TECHNICAL MANUAL

HLS-II

Heat Limit Controller II

Sixth Edition
April 15, 1997

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PURPOSE

This device is designed as a simple electronic heat limit switch for environmental and reliability test chambers. Whenever the measured temperature exceeds a preset limit, the controller's output switches to the off state to disable the heating system. A flashing visual indication is then provided, and the output is held off until manually reset by the user. Automatic reset action is also available as a user selected option.

DESCRIPTION

This device is packaged as a single, panel-mounted component, with an attractive anodized aluminum cover. The controls and indicators are mounted on the face of the cover, and consist of:

- a RESET button,
- a LIMIT set point dial, calibrated "0 - 550°F,
- a green NORMAL status indicator LED, and
- a flashing red LIMIT status indicator LED.

The controller is designed for use with ISA type T (copper vs. constantan) thermocouples. Electronic cold junction compensation is provided, and the input is not significantly effected by sensor leadwire resistance. In the event of an open sensor circuit, the controller will produce an upscale temperature indication exceeding the highest possible limit setting, ensuring that the heating system will remain inoperative until protection is restored.

The output of the controller consists of a single pole, normally open relay contact, rated 15-amps at 240vac. This contact is closed during all periods of normal operation, and opens when the limit setting is exceeded, or when power is removed from the controller.

Input power requirements are 1.5VA max at 110/120vac or 208/240vac, 50/60 Hz. All connections are made at miniature terminal blocks, which are accessible without disassembling the unit.

INSTALLATION & WIRING

Install the controller at a location that is convenient to system wiring, reasonably free of vibration and temperature extremes, and accessible to service personnel. Four holes for mounting screws are required on 2.5"x 5.5" centers (W x H). A 3-inch clearance is required above the mounting location.

Route the sensor cable to the top of the controller, connecting the (+) BLUE wire at the terminal marked "Blue +", and the (-) RED wire at the "Red -" terminal.

The power and output wiring should be routed to the bottom of the unit. Connect the control power as follows:

110/120vac circuits	208/240vac circuits
L1 to terminals 2 & 3 L2 to terminals 4 & 6 ground to GND	L1 to terminal 2 jumper terminals 3 & 4 L2 to terminal 5 ground to GND

The controller's output is available at the terminals marked "COM" and "N.O.". This normally-open contact is rated 15-amps maximum at 240vac. It will be closed when the green "Norm" light it on; it will be open when the red "Limit" light is flashing, or when the power is off.

RESET MODE SELECTIONS

The controller may be set up for either manual or automatic reset following over-temperature trips. When set for manual reset, operator intervention is required to enable the system after the preset limit temperature has been exceeded. When set for automatic reset, the controller will self-reset when the temperature returns to a value less than the limit setting.

The controller may also be set up for either manual or automatic reset at power-up. If set for manual power-up reset, operator intervention will be required to enable the system when power is applied. In the automatic mode, the controller will enable the system automatically at power-up, provided that the temperature is less than the limit setting. In situations where frequent power outages may create a reset nuisance, the automatic mode would normally be chosen. In other applications requiring a controlled start-up sequence, the manual power-up reset mode may be selected.

Movable shunts at the upper left-hand side of the printed circuit board assembly (see page 10) provide the means of selecting the desired reset options.

OPERATION

The limit temperature can be set by simply adjusting the pointer knob on the controller's cover to the desired value. Any temperature in the range of 0 - 550°F may be selected. The dial is graduated in 10-degree increments, and can be set to within approximately +/- five degrees.

When power is first applied, the controller will start-up in the "LIMIT" mode. Its red LIMIT indicator will flash on and off to signal this condition. To start the equipment, press the RESET button. If the measured temperature is less than the set limit, the red indicator will then switch off, and the green NORMAL indicator will be turned on.

During all periods of normal operation, the NORMAL indicator will remain on, and the heating system will be enabled through the controller's output contact. If the measured temperature ever exceeds the limit setting, the controller will immediately switch back to the LIMIT status. The flashing red indicator will be enabled, and the controller will disable the heating system. This status will be cleared by pressing the RESET button after the measured temperature has returned to a value that is at least 10°F lower than the limit setting.

CIRCUIT ANALYSIS

Please refer to schematic diagram on page 4

The controller's temperature measuring circuit, U5, converts a low level thermocouple input to a scaled and compensated high level analog voltage. The sensor, "mj" (measuring junction) is connected to U5-3, the input of this amplifier. C14 provides low pass filtering for this input. The controller is designed to measure temperatures over the range of 0°F to 550°F, using a type T (copper vs constantan) thermocouple. Over this temperature range, this sensor produces emf's ranging from -0.674mV to +14.153mV. This input is amplified and scaled to provide a 0v to +5.0v analog output at U5-6.

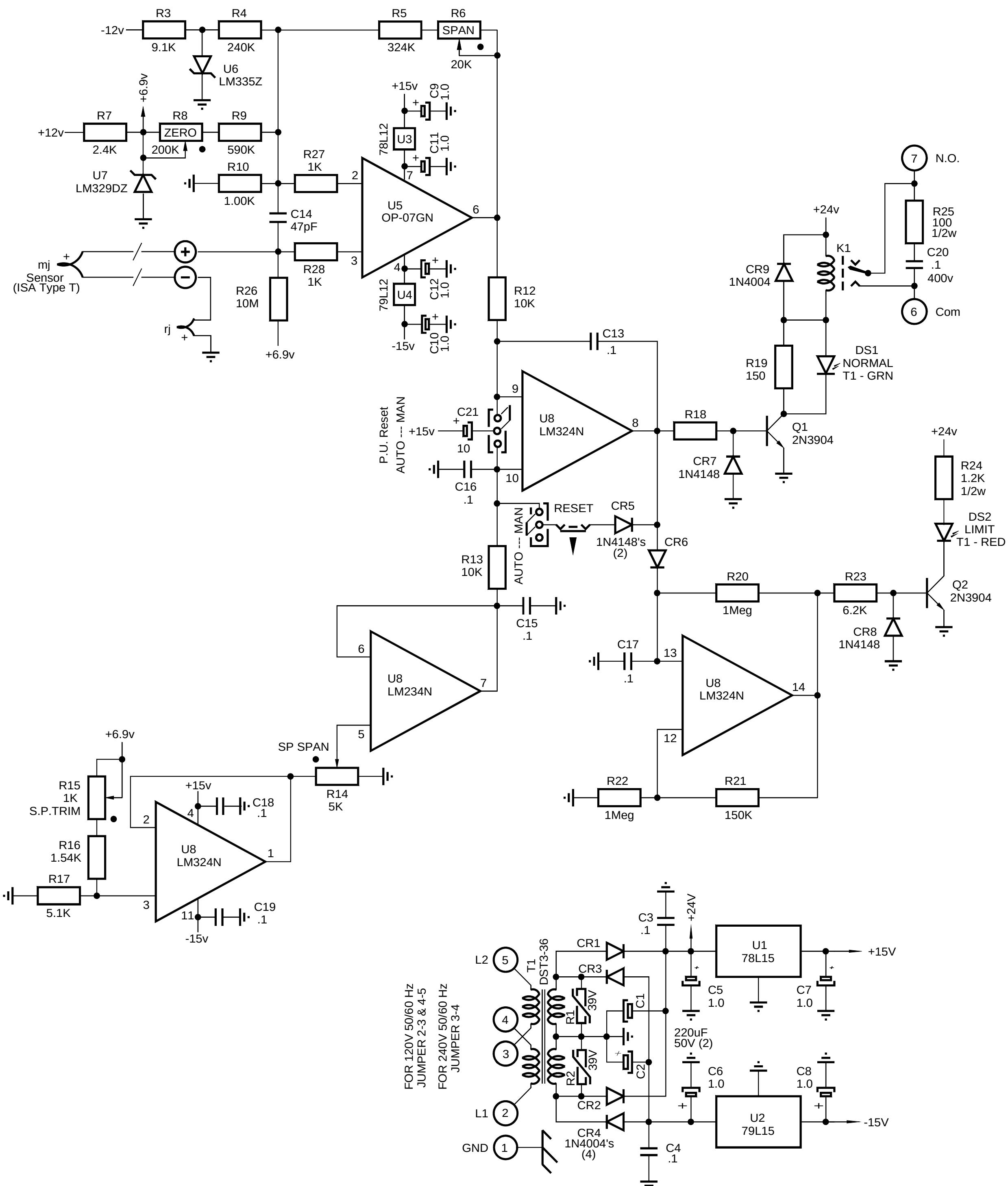
To achieve this, the gain of the amplifier is set at

$$Av = 5.0V/14.827mV = 337.2$$

... by R5, R6 and R10. This non-inverting amplifier will always settle at the point where the potential at its inverting input, U5-2, is exactly equal to its input, U5-3. This condition is established by a feedback current, passed from the output, U5-6, through R5 and R6 to the amplifier's inverting input. For a given input, the magnitude of the feedback current required to establish this balance is a function of R10. Having established that, the magnitude of the amplifier's output voltage then becomes a function of the feedback resistors, R5 and R6. The resistor values used permit the gain to be set exactly at 337.2 using standard values of practical components, with all tolerances accommodated.

Thermocouple circuits necessarily produce a second junction, sometimes called the "reference junction", when connected to some measuring device. This junction, shown as "rj" on the schematic, has the same "emf vs. temperature" characteristic as the sensor. It occurs in series with the sensor's emf, with the opposite polarity. The emf produced by the "rj" junction therefore subtracts from the sensor emf, and any variation in the temperature of the reference junction directly effects the measurement.

U6, R3 and R4 provide reference junction compensation that minimizes errors due to the variation in ambient temperature. U6 is an integrated circuit temperature sensor, which produces an output which is proportional to its absolute temperature. This output varies 10mV/°C, and is scaled by R4 to produce a feedback current through R5 and R6 that will be approximately equal and opposite to that being caused by the influence of the reference junction. At room temperature, the emf produced at rj varies about 40.7uV/°C which, in turn, produces a feedback current of about 40.7nA through R10. A 1°C ambient temperature change will also result in a 10mV variation at U6. This will produce a -41nA change in the total feedback current, which approximately cancels out the shift produced by rj.


-12v
R3
9.1K
R4
240K
U6
LM335Z
R5
324K
R6
SPAN
20K
+6.9v
+12v
R7
2.4K
R8
ZERO
200K
R9
590K
U7
LM329DZ
R10
1.00K
R27
1K
+15v
C9
1.0
78L12
U3
C11
1.0
U5
OP-07GN
C14
47pF
mj
Sensor
(ISA Type T)
R28
1K
R26
10M
79L12
U4
C12
1.0
C10
1.0
-15v
rj
R12
10K
C13
.1
+24v
K1
CR9
1N4004
R25
100
1/2w
C20
.1
400v
N.O.
Com
R19
150
DS1
NORMAL
T1 - GRN
P.U. Reset
AUTO --- MAN
C21
U8
LM324N
R18
Q1
2N3904
CR7
1N4148
C16
.1
RESET
CR5
1N4148's
(2)
CR6
R24
1.2K
1/2w
DS2
LIMIT
T1 - RED
R13
10K
R20
1Meg
R23
6.2K
Q2
2N3904
CR8
1N4148
C15
.1
C17
.1
U8
LM234N
U8
LM324N
+6.9v
SP SPAN
R14
5K
R15
1K
S.P.TRIM
R16
1.54K
R17
5.1K
C18
.1
C19
.1
R22
1Meg
R21
150K
C3
.1
+24V
U1
78L15
+15V
C5
1.0
C7
1.0
CR1
CR3
L2
T1
DST3-36
R1
39V
C1
R2
39V
C2
220uF
50V (2)
FOR 120V 50/60 Hz
JUMPER 2-3 & 4-5
FOR 240V 50/60 Hz
JUMPER 3-4
L1
CR2
CR4
1N4004's
(4)
GND
C4
.1
C6
1.0
C8
1.0
U2
79L15
-15V

U7, R7, R8, and R9 provide a means of shifting the amplifiers output to zero with a 0°F input at "mj". U7 is a precision voltage reference integrated circuit, which provides a stable +6.9v at its junction with R7 and R8. At 0°F, the mj input will be -0.674mV. Assuming a 25°C ambient temperature, the emf produced by rj will be about +0.922mV, so the net input will be about -1.596mV, producing a -1.6uA input-related feedback current in R10.

Meanwhile, the voltage at the U6, R3 junction varies with absolute temperature by 10mV/°K, and will therefore be about +2.98v (0°C = 273°K). This produces a compensator-related feedback current of about -12.4uA in R10.

The net value of these two error currents is therefore about -14uA. The amplifier itself also has input offsets that must be accommodated. These may produce feedback current factors as large as +/-0.1uA, so the net feedback current for a 0°F input will be somewhere in the range of +9.7uA to +14.6uA. Assuming that R5 and R6 are set at about 336.2°K, the output at U5-6 would fall somewhere within the range of +3.3 to +4.9 volts. To shift the output level back to zero, R8 is adjusted so that the zero network injects a current into the feedback node. This bias current will be equal and opposite to that caused by the various offsets.

The set point for the controller is provided by R14. The excitation voltage is provided by the R15, R16 and R17 network, and has a range of 4.7v to +5.3v. The excitation voltage is buffered by U8a, and is unaffected by the value of R14. R15 is used to accommodate all other circuit tolerances, and may be used to optimize the accuracy of the set point dial in the area of primary use.

The set point voltage is buffered by U8b, and is connected via low-pass filter R13/C16 to one input of comparator U8c. The other comparator input is slew-rate filtered by R12/C15, and varies over the 0/+5v range with the measured temperature. Capacitor C21 is used to kick one input more positive than the other to control what happens at power-up, either tripping or resetting the limit, depending on the position of the shunt, as shown below.

When the temperature analog at U8-9 exceeds the value of the set point voltage at U8-10, the comparator's output, U8-8, falls to its negative limit ... about -14 volts. Diode CR5 will then be forward biased, and the comparator will latch in this state, with about -13.3v on its set point input. Pressing the RESET button will remove the negative level from U8-10, allowing the comparator to resume its positive output if the temperature has returned to a value lower than the limit setting. Moving the shunt to the "auto" position will permanently disable the latching function to provide automatic reset.

The comparator's output also drives the base of switching transistor Q1 which, in turn, operates the output relay, K1, and the NORMAL indicator DS1. This output will handle ac loads of up to 15-amps at 240vac maximum.

U8d and its associated components comprise a gated flasher for the LIMIT indicator, DS2. Assuming that U8-14 is at it's (+) limit, the potential across R20 will be about +11.7v, and capacitor C17 will be charging towards this level. Switching transistor Q2 and the LIMIT indicator will be "on". As C17 charges beyond +11.7v, U8-14 switches to its negative limit, and all of the above conditions are reversed, with the indicator "off". Oscillation continues indefinitely, at a rate established by the R20/C17 time constant, and the ratio of R21 to R22, at about 2 pulses per second. When the comparator's output, U8-8, is high, diode CR6 is forward biased, imposing a potential of about +13.3v directly on U8-13. The output of the flasher, U8-14, will therefore be clamped at its negative limit, holding the LIMIT indicator off.

Power for the controller circuitry is provided by a conventional bilateral full-wave rectifier circuit comprising of CR1, CR3, C1 and C3 (+ side), and CR2, CR4, C2 and C4 (- side). The +/-24v potentials are stabilized by three-terminal integrated circuit regulators U1 and U2 at +15v and -15v, respectively. Regulator compensation capacitors C5, C6, C7 and C8 prevent high frequency oscillation, and improve line and load transient response. To maximize noise immunity, the +/-15v potentials are re-stabilized at measuring circuit U5 by +/-12v regulators U3 and U4.

HANDLING ELECTRICAL INTERFERENCE

When used in the manually reset mode, this device is a latching mechanism. Momentary bursts of stray electrical energy, which would normally constitute nothing more than a transitory disturbance for other non-latching electronic instruments, may cause this device to latch its load circuit off. Electrical interference, or “noise”, is therefore a matter for special attention in the application of latching electronic limit controllers.

Although this control has been designed to provide a relatively high level of immunity to stray electrical energy, it is not possible to provide for 100% rejection of any noise frequency, wave-shape or amplitude. A few application hints are therefore offered for cases where noise problems occur, or are anticipated:

- Never ground the sensor, or use grounded-sheath type sensors.
- If possible, do not run the sensor cable through conduits or cable trays with switched current-carrying conductors. If it is not possible to separate sensor cables and power wiring, use shielded thermocouple extension cable, connecting the shield to ground (the electrical panel) at the controller’s chassis. *Do not ground the shield on the sensor end*.
- Transient electrical signals can be conducted into the controller through its power wiring. It is therefore good practice to take power for this device directly from the source (typically the control power step-down transformer), rather than from a “daisy chain” bus connection. As with the sensor cable, the power supply leads can also pick up stray electrical signals from adjacent wiring serving switched inductances (relay coils, etc.). If the controller can not be mounted close enough to the power source to permit a short, separate hook-up, twisting its “line” and “common” hook-up wires is recommended as a means of minimizing such pick-up. In extreme cases, use two-wire shielded control cable for the power connection.
- As a rule, electrical interference is best treated at its source. A simple RC snubber network (typically .047uF in series with 100 Ohms) connected across the terminals of a troublesome switch, relay coil or motor, will provide an easy and totally effective solution, whereas it may be next to impossible to achieve the same result by altering the controller’s hook-up wiring or internal circuitry.

FIELD CALIBRATION PROCEDURE

1. Electrical adjustments marked ZERO and SPAN are provided on the controller's circuit board, which is accessible by detaching the unit from its mounting location.

2. To trim these adjustments, disconnect the sensor cable and connect a portable potentiometer or millivolt source to the (+) and (-) terminals.

3. Set the input at "0°F" or its equivalent emf. Adjust the set point knob to exactly "0". While holding the RESET button down (not required if the unit is set up for automatic reset), adjust the ZERO trimmer to the point where the output relay can be heard to click on and off.

4. Likewise, set the input at "550°F" or its equivalent emf, and adjust the set point to exactly "550". While holding the RESET button down, adjust the SPAN trimmer to the point that causes actuation of the output relay.

5. This procedure normally results in a calibration accuracy of +/-2.5% of Span, which will normally be sufficient for limit switch operation. For closer calibration, refer to the more detailed bench procedure, which follows.

TEST BENCH CALIBRATION PROCEDURE

Please refer to the circuit board layout on Page 10

Adjustments are provided to permit zero and span measuring circuit calibration, and set point span trimming. These are marked, “zero”, “span” and “sp span” on the printed circuit board.

To adjust the measuring circuit zero, disconnect the sensor and connect a portable potentiometer or millivolt source to the (+) and (-) input terminals. Set the portable potentiometer at “0°F”, or adjust the millivolt source to the equivalent 0°F emf input ...

e.g.:	mj at 0°F:	-0.674mV
	rj at 71°F:	- +0.857mV
	set net emf:	-1.531mV

... then adjust “zero” trimmer R8 to provide exactly 0.00v at U5-6.

Now set the portable to “550F”, or the millivolt source to the equivalent net emf at 550°F ..

e.g.:	mj at 550°F	+14.153mV
	rj at 71°F:	- 0.857mV
	set net emf:	+13.296mV

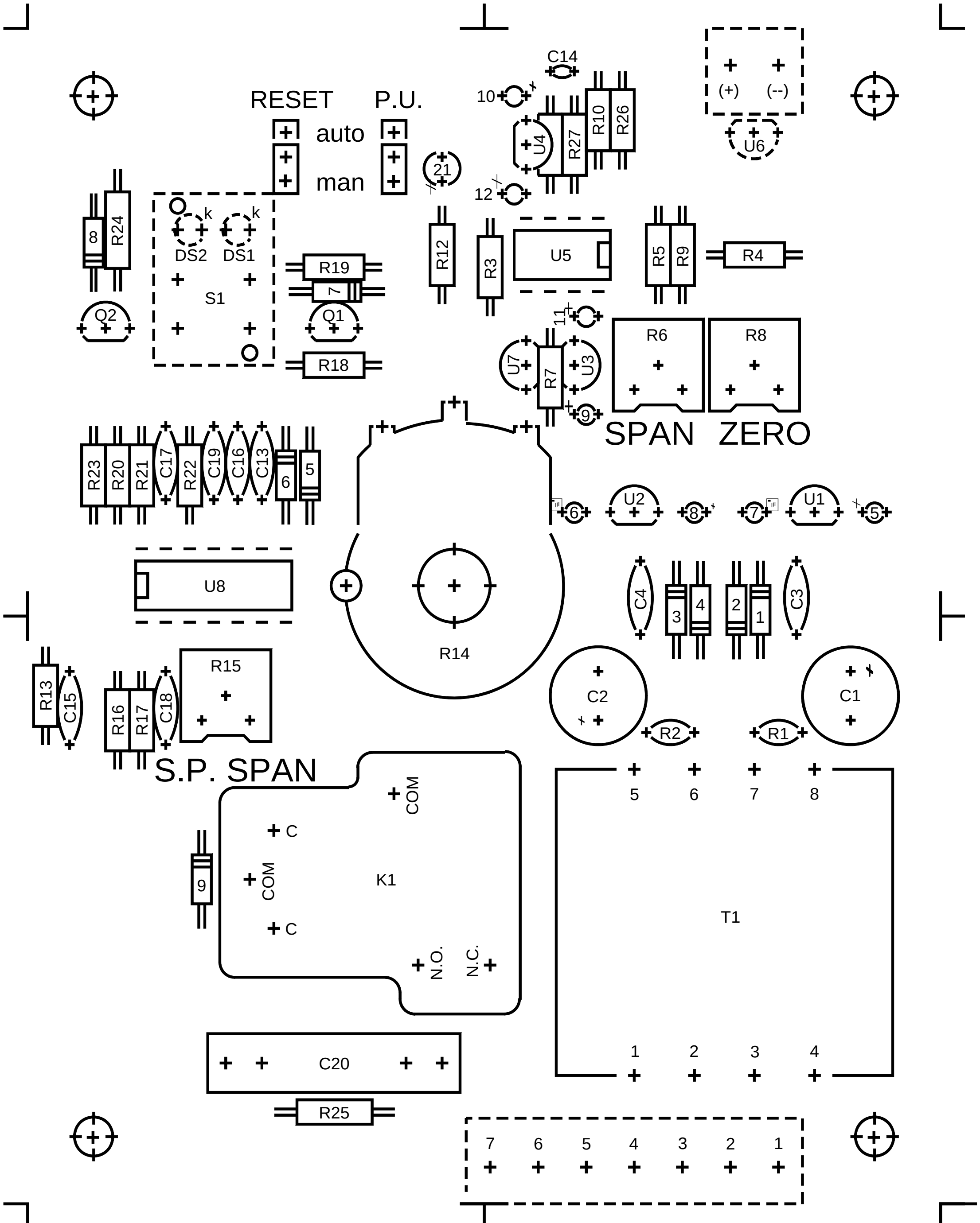
... then adjust “span” trimmer R6 to provide exactly +5.00v at U5-6.

The set point dial is calibrated by “set point” trimmer R15 to provide +5.00v at U8-7 with the dial set at “550”. Realizing that the linearity of the set point potentiometer constitutes the greatest uncertainty in the calibration scheme, it might be desirable to optimize the accuracy of the set point dial in the range of typical usage. This is easily done by (1) calculating the analog voltage for that setting, (2) setting the dial at that temperature, and (3) readjusting R15 to provide the calculated voltage at U8-7:

e.g.: for “350°F”: emf at 350°F = 8.062mV

$$\frac{5(8.062+.674)}{.674 + 14.153} = 2.95\text{v}$$

The set point knob is factory adjusted so that the set point analog voltage falls to zero exactly when the index line on it’s skirt is in line with the “0” mark on the temperature scale. Should the knob become loose, or if the potentiometer is replaced, the mechanical position of the knob should be set to zero the buffered set point voltage (U8-7) at the “0” setting. If this is not immediately possible, rotate the potentiometer fully counterclockwise, the adjust the knob so that its index pointer is aligned with the “*” just below the “0” position.


RESET
P.U.
auto
man
C14
R10
R26
R27
U4
U6
(+)
(--)
R24
DS2
DS1
S1
R19
Q1
Q2
R12
R3
U5
R5
R9
R4
R18
R6
R8
U7
R7
U3
SPAN
ZERO
R23
R20
R21
C17
R22
C19
C16
C13
U2
U1
U8
R14
C4
C3
R15
R13
C15
R16
R17
C18
C2
C1
R2
R1
S.P. SPAN
COM
K1
N.O.
N.C.
T1
C20
R25

REPLACEMENT PARTS LIST

Part Number: 012014
Drawing Number: 470661 (see Page 10)

"HLS-II" HEAT LIMIT CONTROLLER II

PART #	DESC		MFGR	MFGR'S NO	QTY	UM
051053	RESISTOR, CFLM 1/4W 5%	150	MOUS	29SJ250-150	1	EA
051073	RESISTOR, CFLM 1/4W 5%	1.0K	MOUS	29SJ250-1.0K	2	EA
051077	RESISTOR, CFLM 1/4W 5%	1.5K	MOUS	29SJ250-1.5K	1	EA
051082	RESISTOR, CFLM 1/4W 5%	2.4K	MOUS	29SJ250-2.4K	1	EA
051087	RESISTOR, CFLM 1/4W 5%	3.9K	MOUS	29SJ250-3.9K	1	EA
051090	RESISTOR, CFLM 1/4W 5%	5.1K	MOUS	29SJ250-5.1K	1	EA
051092	RESISTOR, CFLM 1/4W 5%	6.2K	MOUS	29SJ250-6.2K	1	EA
051096	RESISTOR, CFLM 1/4W 5%	9.1K	MOUS	29SJ250-9.1K	1	EA
051097	RESISTOR, CFLM 1/4W 5%	10K	MOUS	29SJ250-10K	2	EA
051125	RESISTOR, CFLM 1/4W 5%	150K	MOUS	29SJ250-150K	1	EA
051130	RESISTOR, CFLM 1/4W 5%	240K	MOUS	29SJ250-240K	1	EA
051145	RESISTOR, CFLM 1/4W 5%	1.0M	MOUS	29SJ250-1.0M	2	EA
051169	RESISTOR, CFLM 1/4W 5%	10M	MOUS	29SJ250-10M	1	EA
051249	RESISTOR, CFLM 1/2W 5%	100	MOUS	29SJ500-100	1	EA
051275	RESISTOR, CFLM 1/2W 5%	1.2K	MOUS	29SJ500-1.2K	1	EA
052301	RESISTOR, MFLM 1/4W 5%	1.00K	NIC	1.00KQ	1	EA
052550	RESISTOR, MFLM 1/8W 1%	324K	NIC	324KQ	1	EA
052575	RESISTOR, MFLM 1/8W 1%	590K	NIC	590KQ	1	EA
054007	POTENTIOMETER, TRIM 1T	1K	BRNS	3386P-1-102	1	EA
054011	POTENTIOMETER, TRIM 1T	20K	BRNS	3386P-1-203	1	EA
054014	POTENTIOMETER, TRIM 1T	200K	BRNS	3386P-1-204	1	EA
054042	POTENTIOMETER, CONT 1T	10K	ALPH	31VC401	1	EA
056001	VARISTOR, 180mJ	31VDC	PANA	P7020	2	EA
062016	CAPACITOR, CRMC 50V	47pF	PANA	P4008	1	EA
062067	CAPACITOR, CRMC 50V	.1uF	NIC	NCD.1M50MX5U	8	EA
063013	CAPACITOR, TANT 35V	1.0uF	NEC	1.0M35	8	EA
063045	CAPACITOR, TANT 25V	10uF	NEC	10M25	1	EA
064011	CAPACITOR, ELEC 35V	220uF	PANA	P6253	2	EA
067084	CAPACITOR, FILM 630V	0.1uF	SIEM	B32522-104-630J	1	EA
071004	TRNSFORMER, PWR 240/36V@65mA		SGNL	DPC3-36	1	EA
081001	DIODE, SIG		MOUS	1N4148	4	EA
081003	DIODE, RECT 400V	1A	MOT	1N4004	5	EA
083021	TRANSISTOR, NPN		MOUS	2N3904	2	EA
093002	IC, QUAD OP AMP		NS	LM324N	1	EA
093006	IC, +15V 100mA REGULATOR		NS	LM78L15ACZ	1	EA
093007	IC, -15V 100mA REGULATOR		NS	LM79L15ACZ	1	EA
093011	IC, +12V 100mA REGULATOR		NS	LM78L12ACZ	1	EA
093012	IC, -12V 100mA REGULATOR		NS	LM79L12ACZ	1	EA
093016	IC, PRECISION 6.9V REFERENCE		NS	LM329DZ	1	EA
093029	IC, TEMPERATURE SENSOR		NS	LM335Z	1	EA
093034	IC, PRECISION OP AMP		LT	OP-07GN	1	EA

continued...

REPLACEMENT PARTS LIST (continuing ...)

Part Number: 012014
Drawing Number: 470661 (see Page 10)

"HLS-II" HEAT LIMIT CONTROLLER II

PART #	DESC		MFGR	MFGR'S NO	QTY	UM
...continuing						
102010	SWITCH, PUSH-BUTTON PCB 1P2T		LEDX	N-623406-003	1	EA
109006	KEY CAP, GRY 2-LED		LEDX	N-623306-003	1	EA
111003	RELAY, MIN PCB 24V 1P1T		P&B	T90N1D1224	1	EA
111004	COVER, MIN PCB RELAY		P&B	35C620	1	EA
121003	LED, T1 MIN DIFF	RED	ROHM	SLR-34 UR3	1	EA
121010	LED, T1 MIN DIFF	GRN	ROHM	SLR-34 MG3	1	EA
173002	SHUNT	2-W	APT	929950-00	2	EA
173005	HEADER, STR/SR PCB	2-W	APT	929834-01-36	2	EA
175001	SOCKET, IC SOLDER TAIL	8-PIN	AMP	A9308	1	EA
175002	SOCKET, IC SOLDER TAIL	14-PIN	AMP	A9314	1	EA
176006	TERMINAL BLOCK, PCB	3-W	PHNX	1715035	1	EA
176007	TERMINAL BLOCK, PCB	2-W	PHNX	1715022	3	EA
261004	KNOB, CONTROL 1.5" SKT PTR		DAKA	1600-1	1	EA
271026	SCREW, BDR HD 6-32x.250	SS			4	EA
271261	SCREW, TRUS HD 6-32x.500	BLK			1	EA
272041	WASHER, NYLON PLAIN #6 REG		KYST	3163	2	EA
272053	WASHER, FLT FIBER .250"x.500"		KYST	3135	4	EA
279009	THREADED INSERT, SS 6-32		CFC	CFL-632--1	1	EA
279036	STAND-OFF, CAPTIVE 6-32x.5		CFC	CFBSOA-632-16	4	EA
351038	CHASSIS, HEAT LIMIT CONT II		WRNR	470663	1	EA

(Notes ...)

(Notes ...)

FireRight Controls™
WARNER INSTRUMENTS

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