Heathkit of the Month:
by Bob Eckweiler, AF6C

Heathkit SK-211
AC Monitor

Introduction:
When club president, Nicholas - AF6CF, mentioned he had two Heathkit SK-211 AC Line Monitors that he bought sometime back - one he had built and one was still in the box - my ears perked up. He offered me a "loan" of the unbuilt kit to use as the basis of this month's column, and I accepted. He presented me the box at the August club meeting and I promised to keep my soldering iron locked up while I had it!

The SK-211 is one of the later kits that Heathkit produced. It was originally introduced sometime in mid-to-late 1986 and continued in production at least through 1991 when Heathkit was near closing down. I have no catalogs for 1986 through 1988, but after a search I found it in the Fall 1989 catalog. At that time it was selling for $29.95; that is the same price as in the winter 1991 catalog – the last catalog in my collection. (Heathkit closed its kit business on March 30, 1992).

The SK-211 was difficult to locate in the catalog. Heathkit had a couple of pages of "SK" "starter kits" but the SK-211 wasn't among them. It was finally found in the computer accessory section.

The SK-211 AC (Line) Monitor:
This simple (Skill Level 1) kit is a plastic box that plugs directly into an AC wall socket. It is shown in Figure 1; it has ten red LED lamps and a **RESET** button on the

Figure 1: Heathkit SK-211 AC Monitor

side opposite the AC plug. Eight of the LEDs are in a vertical row on the right with the nomenclature **LINE VOLTAGE**. The eight LEDs are individually marked from **130** (at top) down to **95** in steps of 5. All the LEDs whose threshold value is at or below the current line voltage will be lit. For figure 1 the voltage is 115 volts or more, but less than 120 volts. Accuracy is nominally ±5 volts without calibration and less than ±3 volts with calibration. Calibration requires an accurate ohmmeter.

To the left of the eight LEDs are the remaining two LEDs in a separate vertical row. The top LED is marked **FAULT** and the lower one is marked **SPIKE**. A **RESET** button is located below these two LEDs. The FAULT light latches on should the voltage

drop below 90 volts for one or more AC cycles. The SPIKE light latches on if a repetitive voltage spike above 250 volts is sensed on the AC line or if an intermittent spike of around 300 volts is sensed. The specifications for the SK-211 AC Monitor are given in table I.

The SK-211 Circuit:
The circuit is shown in figure 4. All components mounts on a single circuit board, and can be divided into four sections: the power supply, the spike circuit, the eight LED voltage indicator and the fault circuit.

Power Supply:
The SK-211 runs directly off the AC power and has no transformer. Thus it is designed, for safety reasons, not to be easily powered up when not totally encased in its insulated box. Since most of the circuitry needs a voltage between 15 and 18 volts the power supply must drop the 120 VAC down to where it can be rectified, filtered and regulated to the needed voltage. C1, a 2.2µF capacitor is connected to the hot side of the AC line and provides about 1.2KΩ of AC impedance to the 60 cycle AC power. This reactance has no power loss other than imperfections in the capacitor and limits the AC current to around 100 mA RMS. Two 13.5 volt zener diodes in series (D1 & D2) complete the circuit to the neutral side of the AC line, which is the common point for all the circuitry. On the positive half of each cycle about 27 volts is developed across the zener diodes. This is rectified by D3 and charges up C2. On the negative half of the cycle the zener diodes are forward biased and drop very little voltage allowing C1 to discharge, but not C2 which is isolated by D3. Thus C2 is kept charged to around 27 volts (peak) on each positive cycle.

Voltage Display:	One to eight LEDs light in a string to indicate the AC line voltage from 95 to 130-volts AC, in 5-volt steps.
Accuracy:	± 5-volts AC at each threshold (± 3-volts AC, if calibrated with an ohmmeter).
Fault Indication:	A separate LED lights whenever the voltage fall below 90-volts AC for at least 1 cycle (0.016 second). The LED remains lit until the RESET button is pressed.
Spike Indication:	A separate LED lights if a voltage transient occurs. Typical sensitivity is 250-volts for repetitive spikes and 300-volts for intermittent spikes. The LED remains lit until the RESET button is pressed.
AC Voltage Input:	80 to 135 VAC 60 Hz, 2.5 watts.
Dimensions:	3-5/8" H x 2-3/8" W x 1-1/4"D (9.2 x 6.0 x 3.2 cm).
Weight:	3-1/2 oz. (100 g)

Table I - Heathkit SK-211 Specifications from the 1986 manual (595-3616)

The voltage across C2 is fed to U1 an LM-317 voltage regulator IC whose output is set by R3 and R4 to 16.5 VDC. This is the V+ voltage that feeds the other circuits.

This type of AC circuit has its drawbacks. While the reactance of C1 is 1.2KΩ at 60 Hz, voltages with higher component frequencies (such as transients and AC from a square wave inverter) will see less reactance. Two resistors, R1 and R2, are in series with the capacitor to help protect against transients and non-sinusoidal AC power. Heathkit even warns about this in their manual; though they say it will affect

the accuracy of the instrument, it may also tax the power supply.

The Spike Circuit:

The AC line voltage is divided by three in a voltage divider consisting of 3 33KΩ resistors (R9, R11 & R12). The AC is then coupled to Q1 as follows: Diodes D6 and D8 separate any positive going transients from any negative going transients. Each transient is then fed through a 110-volt zener diode so only pulses greater than around 300 volts reach Q1. Positive transients, large enough, reach the base of Q1 drive it positive with respect to the emitter which is held at ground potential by R19. Negative transients, large enough, reach the emitter of Q1 drive it negative with respect to the base which is held at ground potential by R16. When Q1 conducts momentarily it pulses low. The large value of the collector resistor R17 allows Q1 to respond with high sensitivity to the transients.

U3 is a quad CMOS NAND gate. The output of each gate is low only if both of its two inputs are high. U3A and U3B are coupled as a latch. Pins 1 and 6 are the latch inputs. Normally they are both high due to R17 and R29. Should pin 6 go low (the RESET pushbutton pressed) the output of U3B will go high forcing the output of U3A to go low, driving pin 5 of U3B low which keeps the output of U3B high even when the RESET button is released. Should Q1 pulse low, the reverse will happen and the output of U3A will go high and latch high until the reset is again pushed. When the output of U3A is high it turns on Q2 lighting the SPIKE LED.

Voltage Indicator LED Circuit:

The heart of this circuit is U2 an LM-3914 Dot/Bar Display driver integrated circuit. A reference voltage is applied to the IC between the REF_{HI} and REF_{LO} terminals. A precision voltage divider divides this voltage into 10 equal segments and applies each to one side of a comparator. The other side of the comparators are all tied together and to the input pin. The IC has two modes, bar and dot modes. In the bar mode the output of all the comparators whose input voltage is above their reference will go low. In the dot mode, only the highest one will go low. The SK-211 uses the dot mode. The LM-3914 data sheet is available here:

http://www.ti.com/lit/ds/symlink/lm3914.pdf

The reference voltages for the comparator are set by D4 and D5, two precision 5-volt zener diodes in series and a precision voltage divider. The lower reference voltage is connected to the bottom zener setting VLO to 5.0 volts. This should correspond to the lowest voltage, or 85 volts. (A ratio of 17 volts/volt). If each of the ten LEDs correspond to 5-volt increments, then the high reference should correspond to 135-volts, and at the given ratio the high reference should be 7.94 volts. This is the voltage provided by the voltage divider consisting of R14, R15, R_{CAL} and the internal resistance between REF_{HI} and REF_{LO} (if you are doing the calculations, use 7.15K for R_{CAL} and 10 K for the internal resistance).

The AC voltage is coupled to the input pin of U2 through a voltage divider consisting of R5 through R8. This divider reduces the AC voltage to the correct value so 135 volts corresponds to 7.94-volts and 85-volts corresponds to 5-volts. But wait! These are RMS voltages and the comparator works on peak voltages so a correction of 1.4 must be made to this divider. In-

stead of a ratio of 17 volts/volt it must be a ratio of 17 times 1.4 or a ratio of 23.8. This is the ratio provided by the voltage divider consisting of R5, R6, R7, and R8.

The outputs of U2 corresponding to 95 through 135 volts are connected to a series chain of eight LED diodes. (The 130V and 135V outputs are connected together). Whichever output of U2 is low its corresponding LED and all the lower voltage LEDs will light.

Fault Detector Circuit:

U3C and U3D make up a latch similar to the one used in the spike circuit. The FAULT LED comes on should the voltage drop below 90 volts for a cycle or more. Should the power go off entirely, the FAULT LED should also come on when power is restored. This is handled by C9, R28 and D13. When power is applied, pin 8 of U3C will remain low until C9 charges through R28, forcing the output of U3C high and turning on the FAULT LED. The latch remains set via diode D12 until RESET is pressed. D13 causes C9 to discharge quickly if power fails momentarily

Pin 1 of U2, the 90 volt output, instead of being connected to an LED, goes to the fault circuit. As long as the AC line voltage exceeds 90 volts, this pin will go low for a part of each each cycle. C9 is constantly being charged by R26, a multi-megohm resistor. However each time pin 1 of U2 goes low it discharges the C9 through diode D11. Should the voltage drop below 90 volts C9 will continue to charge and cause the latch to set, lighting the FAULT LED.

SK-211 Checkout and Calibration:

Each of the two AC voltage dividers have a jumper that is normally installed and can be removed for checking out a particular circuit. When J1 is removed, voltage is removed from the input of U2 simulating a "low-voltage" fault. With this jumper removed the FAULT LED should light and none of the voltage LEDs should be on.

Jumper J2 disables the voltage divider to the spike circuit, applying the full AC line voltage to its input. This simulates a spike condition and should cause the SPIKE LED to light. While not mentioned in the manual, replacing the jumper with an appropriately rated diode, first in one direction and then in the other, will confirm that both positive and negative peak detection is working properly.

Measured Resistance Between S3 and S4*	Calibration Resistor Value
6,000 to 7,700Ω	4,990Ω 1%
7,701 to 9,200Ω	5,900Ω 1%
9,201 to 11.3KΩ	7,150Ω 1% **
11.3K to 15.0KΩ	9,090Ω 1%
* Remove jumper between S3 & S5 to measure. ** Nominal calibration resistor value.	

Table II - Calibration Chart

The internal resistors of U2 that make up the reference divider chain are precisely matched in resistance during the manufacturing process; however their actual resistance tolerance is not. Thus the overall resistance of the chain my vary between 6KΩ and 15KΩ. Heathkit offers a way to calibrate the unit to correct for this variation. You need a good ohmmeter to measure the internal voltage divider chain resistance. This is done by temporarily removing jumper between terminals S3 and S5 and then measuring the resistance between terminals S3 and S4. Using the re-

sistance measured you select the proper calibration resistor as shown in a table in the Heathkit manual. The table is repeated in Table II.

If you don't have an ohmmeter you can just select the nominal calibration resistor which will provide reasonable accuracy.

Using the SK-211 AC Monitor:

Use of this device is quite straightforward. First you plug it into a convenient AC outlet. The plug is polarized and only goes in one way, and may block the other socket on a duplex AC outlet. Once plugged in, the FAULT LED will be lit as well as some of the AC Monitor Voltage LEDs. Pressing the RESET button should extinguish the FAULT LED. Reading the highest lighted LED tells you the AC line voltage.

Should a fault or spike occur the corresponding LED will light to inform of such an occurrence; the light will remain lighted until the RESET button is pressed.

Figure 2: Heathkit SK-211 Catalog Ad.

Figure 3: Heathkit SK-211 Unpacked.

73, from AF6C

Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Thanks - AF6C

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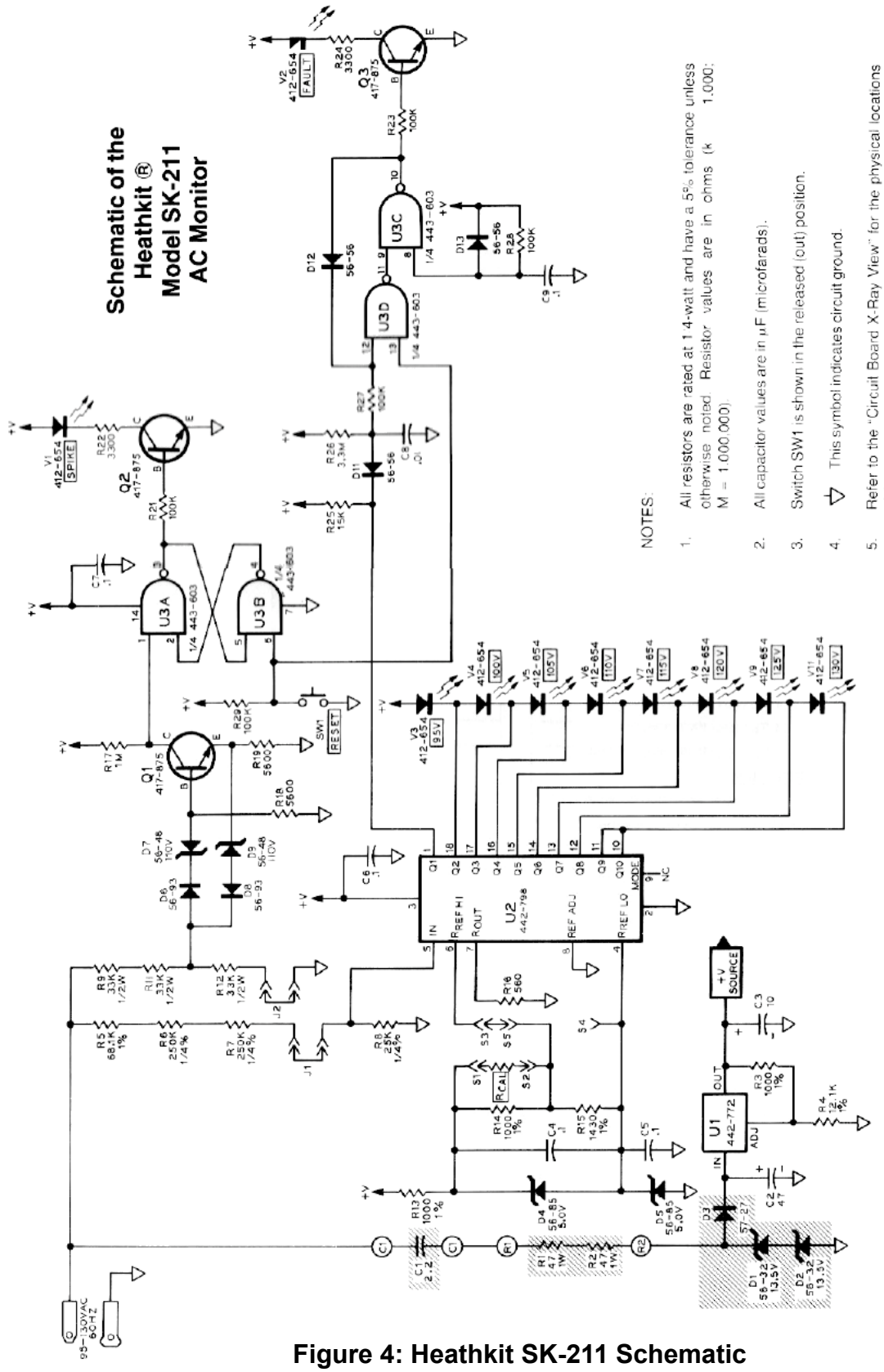

Figure 4: Heathkit SK-211 Schematic