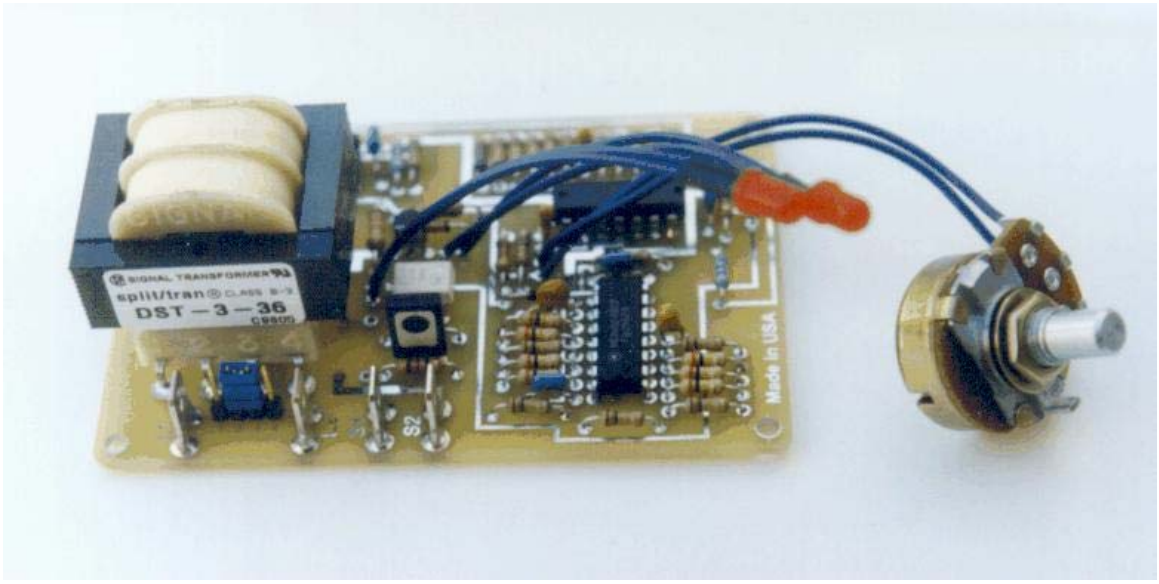
AutoMate Module

Turn-Up Controller Module for KilnSitters



General Description

The AutoMate Module is basically a progressive *percentage timer* designed to assist in the control of ceramic kilns. The device provides a means of automatically increasing the kiln's heating capacity during the early stages of a firing, so as to provide ample time for the ware being fired to adjust to increasing temperature, thereby preventing damage due to excessive thermal stress. For kiln user's, the device may be viewed simply as an *Infinite Control Switch* that turns itself up according to a schedule they can preset.

Purpose

Ceramic kilns are used by potters, artists and hobbyiest to heat treat, or "fire", objects made of clay, and to mature finishing glazes. The ware being fired varies widely from decorative and artistic objects such as nicknacks, scuptures, decorative vessels and dinnerware, to utilitarian items such as tiles and electrical insulators. Kilns have a variety of designs, including outdoor kilns fired by natural fuels, gas-fired kilns and electric kilns. This device is designed for use with electric kilns.

The firing process involves exposing the ware to an amount of heat necessary to accomplish vitrification. This is ordinarily done simply by loading the ware into the kiln, heating it to a specified limit, then turning the kiln off allowing it to cool on its own.

The heat treating process is often monitored using *Pyrometric Cones*, which are basically specially calibrated clay formulations which become plastic and melt upon exposure to differing degrees of heat. These devices take their name from the fact of their shape, and are identified by number, with increasing numbers corresponding to higher firings. The firing requirement for a given clay or glaze is popularly specified by citing a cone number, and is assumed to have been accomplished when a cone of that

number, placed in the vicinity of the ware being fired, becomes plastic and begins to bend over.

A mechanical shut-off device, invented in the 1950's by W.P. Dawson, has found widespread use in helping to automate this firing process. This simple device, widely known as the *Dawson KilnSitter*®[1], provides a set of electrical contacts with a latch which is manually engaged, then released by the deformation of a pyrometric cone which is mounted in a special tripper mechanism. The use of this device relieves the kiln operator from having to be present at the end of the firing to gauge when that point has been reached, and to turn the kiln off.

What happens during the very early stages of the firing is of little practical significance to the end result. However, since ceramic kilns are designed to produce temperatures as high as 2500°F (1371°C), they have the capability of rapidly increasing the heat when the firing chamber's temperature is relatively low. It therefore becomes necessary to throttle the heating capacity during the early firing stages, in order to prevent damage to the ware being fired, either through the explosion of steam pockets within the material, rapid expansion, or non-uniform temperatures within particularly heavy pieces. Accordingly, practical electric kilns are equipped with switches which permit the operator to do this.

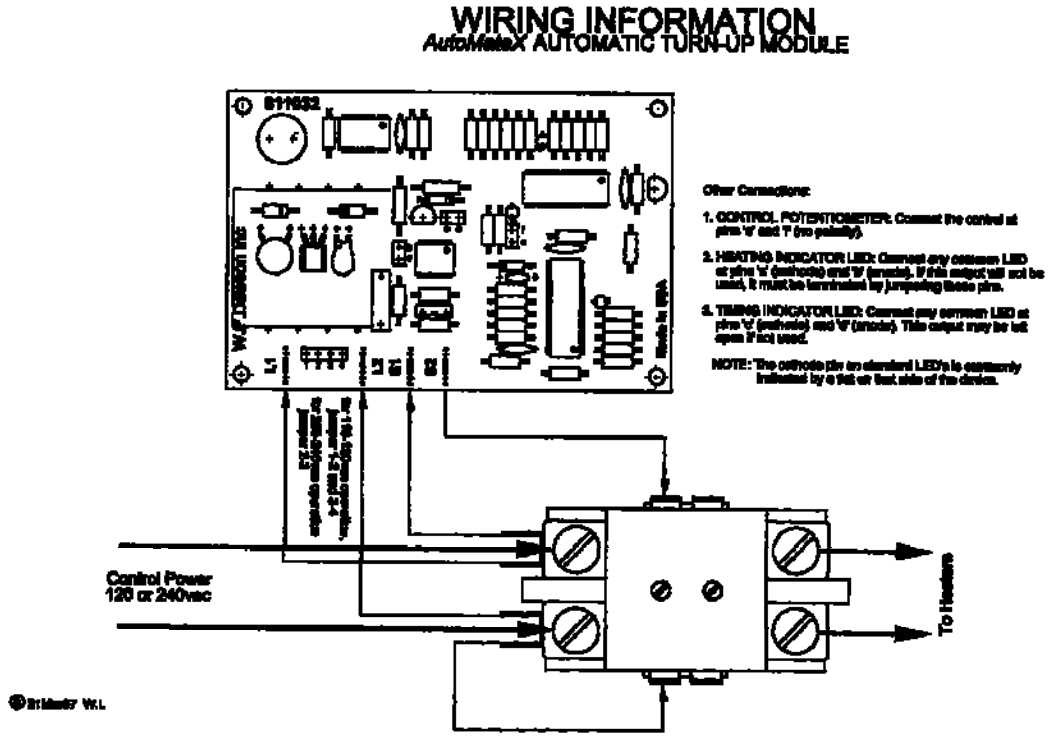
Two approaches have been used; *three-heat* and *infinite control* switches. The three-heat scheme is implemented using simple toggle switches to connect sections of tapped heating elements across 120vac or 240vac on a standard single-phase circuit, to provide "Low", "Medium" and "High" modes. Infinite switches are adjustable bi-metal current proportioning controls, similar in function to the stepless burner controls found on electric kitchen ranges. Practical kilns are usually fitted with 7.5-amp heating elements, and have one such switch or control per element. Three-heat switch systems have the disadvantage of sometimes drawing current through the "neutral" connection. Either system has the disadvantage of requiring an identical control for each heating element (up to eight), and requiring the presence of an operator during the early firing stages, to turn them up at the appropriate times. The "switch schedule" typically involves being available during the first two to four hours of the firing.

The AutoMate Module is functionally identical to the *AutoMate II Automatic Kiln Switch*, except that it is designed for use as a component of the *Dawson KilnSitter*. Combining the turn-up and shut-off functions in a single unit provides the means of fully automating electric kilns using a single, low-cost, easy-to-operate control.

Installation

The AutoMate Module is integrated with the KilnSitter so that it's indicators and time adjustment are convieniently available on the device's control panel, with the circuit board and all necessary electrical connections concealed behind the panel.

The necessary electrical connections are shown in the representative wiring diagram (download the higher resolution image by right-clicking the diagram and selecting "Save Picture As ..."):



Only four connections are required; two to provide power to the printed circuit board, and two to enable the load device. Input power is ordinarily connected first to the KilnSitter's contacts, then to the load device, so that tripping the KilnSitter removes all power from every part of the system. The load device will ordinarily be a definite purpose contactor, but can be any ac-operated device requiring 240vac @ 2-amps, or less.

Operation

To operate the KilnSitter/AutoMate combination control, users first select a numbered pyrometric cone according to the instructions provided with the clay or glaze being fired, and mount it in the usual matter in the KilnSitter's tripper mechanism. They next adjust the *Turn-Up Time* control according to the "Switch Schedule" recommended in the kiln's instruction booklet, or according to their experience with the particular type of firing about to be executed.

At this point the kiln is ready to fire. Manually engaging the KilnSitter's contacts by depressing a button on its front panel starts the process.

During the early stages of the firing, the AutoMate module will throttle power to the electric heaters using a *duty-cycle proportioning (time proportioning)* scheme, which

progressively increases the "On" time within a fixed *cycle time* until full power is connected to the heaters 100% of the time. This protects the ware being fired from undue thermal stress during the early stages of the firing. Beyond the "100% On" point, the kiln continues to heat until reaching the point where the cone mounted in the KilnSitter begins to bend. This eventually causes the KilnSitter mechanism to trip, removing all power from the system, and permitting the kiln and load to cool naturally.

Thus, with only a few moments required for set-up, the operator is completely relieved of the burden of adjusting and monitoring the kiln during the several hours normally required for routine firings.

Circuit Operation

Please refer to the schematic diagram on the following page (download the higher resolution image by right-clicking the diagram and selecting "Save Picture As ...").

Electrical power for the module is introduced at terminals L1 and L2. Either 120vac or 240vac may be used by properly setting the jumpers at the header between these two terminals. For 120vac power, pins 1 & 2 and pins 3 & 4 are jumpered. For 240vac power, a single jumper is placed over pins 2 & 3. The power transformer T1 is used to isolate the circuitry from the ac line, and to reduce the input voltage to 24vac. A filtered full-wave rectifier circuit converts this to 24vdc, which is further reduced to 15vdc by voltage regulator U4. The regulated 15vdc power is used to operate all parts of the circuit except the two indicator LED's, which are driven by the unregulated 24vdc supply.

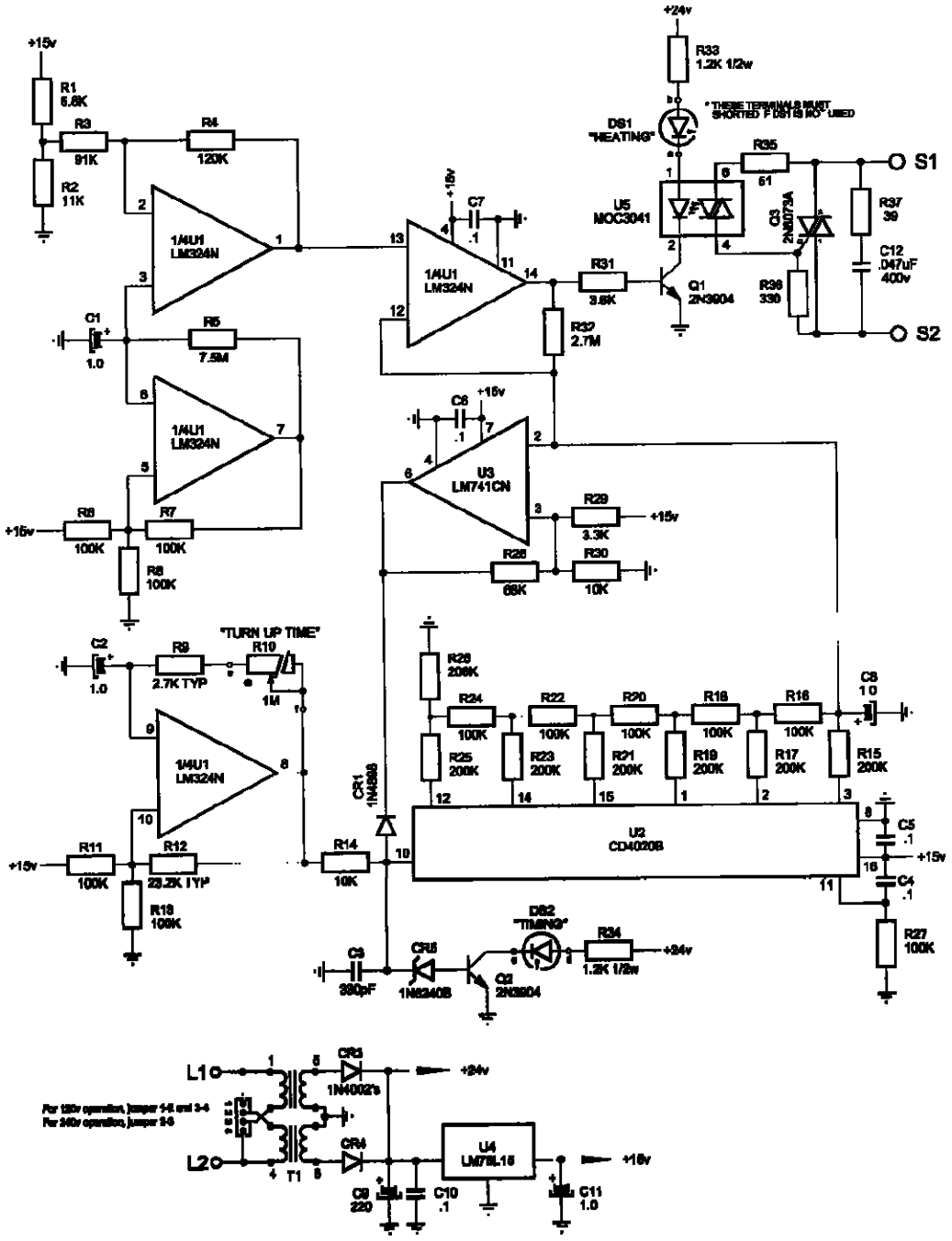
One section of U1, a quad op amp, provides the adjustable timing reference for the circuit. This circuit as an astable multivibrator, which provides a square wave output at U1-8. The frequency of this signal is user-adjustable by means of potentiometer R10, and varies linearly with its resistance. With R10 set at its fully clockwise position, the maximum frequency results, and the circuitry is designed such that this setting produces an output duty-cycle increase of approximately 1%/second. This is referred to on the control panel as the *SET* position. When R10 is adjusted to the opposite extreme (fully counter-clockwise), its wiper

moves off the end of its conductive element, opening the circuit between U1-8 and U1-9 and casuing the circuit to stop oscillating. This setting is labeled *HOLD* on the unit's control panel. The dial used for R10 is otherwise graduated from *0* through *10*, these numbers representing the approximate *TURN-UP TIME* in hours.

This timing circuit is "calibrated" by measuring the value of R10 when set at mid-scale, in order to determine a compensating value for the timing capacitor, C2. After C2 has been selected and its exact value determined, then the appropriate value for resistors R9 and R12 are calculated. This is done for each production lot using a simple computer program, which provides a print-out giving the designated values for each unit.

The output from U1-8 is connected to a *TIMING* indicator light, DS2, which flashes on and off at a rate corresponding to the output frequency. This provides users with a quick visual indication of the kiln's firing rate.

The output is also connected to a binary counter, U2, the outputs of which are connected to a simple R/2R D/A converter network. The scaling is designed so that during the set turn-up period the output of this network, which appears at the R15/R16 junction, increases from 0vdc to 10vdc. This output is connected to U3, which stops the counting process after the D/A output has reached a level of about 11.4vdc in order to prevent counter roll-over. This also extinguishes the *TIMING* light, signaling users that.



the timing period has ended, and the kiln is now firing a full capacity. The counter is zeroed at turn-on by the reset network connected to U2-11.

Two further sections of U1 comprise a "triangle-wave generator", the output of which continuously varies linearly from 0vdc to 10vdc and back to 0vdc, with each triangular cycle taking approximately 45-seconds. The first section of this circuit is an astable multivibrator, which produces a square-wave output having an interval of 45-seconds at

U1-7. This is applied to a wave-shaping circuit, which produces the desired triangular wave shape at U1-1.

The triangular "proportioning" signal and the output from the D/A converter appear as inputs to the fourth section of U1, which is configured as a simple comparator circuit. Whenever the dc level from the D/A converter exceeds the level of the proportioning triangle wave, the output at U1-14 will switch to approximately 13.5vdc. Then the proportioning wave rises above the level of the D/A output, U1-14 falls back to approximately 0vdc. This results in the output being turned on for approximately 10% of the proportioning wave's cycle time when the D/A output is at 1.0vdc, 20% for 2.0vdc ... and 100% for 10.0vdc.

The output produced at U1-14 is used to drive an optically isolated triac trigger circuit, which switches triac Q3 on and off. The triac serves as a simple switch, capable of driving remote loads up to 2-amps, which can be connected to output terminals *S1* and *S2*. A snubber network, R37 and C12, may be used to protect against triac false-triggering due to excessive load inductance. A *HEATING* light is connected in series with the opitcal isolator, and will be on whenever the output is enabled.

FireRight Controls/Warner Instruments
1320 Fulton Street Box 604
Grand Haven, Michigan 49417-0604 USA
Phone: (616) 843-5342
e-mail: *info1@fireright.com*
Internet: *http://www.fireright.com*

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