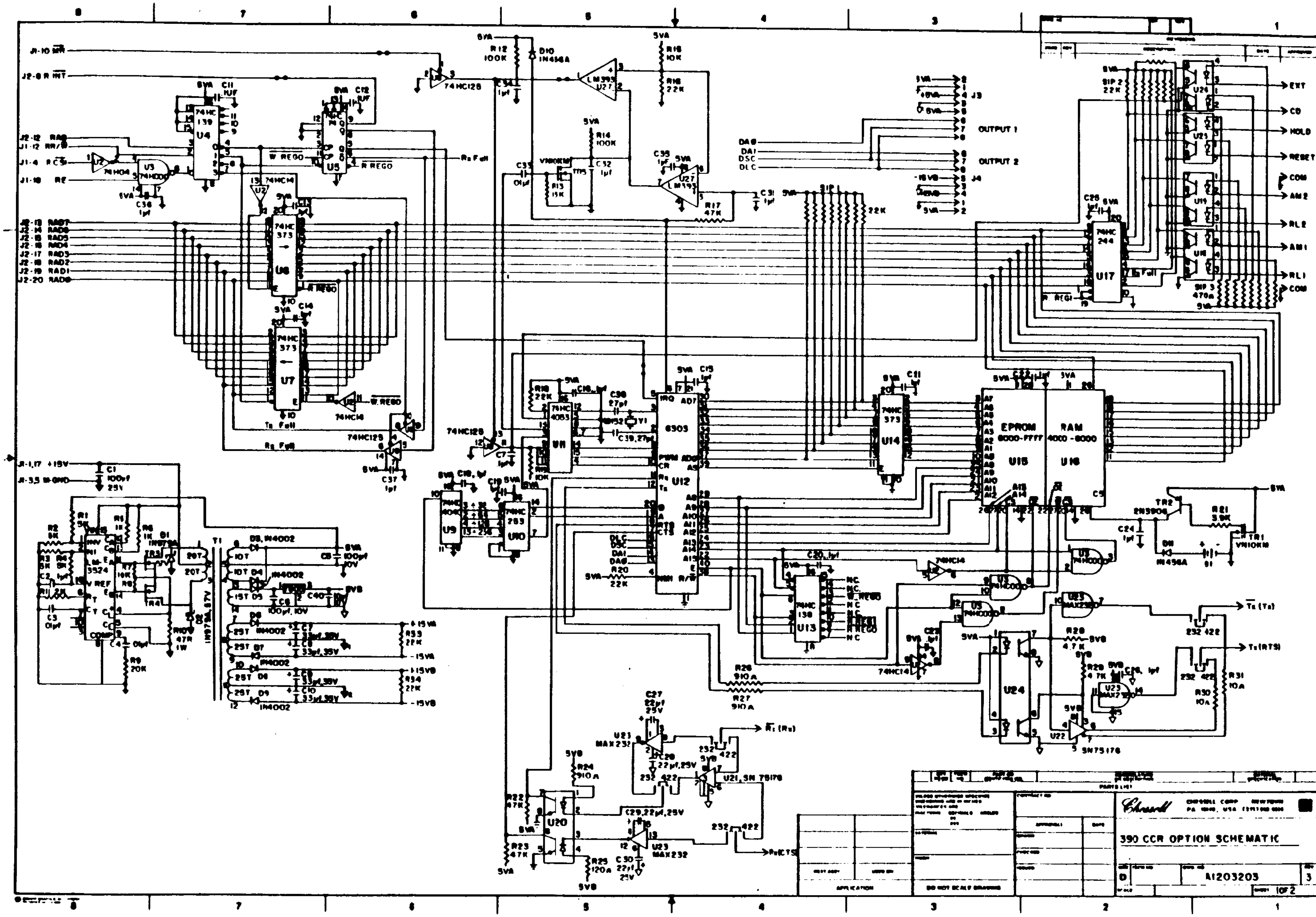
The output contacts are controlled by flip-flops U1 and U2. The output of the flip-flops drive transistors TR1 and TR2 which activate the output contacts either TRIACs or relays.

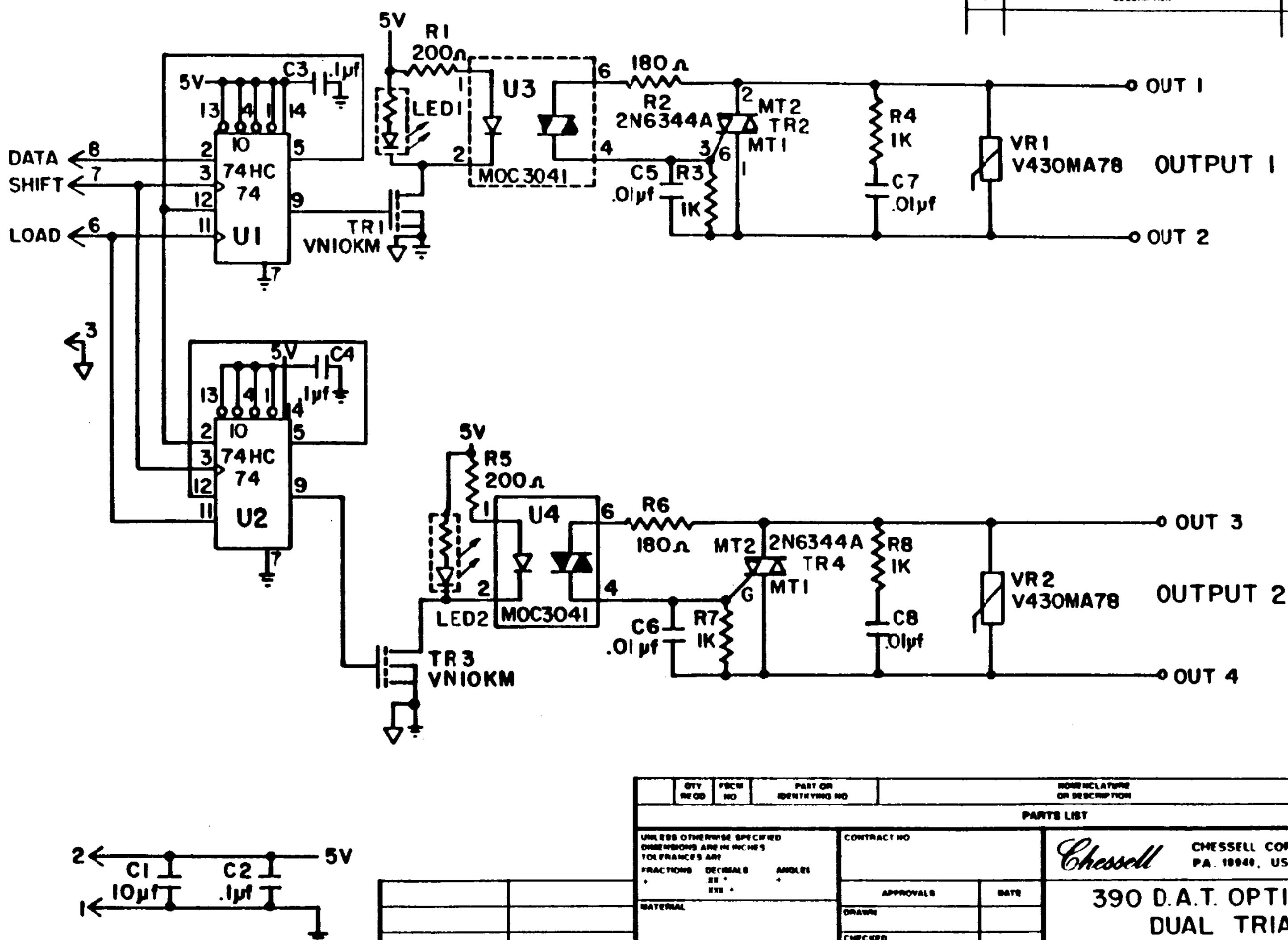
The TRIAC output units are zero-crossing fired by U3 and U4 to prevent generation of EMI interference. Resistor, capacitor network R4, C7 and R8, C8 provide the required snubbing to prevent false triggering in noisy environments.

4.4.3. CAT Output Card

The 4-20mA current output card mounts on the option card and is connected to this card via an eight pin connection cable. The printed circuit card assembly is available in two forms, single output or dual output. Refer to figure 4 for the following discussion.

The current output card uses a 12 bit digital to analog converter U3 to generate an isolated 4-20mA output signal. The digital to analog converter is optically


390 CCR OPTION SCHEMATIC
A1203203
1 OF 2
CHESSELL CORP
DO NOT SCALE DRAWING
APPLICATION
EPROM 8000-FFFF
RAM 4000-8000
6303
OUTPUT 1
OUTPUT 2
EXT
CO
HOLD
RESET
COM
AM2
RL2
AM1
RL1



REVISIONS

REV	DESCRIPTION	DATE	APPROVED

PARTS LIST

QTY REQD	FSCM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

CONTRACT NO

APPROVALS / DATE — DRAWN — CHECKED — ISSUED

MATERIAL

FINISH

NEXT ASSY — USED ON

APPLICATION

DO NOT SCALE DRAWING

Chessell — CHESSELL CORP., NEWTOWN PA. 18940, USA, (215) 968 0600

390 D.A.T. OPTION CARD
DUAL TRIAC

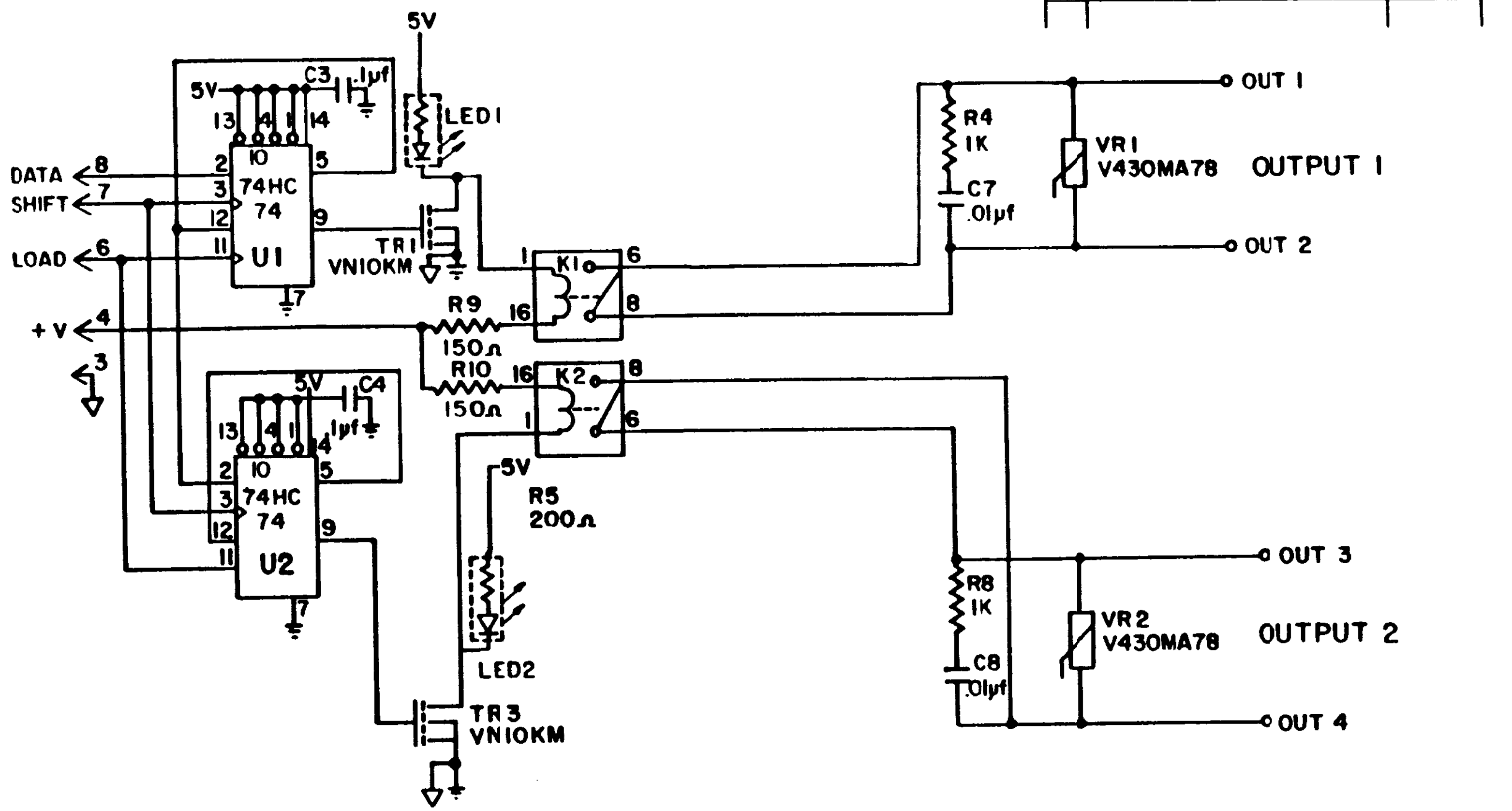
SIZE B — FSCM NO. — DWG. NO. A1 203248 — REV

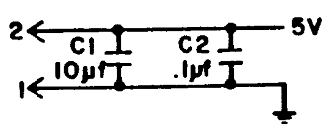
SCALE — SHEET 1 of 2

DWG NO.	SH	REV

REVISIONS

REV	DESCRIPTION	DATE	APPROVED





QTY REQD	FSCM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

MATERIAL

FINISH

DO NOT SCALE DRAWING

CONTRACT NO

APPROVALS	DATE
DRAWN	
CHECKED	
ISSUED	

NEXT ASSY	USED ON
APPLICATION	

Chessell — CHESSELL CORP., NEWTOWN PA. 18940, USA, (215) 968 0600

390 D.A.T. OPTION CARD
DUAL RELAY

SIZE	FSCM NO.	DWG. NO.	REV.
B		A1 203248	1

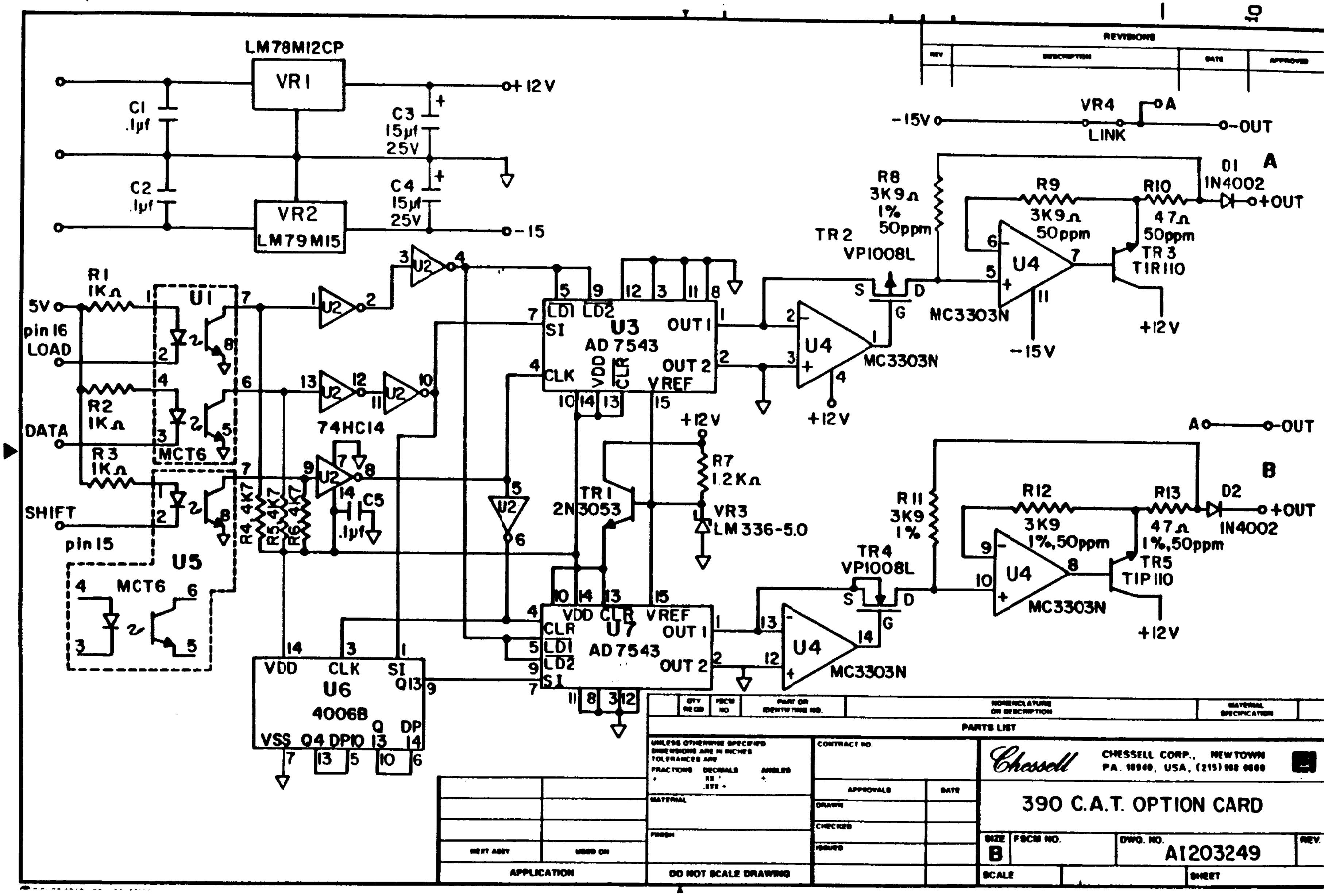
SCALE | SHEET 2 of 2

13 A

isolated from the measuring circuit by isolators U1 and U5. The output data is transfered from the option card in a bit serial format via the Data, Shift and Load signal lines. The current output from U3 is level shifted by amplifiers U4 to provide the required compliance voltage at 20mA.

The second current output operates in the same mode as described above. The difference being that the data input to U7 is delayed by 12 shifts via shift register U6. The first 12 bits in the serial transfer therefore control output B and the next 12 bits control output A.

Power supply regulation is provided VR1 and VR2 for both outputs on the card.


LM78M12CP
VR1
+12V
C1 .1µf
C3 15µf 25V
C2 .1µf
C4 15µf 25V
VR2 LM79M15
-15
-15V
VR4
LINK
A
-OUT
R8 3K9Ω 1% 50ppm
R9 3K9Ω 50ppm
R10 47Ω 50ppm
D1 1N4002
+OUT
TR2 VP1008L
TR3 TIP110
U4 MC3303N
+12V
-15V
R1 1KΩ
R2 1KΩ
R3 1KΩ
5V pin 16
LOAD
DATA
SHIFT
pin 15
U1 MCT6
U5 MCT6
U2 74HC14
R4 4K7
R5 4K7
R6 4K7
C5 .1µf
U3 AD7543
LD1 LD2 SI CLK VDD CLR VREF OUT 1 OUT 2
TR1 2N3053
R7 1.2KΩ
VR3 LM336-5.0
R11 3K9 1%
R12 3K9 1%,50ppm
R13 47Ω 1%,50ppm
D2 1N4002
B
TR4 VP1008L
TR5 TIP110
U7 AD7543
U6 4006B
VDD CLK SI Q13 VSS Q4 DP10 Q13 DP14
REVISIONS
PARTS LIST
APPLICATION
DO NOT SCALE DRAWING
Chessell
CHESSELL CORP., NEWTOWN
390 C.A.T. OPTION CARD
SIZE B
DWG. NO. A1203249
SCALE
SHEET

5. Controller Description

5.1. Output Types

There are two types of outputs available. They are the current adjusting type output and the duration adjusting type output. The CAT output is a 4 mA. to 20 mA. signal used to drive continuous end elements such as valves.

The DAT output physically consists of a relay or TRIAC. It is used to drive such end elements as heater coils. The percentage output value is converted to a percentage of the total period (cycle rate). The percentage output value represents the amount of time the output is 'on'. For example, a one minute cycle rate output, with a current output value of 25%, would represent an 'on' time of 15 seconds and an 'off' time of 45 seconds. Each side of a dual DAT output may have a unique cycle rate.

Each loop (1 or 2) can have a single or dual output. Dual outputs must be similar types. For example, loop 1 could be a duplex loop with 2 DAT outputs, one for heat and one for cool, but both must be DAT. Loop 2 could have a single or dual output of DAT or CAT, independent of loop 1.

Each loop's single or dual output is contained on a daughter card mounted above the option card. The terminations unique to that output(s) is mounted on the daughter card. The type of daughter card determines the type of output.

The output of each loop is conditioned by several functions. These are:

- slew rate limiting (rate of output change)
- output limiting
- deadband (used for duplex only)

A duplex output involves driving 2 physical outputs with 1 controller output value. This output value ranges from -100% to 100%. The A side of the duplex output is active when the output value is positive, and the B side is active for negative output values. This method allows the controller to retain 0.1% resolution of output for the full 200% duplex span. Keep in mind that the B output will increase in value as the output becomes more negative. See figure 5.

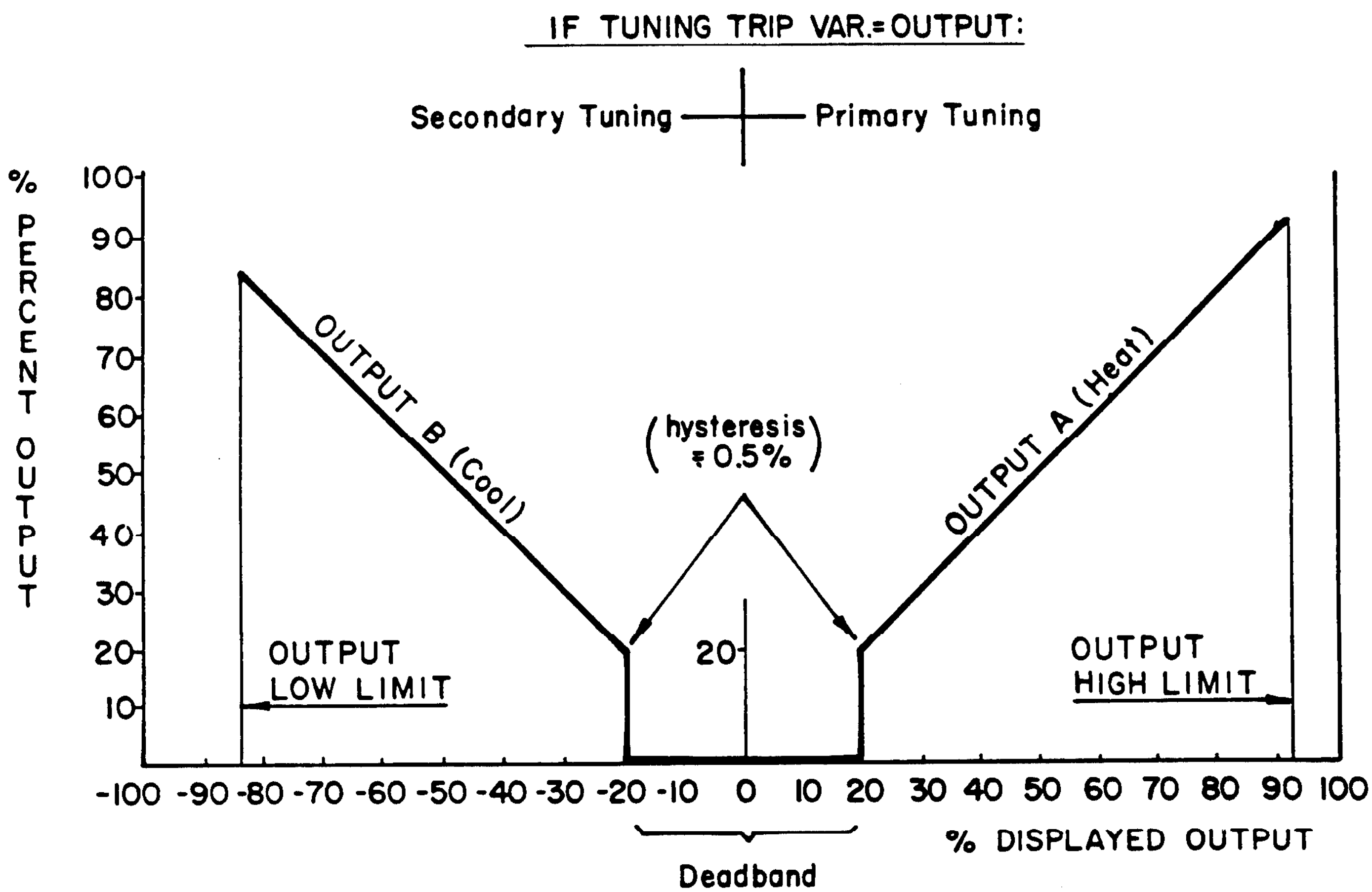


Figure 5 - Duplex Output Characteristics

5.2. PID Algorithm

The control algorithm used is the classic three term PID scheme incorporating the following enhancements. Figures 6 and 7 present the basic structures of the two loops.

Bumpless Transfer - The controller output will remain stable after a transfer from manual to automatic control, provided that there is a non-zero reset tuning parameter entered (the integrator isn't turned off).

Anti Reset-Windup - The integration of the I term will stop anytime the output value reaches the low or high programmed output limits. This will prevent the integrator from 'winding up'. This does not apply to duplex output deadband.

Cutback - Cutback is a mechanism which aids in balancing a process at its' operating point quickly from startup conditions. It does this by causing the value of the I term integrator to be set at its' normal operating level faster than the rate dictated by reset time.

The sequence in which cutback works is as follows. First, the basic PID control settings cause the output value to reach one of the output limits. In startup, this is normal. For example, if a furnace operates at 1000 degF and starts from room temperature, it is reasonable to assume that the output will rise to its' high limit under automatic control. Second, cutback is activated if the value of deviation exceeds the programmed cutback setting, while the output is at an extreme. Once cutback is activated, the output is held at the extreme until the deviation falls below the cutback setting, even if the normal PID control doesn't call for extreme output. Third, and most importantly, when the cutback setting is reached, and cutback is de-activated, the controller is put through a bumpless transfer operation using the extreme output value. This will cause the I term to be initialized at a level which will be:

I = extreme output - new P term - new D term

The result of this operation is to set the I term very near the level at which it normally operates, without waiting for it to ramp there under the constraints of the programmed reset time. So, you can have a slow reset time to achieve correct control of a slow process, and still startup quickly.

Another benefit of cutback is that it prevents overshoot during startup. This is because the controller can be tuned for steady-state conditions, which may involve a long reset time, without worrying about the transient conditions at startup.

There are two cutback settings. One for positive deviations (cutback high) and one for negative deviations (cutback low). Normally, the optimum setting for cutback is:

cutback high = (+ proportional band / 100) * loop span
cutback low = (- proportional band/ 100) * loop span

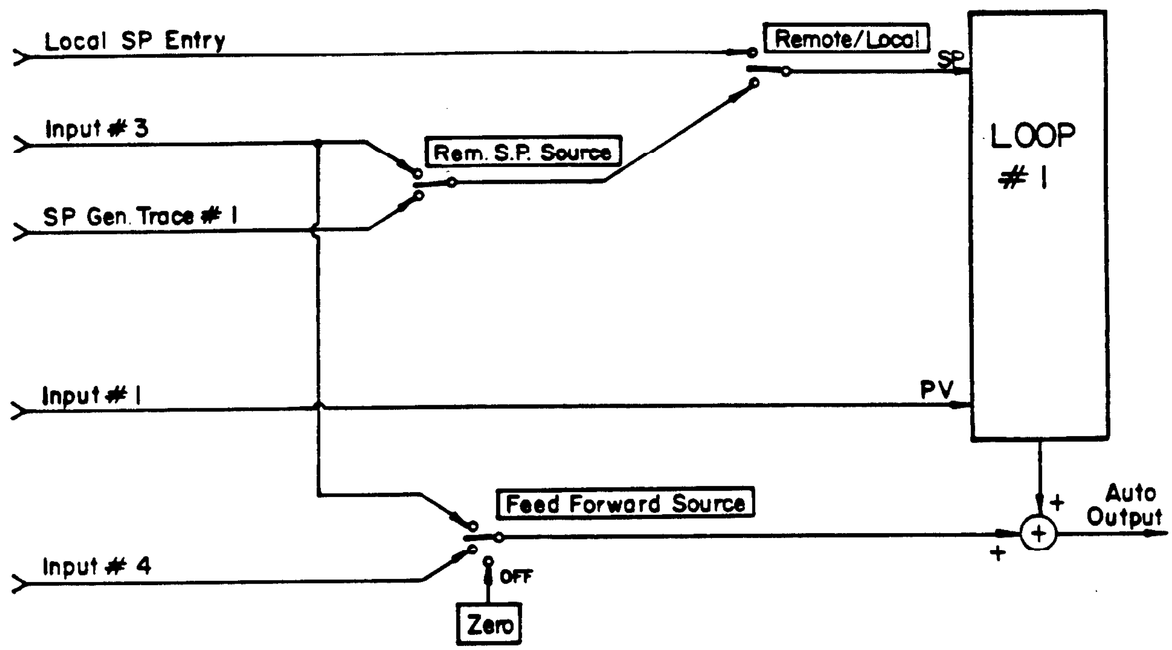


Figure 6 - Loop 1 I/O

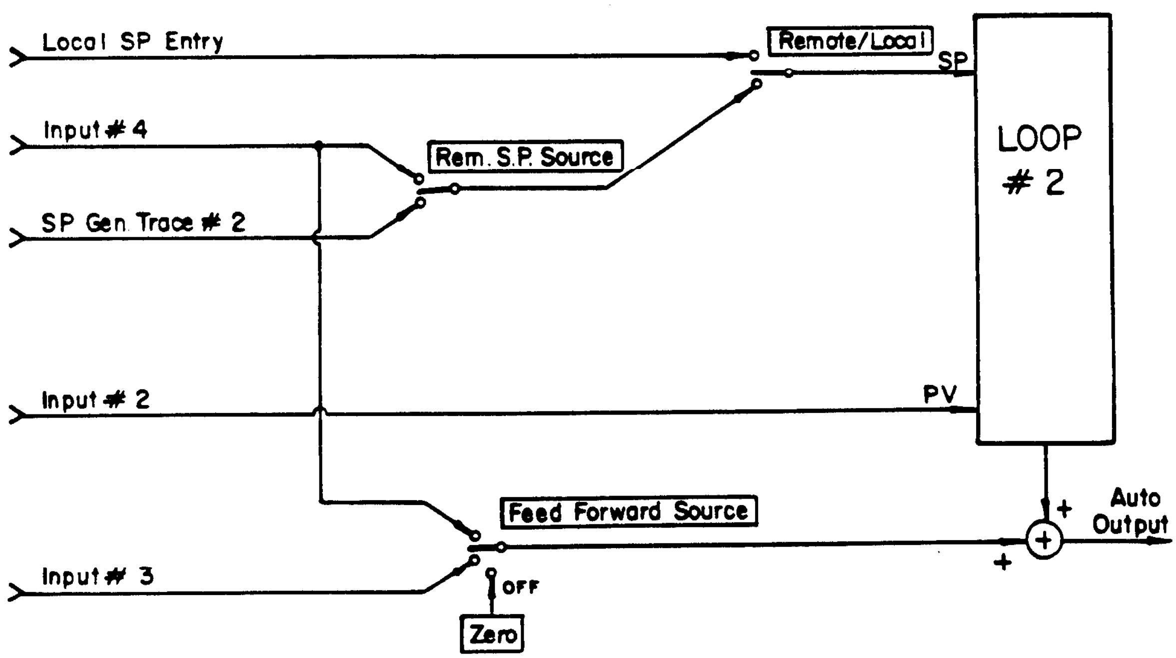


Figure 7 - Loop 2 I/O

However, cutback settings may be widened when a second time constant is involved in the process. Cutback can also be disabled through programming.

Feedforward - Each loop may use a recorder input as a feedforward signal. These signals must be wired to either channel 3 or channel 4. The feedforward signal is applied directly to the output of the PID algorithm. Note that feedforward is incorporated into the bumpless transfer algorithm. Feedforward has no effect during manual control operation.

Remote Setpoint - The instrument will accept a remote setpoint value for each loop. This signal may come from the built-in setpoint generator, a recorder channel, or (in the case of loop 2) the loop 1 output, which makes a cascade configuration.

If the setpoint generator is used, trace 1 will feed the remote setpoint of loop 1, and trace 2 will feed the remote setpoint of loop 2. Both loops do not have to use the setpoint generator. Loop 1 could be using trace 1, while loop 2 could be using a channel. The remote setpoint function may be turned off, which has the effect of disabling the R/L key for that loop.

If a channel is used as the remote setpoint source, channel 3 must be used for loop 1, and channel 4 must be used for loop 2. The units of the channel used must match the units of the loop involved.

Cascade - If the remote setpoint source of loop 2 is selected to be loop 1, then a cascade configuration takes effect. There are some built-in conveniences which only activate when cascade is programmed. First, the auto/manual controls of the loops are interlocked. If loop 2 (which is the inner loop) is put into manual, the outer loop (loop 1) is forced into manual also. This makes sense, since loop 2 represents the control element for loop 1. Secondly, during the time that loop 2 is in manual, the output of loop 1 is forced to be equivalent to the process variable of loop 2. This mechanism keeps the deviation of loop 2 at zero during manual operation, because the output of loop 1 is driving the setpoint of loop 2. Why is this helpful? When the inner loop is returned to automatic, a bumpless transfer will take place at balanced conditions, which is the least disturbing way for the controlled inner loop to transfer to automatic control. When the inner loop stabilizes, the outer loop can then be placed in automatic, and the loop 1 controller can again begin making changes to the loop 2 setpoint.

Take note that an initially confusing situation arises from this scheme. If both loops are in manual, (and loop 1 must be in manual if loop 2 is in manual), then the loop 1 output cannot be manually adjusted. This is true even though loop 1 is in the manual mode. The reason is that the loop 1 output is busy following the process variable of loop 2. The only time that the loop 1 output can be adjusted manually, when cascade is in effect, is when loop 1 is in manual, and loop 2 is in automatic mode.

See figure 8.

Setpoint Tracking - Tracking can be independently enabled for each loop. This mechanism causes the local setpoint of a loop to follow the process variable of that loop when the loop is in manual. The local setpoint can only be adjusted when the loop is in automatic mode. Setpoint tracking insures that the

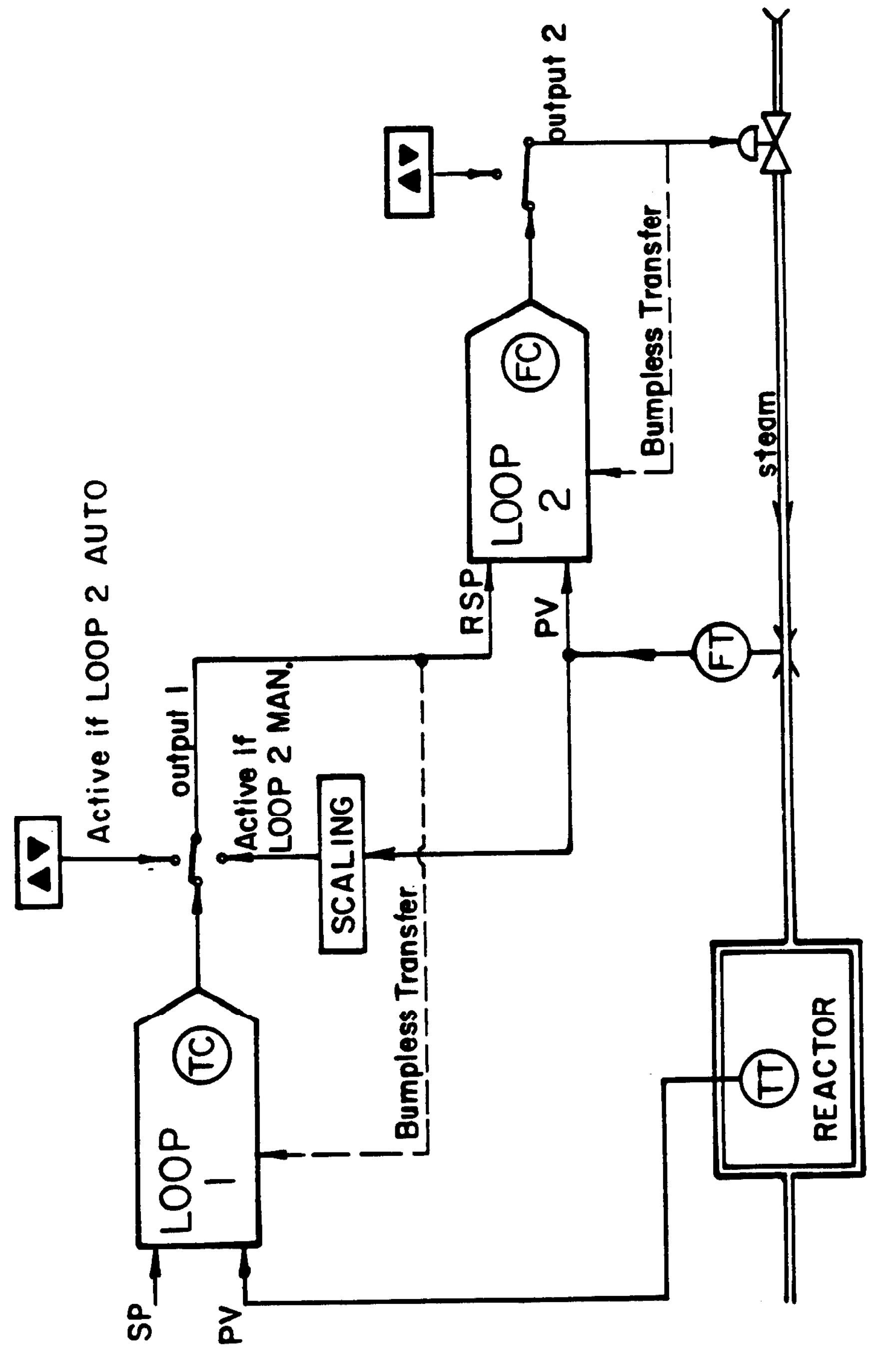


Figure 8 - Cascaded Loops

transition from manual to auto is done at balanced conditions.

<u>Rate Source Selection</u> - The rate term may selectively be applied to either the process variable or the deviation. Taking the derivative of the process variable instead of the deviation has the advantage of avoiding large rate terms on setpoint changes. On the other hand, the derivative of the deviation might be useful when using a setpoint generator as remote setpoint.

<u>Adjustable Loop Span</u> - The span of each loop is programmable. This feature makes the loop span independent of the chart span, as with older circular chart/controller combinations. The advantage of this feature is that changes to the chart span do not affect the tuning of the loop. The loop span is also independent of the recorder input channel programming.

5.3. Tuning Parameters

Definitions - The following definitions apply to the tuning constants used:

Proportional Band - the percentage of loop span which the deviation must equal for the proportional term to reach 100% output.

Reset Time - if a deviation equal to the proportional band exists for this amount of minutes, the output due to the integral term will reach 100%. The reset time is usually set at the value of the process's fundamental time constant.

Rate Time - if the rate of change of the deviation (or process variable) equals

proportional band / rate time

then the derivative term will reach 100%. The derivative term aids in compensating for the secondary dominant time constant of the process. It will initially oppose the action of P and I.

Control Direction - The deviation value is defined to be PV - SP. A direct acting controller will tend to increase output with a positive deviation, and decrease it with a negative deviation. Reverse acting controllers do the opposite. Direct acting controllers are used with exothermic processes and reverse acting controllers are used with endothermic processes.

Secondary Tuning - Each loop can be programmed with 2 sets of tuning constants. Each set of tuning constants contains the following:

- proportional band

- reset time

- rate time

- control direction

Each loop uses its primary set of tuning constants when secondary tuning is disabled, by selecting 'off' in the proper configuration entry. (See section 8.1) If this is the case, the secondary tuning set need never be adjusted or examined. However, if switching to the secondary set is desirable, it can be done in several ways.

There are two basic entries which must be made. The first is to choose a variable which will determine the set of tuning constants to use. This can be:

- process variable
- setpoint
- deviation
- output

This variable will be compared to two entries defining the tuning band. Inside the band, the primary tuning is active, and outside the band, the secondary tuning is active. If a single boundary is desired, one of the band entries is made extremely large. See figure 9.

If output is chosen as the tuning trip variable, then the band entries have no effect. The tuning will switch when the sign of the output changes. Primary tuning is active when the output is positive, and secondary tuning is active when the output is negative. This might be useful in a duplex output loop, such as heat/cool. The process dynamics may be vastly different when the cooling system is on, than when the heating system is on.

When the tuning sets are switched, the loop is automatically put through a bumpless transfer sequence, preventing a process bump when a difference in gains is required.

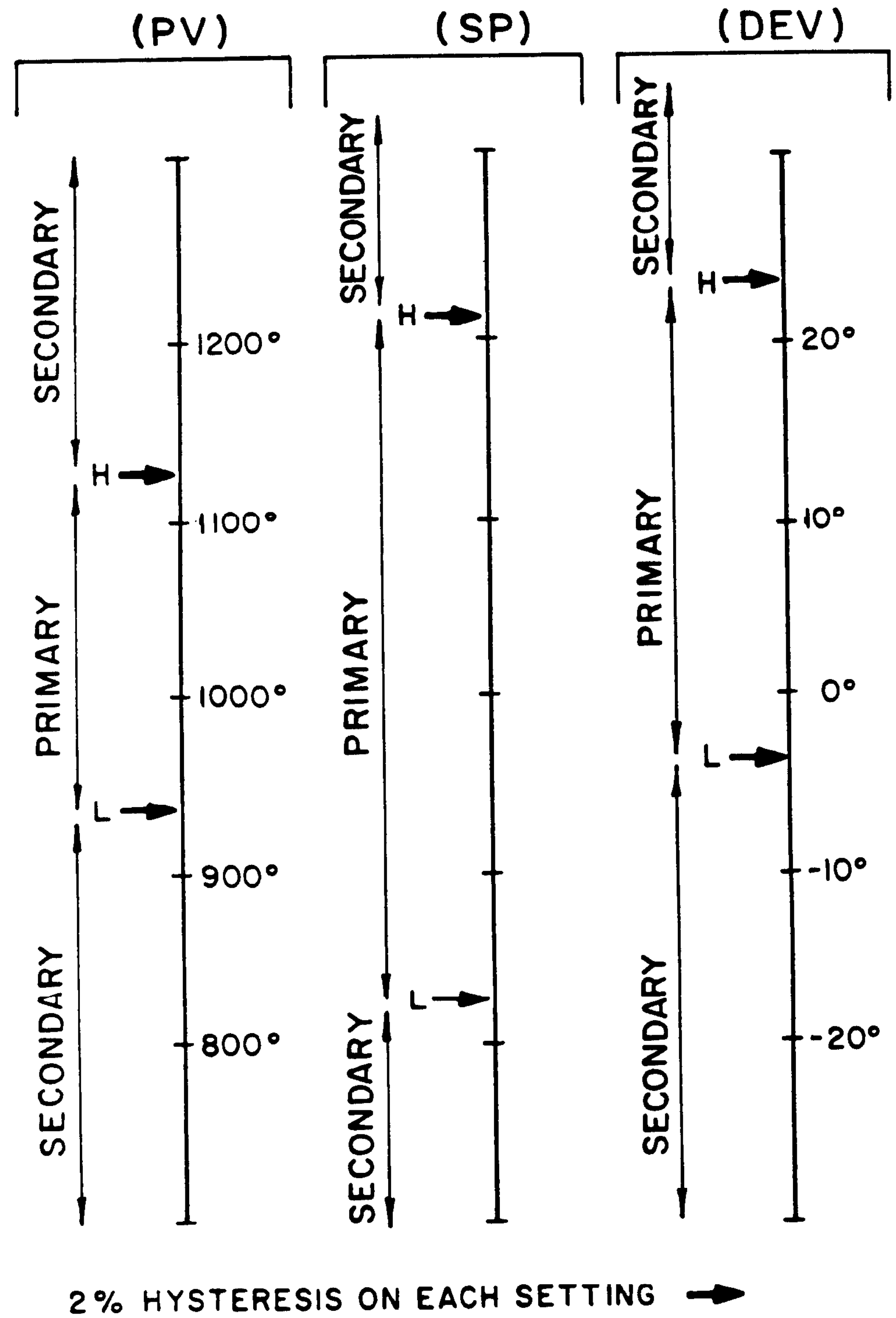


Figure 9 - Secondary Tuning Trip Variable

6. Setpoint Generator Description

The setpoint generator built into the recorder provides a precise, digital replacement for cam driven programmers used with older circular chart recorders. The generator produces 2 analog traces, with a single timebase, and 4 event outputs. The traces may be initialized on the value of any recorder channel and used by the control loops. They may also be retransmitted. (See section 7)

6.1. Organization

The basic unit in the setpoint generator is the segment. The segment contains target values for the traces, duration, event states, etc. One segment is in effect at any given time. Any change to the operation of the generator necessitates a transition to another segment.

A recipe consists of a set of segments, and specifications for initializing the trace values. The maximum number of segments in each recipe is 127. There is only one recipe active at any time.

The setpoint generator can store 4 recipes in its' battery backed-up memory. Therefore, a maximum of 127 x 4 or 508 segments may be stored in the memory. There are 3 types of segments, as defined below.

Target Segments - A target segment consists of a target value (in engineering units) for each trace, a duration for the segment, and states for each event to hold while this segment is active. The target values are the values the traces should equal at the end of the segment duration. There are no ramp rate or soak time entries, just targets and durations.

Target segments can have durations from zero to 999 minutes. A zero duration segment defines a step change in a trace. It might also be used to insert an event change without effecting the traces or recipe length.

NOTE - The events drive the states of the 4 alarm relays on the main card. All of the relays need not be installed. Keep im mind that conflicts can occur between events and recorder and controller alarms. A relay will turn on if either its' setpoint generator event or an assigned alarm are active. It doesn't turn off until both are inactive. Therefore, to allocate some relays to alarms and some to events, avoid setting the events corresponding to alarm relays into the active state in any segment of any recipe. Similarly, avoid assigning alarms to relays used for event output purposes.

Cycle Segments - A cycle segment is placed at a point in the recipe where it is desired to repeat a portion of the recipe. These segments contain a cycle count and a cycle destination segment number. Cycles can be defined from 1 to 999 counts. If more cycles are needed, then cycle segments can be placed in series. A cycle must always be done backwards, or to a segment number less than the cycle segment's. Cycles can also be nested, up to 5 deep. For example, a cycle may be defined from segment 10 to segment 2. Inside this area, a cycle segment could be placed at segment 8 with a destination of segment 4. Then, all of the inner loop's cycles will be completed for each of the outer loop's cycles.

End Segment - Each recipe has an end point, an end segment. The end segment defines whether the recipe will end ("DONE") or will cycle back to a defined segment number. If the recipe ends, the traces will soak forever at their last target values. The events will hold the states defined in the last target segment.

If a repeating end is chosen, the recipe will start over at the defined segment number. The difference between a cycle segment and a repeating end segment is that with the end segment, the elapsed timer for the recipe is reset to zero. Also, a repeating end segment defines a recipe which will run forever, not for specified counts.

6.2. Operation

Overview - The setpoint generator works very much like a cam. There are 2 programmable wheels on the cam to produce 2 traces, which are on a common timebase. Holding the cam holds both traces in soaks, resetting the cam resets both.

The generator also produces 4 event states, which would be analogous to tabs sticking out of the cam. (Think of a washing machine.) When the cam is held the events stop changing state.

To begin a recipe, the recipe is activated, choosing from one of the four stored recipes. Then, the recipe can be placed in the RUN state. When a recipe is activated, it is automatically reset. This means that the trace outputs are set to their programmed initial values, either constants or the value of one of the recorder channels. The events are turned off. The elapsed timer is cleared. After the recipe is reset, the segments, starting with number 1, are processed. The durations of the target segments, and the cycle counts, determine the length of the recipe.

What Happens at a Cycle? - When a cycle segment is encountered, and the cycle count has not reached zero, the current segment number will change to the cycle destination. The traces will ramp to the new segment's targets from wherever they were before the cycle. In other words, there is no pre-determined starting value for the traces, just end values. They do not 'bump', except for zero duration target segments. If this cycle segment is nested inside another cycle, the new cycle segment, (the innermost) will drive the displayed cycle count until it is finished, when the next outer cycle will be replace it with its' current count.

What Happens at a Hold? - When the recipe is held, the time left in the current segment, and the elapsed time in the recipe stop changing. The traces stop trying to reach ther targets, and enter soaks. The events hold their states.

What Happens at a Jump? - If the user chooses to skip over some segments (jumps cannot be backwards) he can use the controls described in section 8.2 to execute a recipe jump. The current segment number will take on the destination value of the jump, and the recipe will automatically be placed in hold. The traces will take on the values of the target segments immediately preceding the new segment number. For example, suppose the recipe is currently executing segment 10. At this time, trace 1 has a value of 1050 degF. The user jumps to segment 20. The current segment becomes number 20. The last target segment before segment 20 is 18 (suppose segment 19 is a cycle segment). The target value of segment 18 is 2000 degF. Then, trace 1 immediately takes on a value of 2000 degF. It will then begin to approach the target of segment 20.

It is possible to jump out of a looping cycle. If this happens, that cycle is automatically un-nested, as if it had counted down to zero.

Normal / 60X - There is a test mode in the setpoint generator which allows the user to execute a recipe at 60 times normal speed. Displayed values of time remain based in minutes, but they update in seconds. The only displayed difference between 60x mode and normal mode is that step changes (zero duration target segments) occupy what appears to be 2 minute time slots. Also, time is updated in increments of 2 minutes, since in real time, the setpoint generator runs every 2 seconds. The setpoint generator will only switch from normal to fast, or vice-versa, during a reset of the recipe.

Trace Engineering Units - The setpoint generator operates as an independent device. Traces are not necessarily tied to any loop or recorder channel. Therefore, the traces must have their engineering units defined by the user. These units apply globally to all 4 recipes. If a trace is to be initialized from a recorder channel, then that trace should have the same units as the channel. If a trace is feeding the remote setpoint of a loop then it should have the same units as the loop process variable.

7. Retransmission Description

It is possible to retransmit all four of the recorder input channels. This can be done using the CAT outputs described for the controller above. Any output can be driven from any channel. One channel can drive all outputs. The possible variables to retransmit include:

- channels 1 to 4
- setpoint of loops 1 or 2
- deviation of loops 1 or 2
- output of loops 1 or 2
- setpoint generator traces 1 or 2

The number of retransmissions possible depend upon the control loops installed. Control loops always will take over the outputs necessary to accomplish control. If an output is not being used by a controller, then it it available for retransmission purposes. For example, if one loop is installed, and it is a duplex loop, then both output 1A and output 1B are unavailable for retransmission. On the other hand, if two loops are installed, but are cascaded, loop 1 needs no physical output, and both output 1A and 1B are available.

Each retransmitted variable can be independently spanned in engineering units on each output.

8. User Interface

The following section describes the user interface for the options of the recorder. For each option, there are two basic sections. The first is operational displays and controls, and the second is configuration. The reader should review the basic recorder manual if he is not familiar with the operation of the basic recorder keypad.

Configuration entries for a function can generally be found "under" the operational display for that function. For instance, to configure a loop, press the side arrow while the scroll is frozen on one of the loop displays. Similarly, to configure the setpoint generator, press the side arrow while the scroll is frozen on any of the four setpoint generator operation displays. Retransmission of signals involves no operational display, therefore configuration of retransmission can be found by scrolling through the main configuration tree under any of the channel displays.

8.1. Controllers

This section describes procedures for operating and configuring the controller option.

8.1.1. Controller Operation

Operation of the controllers can be accomplished via specialized keys on the face of the instrument. The following sections describe how to view and control the loop operation.

8.1.1.1. Loop Display and Indicators

When a control loop is installed, a loop display is automatically added to the run-mode scroll. The loop 1 display appears after the channel 1 display, and the loop 2 display appears after the channel 2 display.

This loop display contains the following:

- loop process variable "PVn"
- loop actual setpoint "SPn"
- loop output (opposite the setpoint in percent)
- loop engineering units

If a loop is installed, a column of LED indicators will appear along the left hand side of the display window. The top 2 indicators apply to loop 1 and the bottom 2 indicators apply to loop 2. There is an "R" indicator, lighting when the loop is using remote setpoint, and an "M" indicator, lighting when the loop is in manual mode.

Loop Process Variable - The process variable of loop 1 is always the value of the recorder channel 1 input. Loop 2 PV is always recorder channel 2. Therefore, as the scroll increments, you should see the value of channel 1, then see it repeated in the loop 1 display as PV. It is repeated so that it can be easily compared to the loop setpoint.

Loop Actual Setpoint - The source of a loop's setpoint can change with configuration and operating conditions. The setpoint displayed in the loop display is always the actual value being used, no matter what source is active. For instance, when the R/L key is pressed, a switch is made between remote and local setpoint. The display will reflect this change.

Loop Output - This displayed value is the desired position or level for the end element. The physical output value (CAT or DAT) may vary from this displayed output due to the action of slew rate limiting or, in the case of duplex loops, deadband. Duplex outputs can also be negative. Review figure 5.

Loop Engineering Units - The engineering units of the loop's PV, local SP, remote SP, span, etc., automatically are presented in the units configured on recorder channel 1 or 2. (Ch. 1 for loop 1, Ch. 2 for loop 2).

8.1.1.2. Loop Control Keys

If a loop is installed, the left hand side of the membrane switch panel will be filled with 12 keys which do not appear on non-controller models. The top row of keys applies to loop 1, and the bottom row applies to loop 2. Both sets are installed even if 1 loop is installed. Pressing any key in the top row will cause the loop 1 display to appear, and the scroll to freeze. Pressing any key in the bottom row will cause the loop 2 display to appear, and the scroll to freeze. The following descriptions apply to both loops.

R/L - The remote / local key is a "push-push" type control which switches the setpoint for the loop from local to remote, or back again. The "R" light for the loop will turn on if the loop is in remote mode. This key will have no effect if the remote setpoint source is configured as "off".

SP inc/dec - The leftmost set of up/down arrow keys manipulate the value of local setpoint for each loop. These keys will change the displayed setpoint value if the loop is in local mode. They will have no effect if the loop is in remote mode. The keys will operate on the least significant digit for 10 counts, and then will shift to the next more significant digit. In this way, the setpoint change can be accelerated by holding the key longer. The local setpoint will stop increasing/decreasing at the programmed values for setpoint limits.

These keys are designed for implementing small changes in local setpoint. Large changes in local setpoint can be accomplished faster by digital entry. The local setpoint entry is accessed by pressing the side arrow key while frozen on a loop display. The local setpoint can be entered digitally even when the loop is in remote mode.

A special limitation is imposed on the setpoint keys when setpoint tracking is enabled. With setpoint tracking, the local setpoint tracks the process variable of the loop whenever the loop is in manual. Therefore, with setpoint tracking, the inc/dec keys will only work if the loop is both in local and automatic.

A/M - The auto/manual key for each loop is a "push-push" type key which switches the loop from manual to automatic mode, and back again. The "M" indicator will light when the loop is in manual mode. Switching from manual to automatic is "bumpless".

Output inc/dec - The rightmost up/down arrow keys for each loop manipulate the manual output value. These keys will change the displayed output value only if the loop is in manual mode. They operate on tenths of percent for 10 counts, then shift 1 significant digit every 10 counts. The output value will stop increasing/decreasing at the programmed output limits.

A special limitation is placed on the loop 1 output keys when a cascade configuration is in effect. Since the loop 1 output is forced to proportionally track the loop 2 process variable when loop 2 is in manual, the loop 1 manual output cannot be manipulated unless loop 1 is in manual and loop 2 is in automatic mode. Also, loop 1 is forced into manual when loop 2 is placed in manual, when cascade is in effect.

8.1.2. Setpoint, Ratio, and Bias

Most of the loop configuration entries, including tuning, cannot be manipulated when the instrument's programming lock switch is set in the DI position. This prevents modifications by unauthorized individuals. However, a few values are changeable even if the lock is set. These values are commonly set by operators while a loop is on-line. To access them, freeze the scroll on the loop's display by scrolling to that display and pressing "enter", or simply by pressing any key in that loop's row. Then, press the side arrow key. The values are defined below in the order in which they appear.

Local Setpoint - At this point, the local setpoint may be entered digitally. Entry may be made even if the loop is in remote setpoint mode. If the value entered exceeds the programmed setpoint limits, the limit value will be displayed as the entry.

R.S.P. Ratio - The remote setpoint ratio is applied to remote setpoints from the recorder channels or from the setpoint generator. It is not applied to the loop 2 setpoint in cascade with loop 1.

actual remote sp = ratio x remote sp input

units: none

limits: 0.00 -> 10.00

R.S.P. Bias - The remote setpoint bias is applied to remote setpoints from the recorder channels or from the setpoint generator. It is not applied to the loop 2 setpoint in cascade with loop 1.

actual remote sp = remote sp input + bias

units: same as PV channel

limits: none

8.1.3. Tuning a Loop

The tuning constant entries for each loop are segregated from other loop configuration entries in order to simplify their frequent modification. There are 2 sets of entries, primary and secondary. Each set has identical units and limits. For an explanation of secondary usage, see section 5.3. The primary and secondary tuning constants can be accessed after scrolling past the BIAS entry. This can only be done if the program lock switch is in the EN mode. When the correct set is displayed, press "enter" to access that set.

Explanations of the function of each tuning entry are contained in sections 5.3 and 9.

Prop. Band - Proportional Band

units: percent

limits: 0.1 -> 200.0

Reset - Reset Time

units: minutes / repeat

limits: 0.0 -> 999.9 (0 turns off reset action, disabling bumpless transfer mechanism)

Rate - Rate Time

units: minutes

limits: 0.00 -> 99.99 (0 turns off rate action)

Direction - Control Direction

choices: reverse acting
direct acting

R.S.P. RATIO	______		R.S.P. BIAS	______	*
PRIM. PROP. BAND	______	PRCNT	SEC. PROP. BAND	______	PRCNT
PRIMARY RESET	______	MIN/R	SECONDARY RESET	______	MIN/R
PRIMARY RATE	______	MIN	SECONDARY RATE	______	MIN
PRIM. DIRECTION	REV. : DIR.		SEC. DIRECTION	REV. : DIR.	
SP. LOW	______	*	SP. HIGH	______	*
OUTPUT LOW	______	PRCNT	OUTPUT HIGH	______	PRCNT
INPUT RANGE LOW	______	*	INPUT RANGE HIGH	______	*
CUTBACK LOW	______	*	CUTBACK HIGH	______	*
SEC. TUN. TRIP LOW	______	*	SEC. TUN. TRIP HIGH	______	*
FEEDFORWARD LOW	______	*	FEEDFORWARD HIGH	______	*
OUTPUT DEADBAND	______	PRCNT	SLEW RATE LIMIT	______	P/MIN
CYCLE RATE A	______	SEC.	CYCLE RATE B	______	SEC.

OUTPUT TYPE — SINGLE : DUPLEX

OUTPUT SLEW RATE — ON AUTO : ON MAN & AUTO

REM. SP SOURCE — OFF : CH. 3 : SP GEN 1

SELECT RATE — ON DEV. : ON PV

SP TRACKING — OFF : ON

SEC. TUNING — OFF : PV : SP : DEV : OUTPUT

FEEDFWD SOURCE — OFF : CH. 3 : CH. 4

DEV. ALARM LOW	______	*	DEV. ALARM HIGH	______	*
ALARM HYSTERESIS	______	*	RELAY	NONE : 1 : 2 : 3 : 4	

* - Units vary with input.

LOOP 1 CONFIGURATION WORKSHEET

R.S.P. RATIO	______		R.S.P. BIAS	______	*
PRIM. PROP. BAND	______	PRCNT	SEC. PROP. BAND	______	PRCNT
PRIMARY RESET	______	MIN/R	SECONDARY RESET	______	MIN/R
PRIMARY RATE	______	MIN	SECONDARY RATE	______	MIN
PRIM. DIRECTION	REV. : DIR.		SEC. DIRECTION	REV. : DIR.	
SP. LOW	______	*	SP. HIGH	______	*
OUTPUT LOW	______	PRCNT	OUTPUT HIGH	______	PRCNT
INPUT RANGE LOW	______	*	INPUT RANGE HIGH	______	*
CUTBACK LOW	______	*	CUTBACK HIGH	______	*
SEC. TUN. TRIP LOW	______	*	SEC. TUN. TRIP HIGH	______	*
FEEDFORWARD LOW	______	*	FEEDFORWARD HIGH	______	*
OUTPUT DEADBAND	______	PRCNT	SLEW RATE LIMIT	______	P/MIN
CYCLE RATE A	______	SEC.	CYCLE RATE B	______	SEC.

OUTPUT TYPE: SINGLE : DUPLEX

OUTPUT SLEW RATE: ON AUTO : ON MAN & AUTO

REM. SP SOURCE: OFF : CH. 4 : SP GEN 2 : LOOP 1 (CASCADE)

SELECT RATE: ON DEV. : ON PV

SP TRACKING: OFF : ON

SEC. TUNING: OFF : PV : SP : DEV : OUTPUT

FEEDFWD SOURCE: OFF : CH. 3 : CH. 4

DEV. ALARM LOW	______	*	DEV. ALARM HIGH	______	*
ALARM HYSTERESIS	______	*	RELAY	NONE : 1 : 2 : 3 : 4	

* - Units vary with input.

LOOP 2 CONFIGURATION WORKSHEET

8.1.4. Configuring a Loop

8.1.4.1. Limits

The following configuration entries set spans, boundaries, and scaling for various functions of each control loop. They are accessed by:

1. freeze on loop 1 or loop 2 display (all entries apply to loop displayed)

2. press "enter"

3. scroll to "Configure Loop?" (must have program lockout off)

4. press "enter"

5. "Config. Limits?" - press "enter"

6. enter values in sequence

S.P. Limit Low - Local and Remote setpoint low limit

S.P. Limit High - Local and Remote setpoint high limit

units: same as PV channel

limits: none

Output Low - Output low limit

Output High - Output high Limit

units: percent

limits: -100.0 -> 100.0

(low limit should be 0.0 or more if single loop type,
low limit should be -100 -> 0.0 if duplex loop type)

Input Range Low - Loop span low endpoint

Input Range High - Loop span high endpoint

Each loop has an independent span. This span can differ from both the recorder channel span which measures PV, and the chart span which records PV. This loop span is used in the computation of proportional band. Therfore, the tuning of loops is not effected by changes in chart span.

units: same as PV channel

limits: none (however, it shouldn't exceed recorder channel span measuring PV, which is channel 1 for loop 1 and channel 2 for loop 2.)

Cutback Low - Negative deviation cutback setting

Cutback High - Positive deviation cutback setting

These settings define the values of deviation which influence cutback operation. See section 5.2 for a detailed explanation of cutback.

units: same as PV channel

limits: low cutback: must be negative or zero

high cutback : must be positive or zero

(Zero entry disables cutback. Can have high cutback disabled, low enabled, both enabled, etc)

Sec. Tun. Trip Low - Secondary Tuning Low Trip Point

Sec. Tun. Trip High - Secondary Tuning High Trip Point

These 2 settings define the band which determines whether the primary or secondary tuning constant set will be used by the loop. Inside the band, the primary set is used, while outside the band the secondary set is used. In conjunction with these settings, the secondary tuning trip variable must be selected. (See below). If the secondary tuning trip variable selection is "off", then these settings have no effect, and only primary tuning will be used. See section 5.3.

units: same as PV channel

limits: none

Feedforward Low - Feedforward signal low span endpoint

Feedforward High - Feedforward signal high span endpoint

The feedforward signal applied directly to the output of the controller can be selected from recorder channel 3, 4 or "off". (See below). These 2 settings define how the signal will be scaled into 0.0% to 100.0% of output. Low span = 0%, and high span = 100.% in the units of the source channel.

units: same as feedforward source channel

limits: none

8.1.4.2. Output

The following entries determine the characteristics of the physical output of each loop. They are accessed by:

1. freeze on loop 1 or loop 2 display (all entries apply to loop displayed)
2. press "enter"
3. scroll to "Configure Loop?" (must have program lockout off)
4. press "enter"
5. scroll to "Config. Output?"
6. press "enter"
7. enter items in sequence

Output Type - see section 5.1

Use the scroll key to change selection, then press "enter".

Choices: single (heat only)

duplex (heat / cool)

Output Deadband - The symmetric deadband value used with a duplex output.

This entry has no effect for single outputs. See section 5.1

units: percent

limits: 0.0 -> 100.0

Cycle Rate A - DAT cycle rate for "A" output of this loop.

Cycle Rate B - DAT cycle rate for "B" output of this loop.

These entries only apply when this loop's output daughter card is a Duration Adjusting Type. They adjust the period over which the percentage output will operate. For example, if:

cycle rate = 60 seconds

output = 75 %

output circuit is "on" for 45 seconds, "off" for 15 seconds

Cycle rate "A" is used for a single output type, or for the heat side of a duplex loop (the side corresponding to positive output values). Cycle rate "B" is used for the cool (negative) side of a duplex output.

units: seconds

limits: 2 -> 250

Output Slew Rate - Slew rate application selection

This entry determines whether the slew rate limit will be applied to automatic control outputs only, or to manual changes and automatic control. Use the scroll key to change selection, then press "enter".

choices: auto only

manual and auto

Slew Rate Limit

This entry sets the limit on the rate at which the physical output can change. This entry has no effect on the displayed value of output. For example, an instantaneous manual adjustment of 20% in the displayed output value might result in a physical output change taking 15 seconds.

units: percent per minute

limits: 0 -> 9999. (a zero entry disables slew rate limit)

8.1.4.3. Loop Type

The following entries determine the characteristics of the control loop. They can be accessed by:

1. freeze on loop 1 or loop 2 display (all entries apply to loop displayed)
2. press "enter"
3. scroll to "Configure Loop?" (must have program lockout off)
4. press "enter"
5. scroll to "Conf. Loop Type?"
6. press "enter"
7. enter items in sequence

Rem. S.P. Source - Remote setpoint source selection

The loop can receive a remote setpoint from the following sources. Selection of "loop 1" has no effect if loop 1 is being configured. If loop 2 is being configured, and "loop 1" is selected, the loops are internally cascaded, and some special mechanisms become active. See section 5.2.

Use the scroll key to change selection, then press "enter".

choices:	off	- R/L key will be disabled
	rec. channel	- ch. 3 if loop 1, ch. 4 if loop 2
	s.p. gen.	- trace 1 if loop 1, trace 2 if loop 2
	loop 1	- see above

Select Rate - derivative source selection

This entry allows a selection of the variable used to calculate the derivative needed for the rate action in the PID control algorithm. If PV is selected, the derivative of the process variable is used. If DEV is selected, the derivative of the loop deviation (error) is used. Each has advantages. Choosing PV eliminates unwanted rate action on setpoint changes. Deviation may be desirable when a setpoint recipe is feeding the loop remote setpoint, since rate action will aid in tracking the profile.

Use the scroll key to change selection, then press "enter".

choices: on PV

on DEV

S.P. Tracking - setpoint tracking selection

Setpoint tracking causes the loop local setpoint to remain equal to the loop process variable when the loop is in manual mode. This insures transition to automatic mode at balanced conditions.

Use the scroll key to change selection, then press "enter".

choices: off

on

Sec. Tuning - secondary tuning trip variable selection

The secondary tuning trip band entered under "limits" above will be applied to the variable chosen here. See section 5.3. Use scroll key to change selection, then press "enter".

If output is selected, the tuning trip band is not used. Instead, the sign of the output determines which tuning set is used. Positive output selects primary tuning and negative output selects secondary tuning. This mechanism may be useful in heat / cool applications where the difference in end elements effects process dynamics.

choices: off - no secondary tuning

PV - process variable

SP - actual setpoint

DEV - deviation (error)

OUTPUT - sign of output.

Feedfwd Source - recorder channel used for feedforward signal.

Each loop can receive its' feedforward signal from either recorder channel 3 or channel 4. Both loops may use the same channel. Use the scroll key to change selection, then press "enter". Be sure to set feedforward scaling entries as explained in previous section.

choices: off - no feedforward in effect

ch. 3

ch. 4

8.1.4.4. Deviation Alarm

The following entries are used to set the loop's deviation (error) alarm. Deviation is defined as: PV - SP. The alarm configuration can be accessed by:

1. freeze on loop 1 or loop 2 display (all entries apply to loop displayed)
2. press "enter"
3. scroll to "Configure Loop?" (must have program lockout off)
4. press "enter"
5. scroll to "Conf. Dev. Alarm?"
6. press "enter"
7. enter items in sequence

Dev. Alarm Low - negative deviation alarm trip point

Dev. Alarm High - positive deviation alarm trip point

Alarm Hysteresis - hysteresis value to use with both trip points

The deviation alarm band can be set asymmetrically using differing high and low trip points. If no deviation alarm is desired, set the high and low trip points wider than the loop span.

units: same as PV channel

limits: low trip: must be negative or zero

high trip: must be positive or zero

hysteresis: must be positive or zero

Relay? - deviation alarm relay selection

The deviation alarm can be selectively assigned to any of the 4 possible relays on the main card, or none. If "YES" is selected, the relay number will be requested. Use the scroll key to select relay number, then press "enter". Be careful in assigning relays, as conflicts can arise between recorder alarms, deviation alarms, and setpoint generator events.

Keep in mind that alarm LEDs 1 and 2 are activated by the loop deviation alarms regardless of any relay configuration.

8.2. Setpoint Generator

The following sections explain procedures for configuring the setpoint generator option. A few clarifying comments might help at this point.

Recipe and Program - The words 'recipe' and 'program' are synonomous in this document.

Active Program - A maximum of four complete recipes, (programs) can be stored. Only one is operated upon by the generator at any time. This is the active program. An active program is not necessarily running. It could be in 'HOLD' or de-activated when the generator is not in use. This simplifies the scroll. (see below).

8.2.1. Setpoint Generator Operation Displays

There are 4 display windows which appear automatically in the operating scroll sequence when a setpoint recipe is active. They are described below. If no setpoint recipe is active, but the setpoint generator option is installed, 1 window will appear in the scroll. It reads:

PROG. INACTIVE

Display 1 - Recipe Operation

The first setpoint generator display to appear in the scroll shows the current condition of the active recipe. It also shows the current segment no. and the number of minutes remaining in that segment. The possible conditions for a recipe are:

RUN	- The generator is progressing through the active recipe.
HOLD	- The active recipe is stopped at the current segment. The hold condition was selected via the keypad.
EXT. HOLD	- A hold is in effect due to the 'hold' contact input.
RESET	- The active recipe is holding in the reset state due to keypad selection. The traces will continuously follow the channel which supplies their initial value. This state can be changed to hold or run, in which case segment 1 will commence.
EXT. RESET	- A reset condition is in effect due to the 'RESET' contact input.
DONE	- The recipe has reached its' end segment.

If the recipe is currently performing a cycle, another item will appear in the display. The number of remaining cycles will appear in the bottom right side of the window, followed by a 'C'. Note that when the last run of a cycle is executing, the cycles remaining read '0'. If cycles have been nested, the remaining cycles count will reflect the state of the innermost cycle. As inner loops are finished, remaining cycles in outer loops will pop into view.

Display 2 - Elapsed Time

This display repeats the recipe condition, and also shows the elapsed time since the last reset or end segment. The elapsed timer stops during hold. The units of elapsed time, in order of appearance, are:

D - days   H - hours   M - minutes

Display 3 - Trace Values

This display window shows the current value of the 2 traces, in their programmed units. Note that if a RESET condition is in effect, these displayed values will follow the recorder channels assigned for initial trace values.

Display 4 - Event States

This window shows the current states of the 4 event outputs of the setpoint generator. The top line is numbered 1 through 4 corresponding to relays 1 through 4 on the main card. Directly below each number is the state of that event output. A zero indicates 'off' and a 1 indicates 'on'. Any 'on' state corresponds to an active relay on the main card.

8.2.2. Setpoint Generator Controls

The setpoint generator controls can be accessed 'under' any of the 4 windows described above, or the PROG INACTIVE window. Freeze the scroll on 1 of the windows, and press the side arrow key. Access to the controls is allowed even with the program lockout switch on.

The top line of the control window displays the current condition of the setpoint recipe, as described in display 1 above. The second line scrolls with the following selections. Select one and press 'ENTER'.

RUN - Remove any hold or reset conditions, and commence progression through the recipe at the current segment.

HOLD - Stop the setpoint generator timebase at its' current value. Hold current trace values and event states.

RESET - Set the current segment to 0. Clear the elapsed timer. Turn off events. Set the traces equal to their programmed initial values or initialization channels. Continue to run through these steps until RUN or HOLD selected. (Segment no. 0 doesn't exist, and cannot be programmed.)

JUMP - When JUMP is selected, the jump destination segment must be entered. Enter this value as you would any numeric entry. The generator will be set to begin executing the selected segment. A HOLD condition will automatically be set. If RESET is in effect, the jump will have no effect. An error message will appear if a jump beyond the end of the recipe, or a jump backwards, or a jump to a cycle segment is attempted. Jumping out of cycling loops is permitted, in which case the cycle is 'un-nested', as if it had counted down to zero cycle counts.

Prog. SP Gen? - This entry provides access to the configuration menu for the setpoint generator. This entry cannot be selected if the program lockout switch is set in the DI position.

8.2.3. Setpoint Generator Configuration

Access to this menu is as follows:

1. freeze scroll on any of 4 setpoint gen. displays
2. press "ENTER"
3. scroll to "Prog. SP Gen?" (only if program lock in EN pos.)
4. press "ENTER"

There are 2 sections below. The first deals with entries which are globally applied to all recipes. The second deals with entries which modify any specific recipe, 1 through 4.

8.2.4. Non-Recipe Entries

Edit Program - See following section, for recipe specific entries.

Activate Prog - After selection, enter desired recipe number. The selected recipe will automatically be placed in the RESET mode, ready for operation. Any currently active recipe will be de-activated.

This action can only be accomplished when the active program is in hold.

De-Activate Prg - Selection of this entry will cause the active recipe to be de-activated. Then, since no recipes are active, the scroll will contain only the message "PROG INACTIVE". Use this entry when the setpoint generator is not being used, in order to simplify the scroll.

This action can only be accomplished when the active program is in hold.

Chng Time Base - There are 2 choices under this entry, NORMAL and 60X. If NORMAL is specified, the setpoint generator will execute in real time. If 60X is specified, the setpoint generator will run at 60 times normal speed. Minutes will represent seconds.

The time base selection is only observed at reset time. Therefore, changing the timebase while a recipe is running or in hold will not change its' speed. The speed will change after the next reset.

The setpoint generator firmware executes every 2 seconds in real time. Therefore, when 60x mode is selected, minutes displayed in the elapsed time and in the remaining segment time will update 2 counts at a time. Step changes, (zero duration target segments), will occupy a 2 second interval.

Eng. Units - The setpoint generator is an independent option, not necessarily associated with any recorder channel or control loop. The units assigned to each trace must be programmed, and the decimal point position specified.

For an explanantion of the method of entering the units string and decimal point position, see the recorder manual under linear inputs, tag strings.

Note that if a setpoint generator trace is to be used as the remote setpoint for a controller, the units of the trace should be programmed to match the units of the loop's PV channel.

8.2.5. Editing a Recipe

These entries apply to the specified recipe only, not to all recipes. Review section 6 for an explanation of segment types and contents.

Editing of recipes is done in a temporary storage area, so that editing operations can later be rejected, or copied to other recipes. When a recipe is selected under "Edit Program", its' current contents are copied to the temporary storage area. All changes are made in the temporary area. Then, under "Save Program", it can replace any of the 4 recipes, not necessarily the one which was selected for editing.

In this way, recipes may be copied to each other, after minor modification. For example, recipe 1 is selected for editing. A large setpoint program is entered. The former recipe 1 is replaced by saving recipe 1. Then, recipe 1 is again selected for editing. A small number of changes are made to accomodate different operating conditions. A program save is done to recipe 2. Now, recipe 1 and recipe 2 are finished, being the same large recipe with minor differences. Editing and saving are independent.

Access to this menu is as described in the previous section. The recipe (program) number is selected using the scroll (up arrow) key.

Save Program - The specified program (recipe) number will be replaced by the current contents of the temporary storage area. A simple copy is:

- edit recipe n
- save recipe m

During the save operation, the recipe is checked for certain unacceptable program steps. These are:

- forward cycles - a cycle segment jumps to a segment greater than itself
- cycle - cycles - a cycle segment jumps to another cycle segment
- active program - an attempt is being made to save the active recipe. In order to change a recipe, it must be inactive. Changes can be made to other recipes while one is active.

When an error message is encountered while saving a recipe, press "CLEAR" and re-enter the recipe editing menu. The recipe in the temporary editing area has not been lost, and can be fixed and saved.

Set Init Seg. - The initial conditions for the traces, or the values they should equal when a recipe reset takes place, are defined here. The traces may be set equal to channels 1 to 4 of the recorder, or a programmed (other) constant value. If the traces are initialized on a recorder channel, they will continuously follow that channel while the recipe is held in reset. It is important that the units used for a trace be similar to a channel it uses for initialization.

Delete Segment - The specified segment will be deleted from the recipe. Preceding and following segments will have their numbers adjusted accordingly.

Insert Segment - The segment entered will be inserted into the recipe just before the specified number. Following segments will have their segment numbers adjusted accordingly.

The new segment is entered in the same fashion as a replaced segment. (See below)

Replace Segment - The specified segment will be replaced with the contents entered as follows. Segments needed beyond the end of the current recipe, (such as in a new recipe), should be entered using Replace Segment.

Choose the segment type, then follow correct section for that type. Use scroll key to select type, then press "ENTER".

See figure 12 for a graphic representation of a recipe.

8.2.5.1. Target Segment

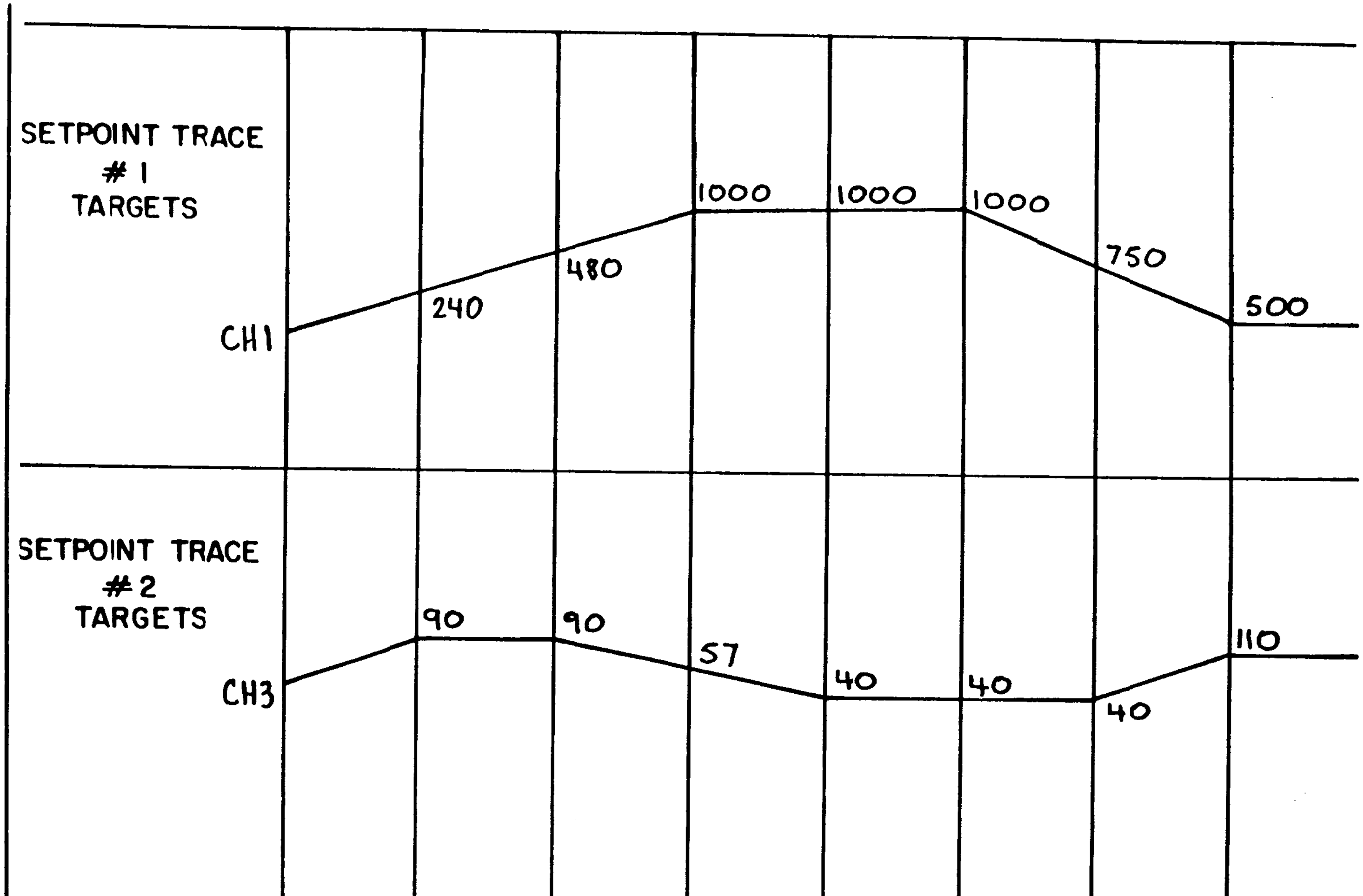
Enter the segment duration, in minutes. This value can be zero to 999 minutes. A zero entry will result in a step change in the trace value. The duration is the amount of time that the segment exists, or the amount of time for the traces to reach their target values.

Enter the target value for trace 1. The setpoint generator will begin the segment with the trace at its' current value, and ramp the trace to the target value in exactly the duration. If a soak segment is desired, simply repeat the last target value.

As the recipe is programmed, the target values will be carried forward, as well as the event states. This will speed up the programming of a recipe, since normally, only one item changes in each segment.

Enter the target value for trace 2.

Enter the event states which should be in effect during the duration of this segment. The events can be changed by using the side arrow key to position the cursor at one of the 4 events, then using the up arrow key to select '1' or '0'. '1' corresponds to an active alarm relay on the main card.



SEGMENT NO.	1	2	3	4	5	6	7	8
DURATION (MIN)	30	30	65	35	100	30	30	0
EVENTS 1-2-3-4	0 0 0 1	0 0 0 1	0 0 1 1	0 0 1 1	0 0 1 1	0 0 0 1	0 0 0 1	0 0 0 0

Figure 12a - Setpoint Generator Recipe

SETPOINT TRACE #1 TARGETS								
SETPOINT TRACE #2 TARGETS								
SEGMENT NO.								
DURATION (MIN)								
EVENTS 1-2-3-4								

Figure 12b - Setpoint Generator Recipe Worksheet

Be careful in using the alarm relays. These relays can be activated by channel alarms, controller deviation alarms, and setpoint generator events. Allocate their usage carefully to avoid conflicts. An active '1' event state in a running recipe will activate the corresponding relay. This cannot be disabled. Therefore, for relays used for alarm purposes, never set the corresponding event to '1' in any recipe.

8.2.5.2. Cycle Segment

Enter the cycle segment number, which is the segment to which the recipe should jump when this segment is encountered. The cycle segment must be less than this segment, or backwards. Forward cycles are not permitted. A forward cycle will be detected when the recipe is saved.

Enter the number of times the cycle should occur. Acceptable entries are from 1 to 999 counts.

Cycles may be nested, up to 5 levels deep. A cycle from segment 10 back to 5 could exist inside a cycle from 11 back to 4, etc. Also, if more than 999 cycles is desired, cycle segments may appear in series. For example, to get 1500 cycles, program segment (N) for 300 cycles, then program segment (N+1) for 5 cycles, to the same destination as segment N.

8.2.5.3. End Segment

Enter the type of end segment, STOP, or REPEAT. A STOP end segment causes the setpoint recipe to enter an infinite soak condition, where the traces hold their last target values, and the events hold their last states. The displayed condition will read "DONE".

A REPEAT end segment causes the recipe to jump to a specified segment number, to repeat part or all of the recipe. The elapsed timer will be cleared before execution begins at the repeat segment number. The traces will ramp from their values at the end segment.

8.3. Retransmission Configuration

The configuration of a retransmitted signal is very simple. The 3 items identified below can be accessed in the following manner:

1. freeze the scroll on any channel display
2. press side arrow to enter main configuration menu
   (can only be accomplished when program lock disabled)
3. scroll to "Config. Retrans?"
4. press 'ENTER'
5. use scroll key to select physical output concerned
6. press 'ENTER'
7. use scroll key to select signal to retransmit
8. press 'ENTER'
9. enter scaling values in normal fashion

Physical Output Selection

A maximum of 4 current adj. type outputs (4 to 20) can be installed in the unit. Each output can be assigned to a different retransmission signal, or the same signal, or any desired combination. The limitation on available outputs is determined by the number of outputs installed and the number of controllers installed. See section 7.

Keep in mind that entries will be accepted for retransmission on unavailable outputs. These entries will be used if and when the output becomes available through controller reconfiguration.

Retransmitted Signal

The following signals can be selected for retransmission:

- channel measured value (channels 1 to 4)
- SPG1, SPG2 (setpoint generator trace 1, 2)
- SP LOOP 1, 2 (actual setpoint of loop 1, 2)
- DEV LOOP 1,2 (loop error (PV - SP) loop 1, 2)
- OUTPUT 1, 2 (current output of loop 1, 2)

Retransmission Scaling

Each selected retransmission signal can be scaled independently. The LOW UNITS entry defines the value of 4 mA., and the HIGH UNITS entry defines the value of 20 mA..

9. Control Tutorial

9.1. PID Controllers

The controller implemented in this instrument is a full featured PID controller providing adjustable proportional, reset (integral) and rate (derivative) control actions. The proper application and tuning of PID controllers requires a basic understanding of the operation of the three controller output actions.

Proportional Control

The basic control strategy in conventional feedback control is to compare the measured value (process variable input) to a desired control value of that variable (setpoint) and if a difference exists, adjust the controller output to bring the measured variable back to the desired setpoint. The main objective is to provide proportional corrective action that will maintain the process at the control setpoint.

The controller adjustment that determines the sensitivity of the controller output to a change in the difference between the measured variable and the control setpoint is called Proportional Band (PB). The Proportional Band setting is expressed as the difference in percent of input span between the measured variable and the setpoint that will cause a 100 percent change in the controller output. A small value for the Proportional Band setting means that a small change in the difference between the measured variable and the setpoint will make a large change in the output of the controller.

For example, assume a controller was setup with an input span of 0 to 200 Deg. F. A Proportional Band setting of 10% means that a difference of 20 Deg. F. (10% of input span) between the measured variable and the setpoint will cause a 100% output change. Similarly a Proportional Band setting of 100% would require a 200 Deg. F. difference for a 100% output change. The relationship between the controller output and the PB setting is illustrated graphically in figure 13.

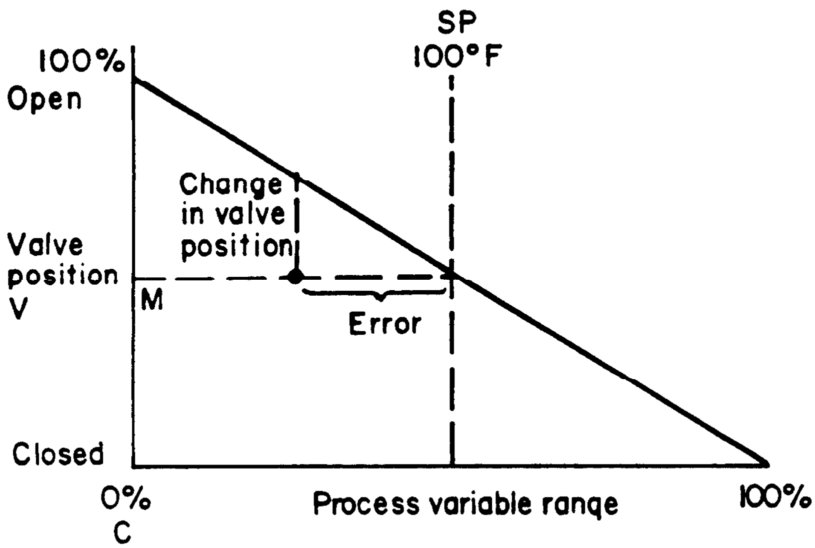
The Proportional Band setting therefore controls the gain of the controller per the following equation:

$$\text{Gain} = 100\% / PB$$

Proportional control assumes that the process load being controlled does not change. If there are load changes, then the controller will not be able to maintain the process at the desired setpoint. The reason for this is that there is only one value of output position for each value of process variable given constant process conditions. A change in the process load may require a different controller output to maintain the process at the same setpoint. The only way a proportional controller can compensate for a change in process load is to add a manually adjusted bias signal to the controller output. This adjustment is commonly referred to as manual reset.

Proportional plus Reset Control

The addition of automatic reset control action to the controller allows the controller to automatically compensate for changes in the process load. Reset



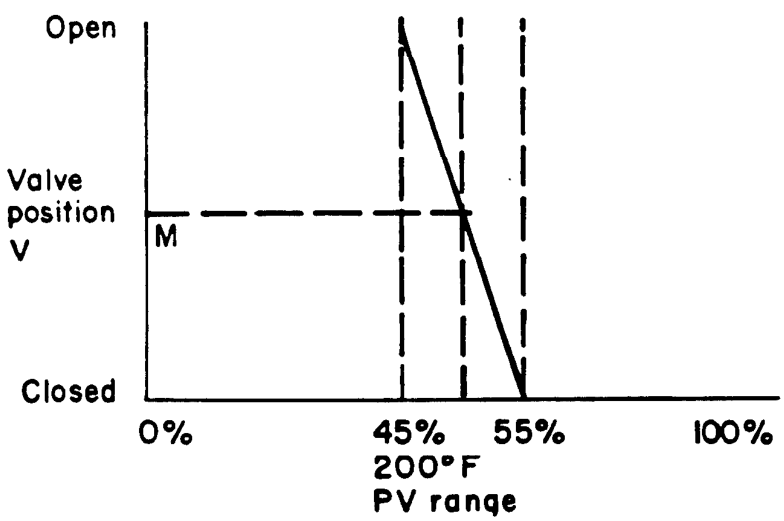


Figure 13 - Proportional Controller Response

action senses that an error, or offset, is present after proportional action has taken place and continues to change the output further in an attempt to eliminate the error completely. The rate at which the output moves due to reset action is proportional to size of the error (difference between the measured process variable and the desired setpoint) and the Reset Time adjustment.

The Reset Time adjustment allows the setting of the rate at which the controller will move the output to correct for an offset of measured variable from setpoint. Reset Time is entered in minutes per repeat. The term "minutes per repeat" refers to amount of time for reset action to ramp the controller output by an amount equivalent to the output change caused by proportional action. Given a constant difference between measured variable and setpoint, a large value for Reset Time will cause the output to ramp slowly. A small value of Reset Time cause the output to ramp quickly.

The relationships between the Reset Time adjustment, proportional action and reset action is illustrated in figure 14. The time graph shows the output of the controller that results from a step change in the error signal. When the error signal is detected the controller immediately steps the output per proportional action. Assuming the error persists, reset action will cause the controller output to ramp at the rate required so that the output change due to proportional action will be repeated exactly once after a time period equal to the Reset Time has expired.

Proportional Plus Reset and Rate

The need for rate action is not as easily understood as proportional and reset actions. The need for rate action arises when the closed loop response of the process variable under proportional plus reset control is analyzed for load changes. The change in load requires the reset action to move to a new output value. To achieve fast corrective action a short Reset Time would be desirable. However if the process variable does not respond quickly, the reset action will cause the output of the controller to overshoot the correct output value and therefore the process variable will also overshoot the setpoint. The controller will eventually bring the process back to setpoint but only after the process variable has overshot the setpoint since excess output accumulated by the reset action can only be "undone" by a change in sign of the error signal. The closed loop response can be improved by the addition of rate action. The function of rate action is to start cutting back controller output as the process variable starts to respond to the proportional and reset actions and therefore reduce the amount of process variable overshoot.

The amount of rate action that is applied to the output of the controller is determined by the rate of change at which the error (difference between the measured process variable and the control setpoint) is changing and the Rate Time setting. The faster the ramp rate of the error signal the larger the effect will be on the output due to rate action.

The Rate Time setting is entered in minutes. The Rate Time is the time period in which the error signal must repeat itself for the output due to rate action to be equivalent to proportional action. Assuming a constant ramp rate on the error signal, larger values of Rate Time cause larger changes in the output of the controller due rate action. Decreasing the Rate Time decreases the effect of

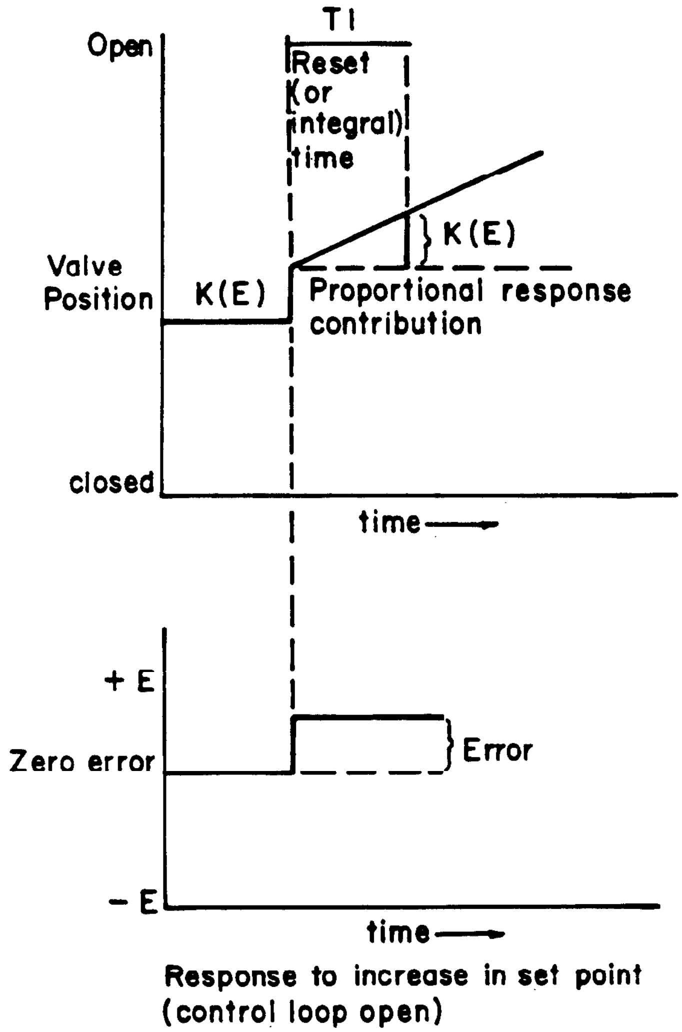


Figure 14 - Proportional plus Reset Control

rate action on the controller output.

The effect of the addition of rate action on the closed loop response is illustrated in figure 15. Curve 1 is the response to a load change using only proportional and reset actions. Curve 2 is the response when rate action is added. Note that with the addition of rate action the amplitude of the deviation from setpoint and the time period for the loop to return setpoint due to a setpoint change are reduced.

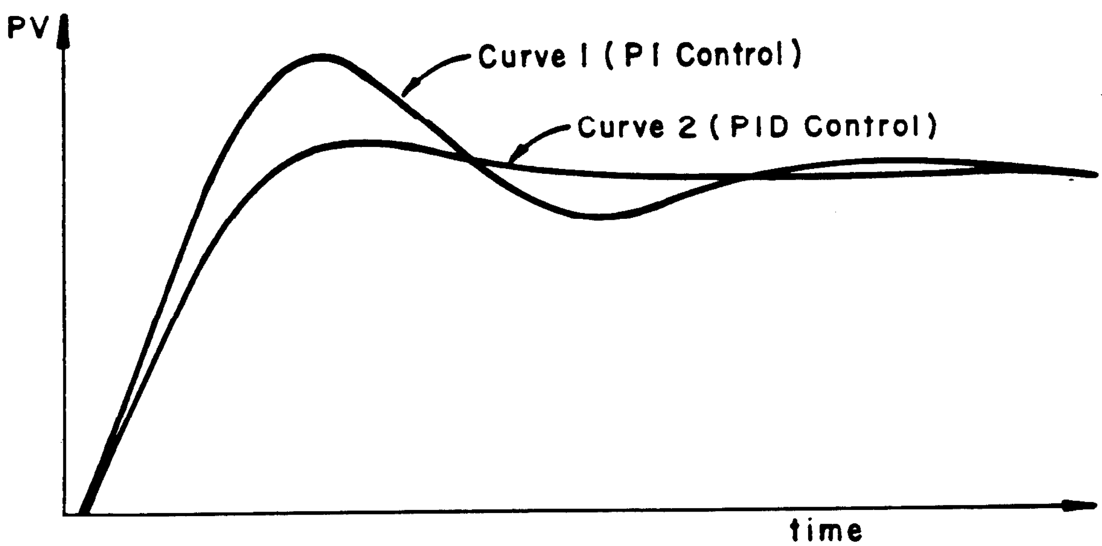


Figure 15 - Proportional plus Reset plus Rate Control

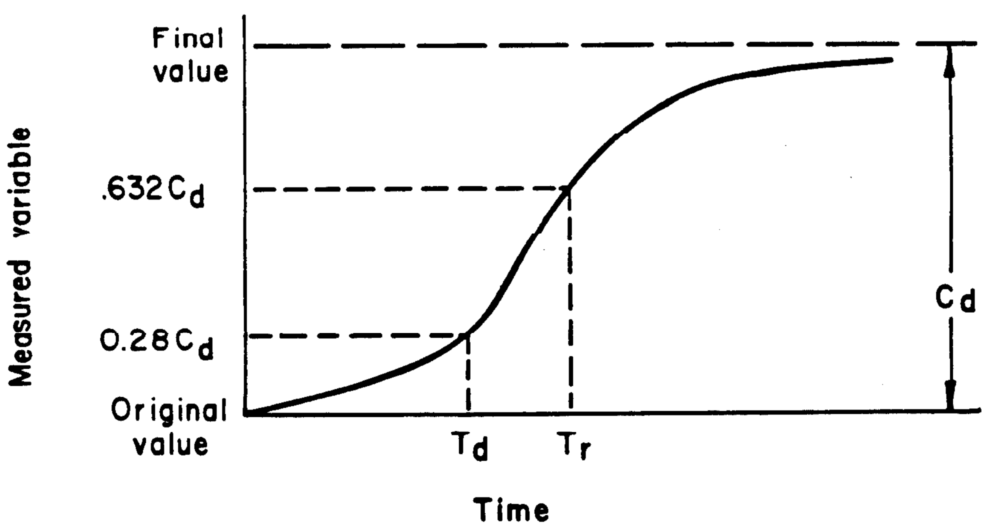


Figure 16 - Process Reaction Curve

9.2. Tuning Procedures

Good control performance requires the controller to be tuned to the process by adjusting the Proportional Band, reset and rate control actions. The definition of good control performance may vary with the process under control and overall system design goals but in general the basic goals should be:

1. Minimum deviation following a process disturbance.

2. Minimum time interval before return to setpoint.

3. Minimum offset due to changes in operating conditions.

There are diverse methods for finding the controller settings that will satisfy these goals. Some are more precise than others, however all result in good approximations that may be fine tuned for final optimizing. The two methods presented here are the ultimate-cycle method (Ziegler & Nichols) and the process reaction curve method (Cohen & Coon).

Ultimate-Cycle Method

The ultimate-cycle tuning procedure is:

1. Set the controller Reset Time adjustment to 99.99 Min./Repeat. Set the Rate Time to 0.0. Set the Proportional Band to 100.0.

2. With the controller on automatic control decrease the Proportional Band setting slowly until the measured process variable begins to oscillate. Write down the Proportional Band setting that results in continuous oscillation. This value is called the ultimate Proportional Band (PBu).

3. Measure the time period of the oscillation, by monitoring the time that elapses between the peaks. This called the ultimate period (Pu).

4. Compute the proportional, reset and rate actions as follows:

Controller Type	Tuning Settings
Prop. plus Reset	PB = 2.22 PBu
	Reset = Pu / 1.2
Prop. plus Reset & Rate	PB = 1.66 PBu
	Reset = Pu / 2
	Rate = Pu / 8

Process Reaction Curve Method

The Process Reaction Curve procedure is:

1. Place the controller into manual and step change the output by a fixed amount (Md). Write down the change used.

2. Monitor the step response of the measured process variable to determine the times for the process variable to reach 28% (Td) and 63.2% (Tr) of the final steady state value. Write down the change in steady state value of the measured process variable (Cd) per figure 16.

3. Compute the process gain, time constant and dead time per the following equations:

Kp = Cd / Md

Tp = 1.5 (Tr - Td)

Od = 1.5 (Td - 0.33 Tr)

a = Od / Tp

The value of the tuning settings can be calculated as follows:

Controller Type	Tuning Settings
Prop. plus Reset	PB = Kp/(0.9/a + 0.082)
	Reset = Tp ((3.33a + 0.333a^2)/(1+2.2a))
Prop. plus Reset & Rate	PB = Kp/(1.35/a + 0.270)
	Reset = Tp((2.5a + 0.5a^2)/(1+0.6a))
	Rate = Tp(0.37a/(1+0.2a))

CHESSELL CORPORATION
One Pheasant Run
Newtown, PA 18940
(215) 968-0660
Telex 685-1130
Fax (215) 968-0662

October 1990