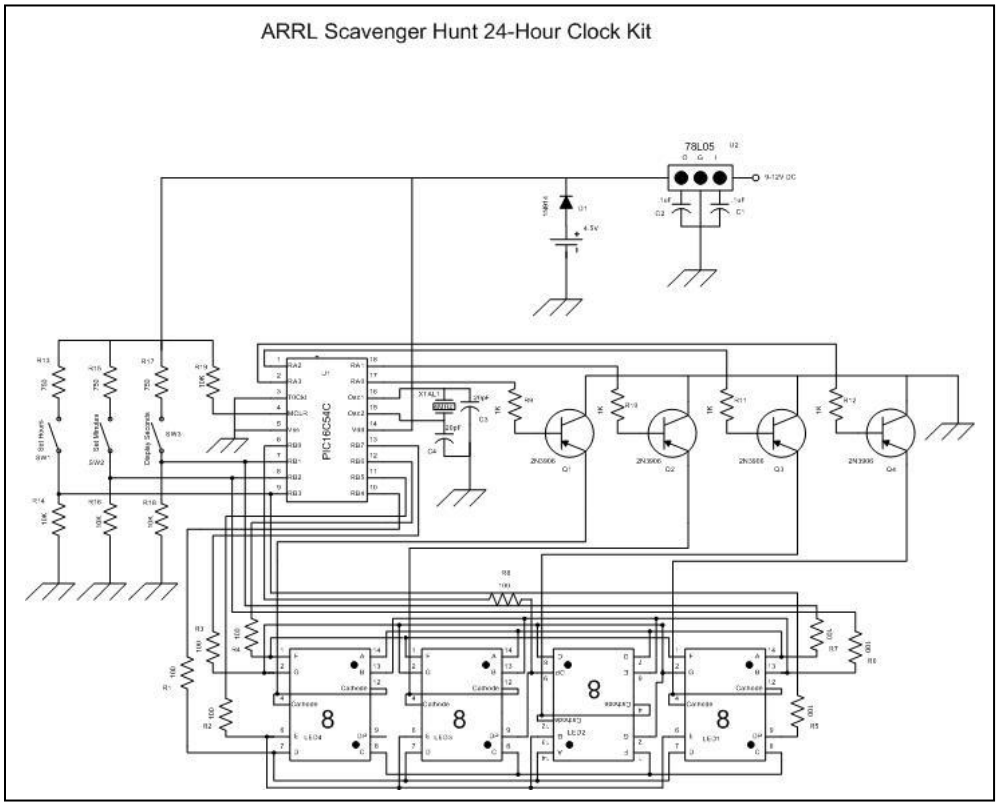
How the ARRL ETP Solder 101 24-Hour Clock Kit Works

This is the circuit diagram of the clock. We will break this circuit down into sections and discuss the operation of each section.



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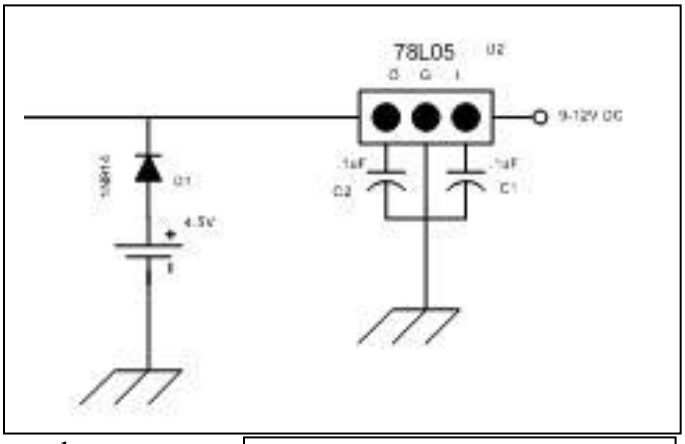
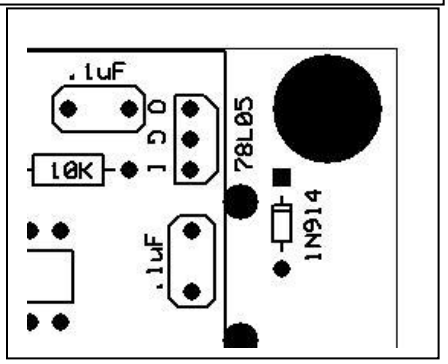
Power Supply

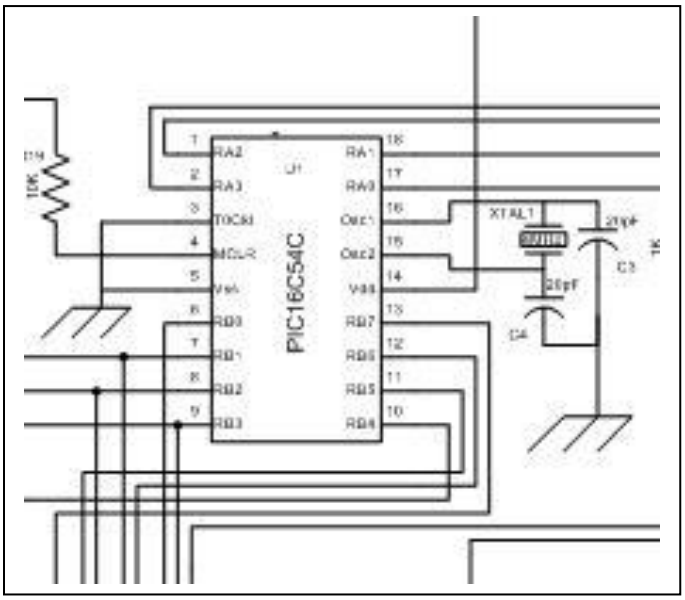


There are two sources of power for the clock, the 9 to 12 volt DC "wal-wart" (primary) and 3-AA Battery cells (backup). The clock draws approximately 20mA of current at 5 volts. The power supply circuit consists of the voltage regulator, U2, that steps down the 9 to 12 volts DC from the "wal-wart" to the 5 volts required for the circuit. The capacitors C1 and C2 are filter capacitors to help mitigate any "noise" generated by the regulator as it responds to current demand transients. The backup battery pack (which is 3-AA cells in series and supplies a voltage of 4.5 volts with fresh batteries) is isolated from the output of the voltage regulator by the diode D1. During normal operation, the cathode side of D1 has 5 volts and the anode side has 4.5 volts, this is a reversed biased condition and the diode is in a non-conductive state. In other words, the current from the regulator powers the circuit. When there is a power failure and the "wal-wart" shuts down, the voltage from the regulator on the cathode side of D1 is zero volts and the anode side has the 4.5 volts from the battery. In this case D1 is forward biased, and the diode conducts and connects the batteries to the circuit to keep the clock operating.

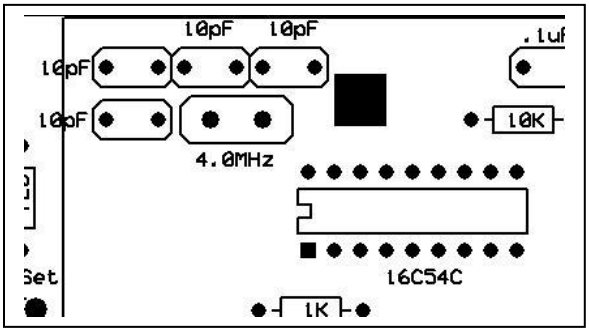


Microcontroller

The main component of the clock is the 16C54 microcontroller or PIC (programmable interface controller). A PIC is a small and dedicated computer that is programmed to do simple tasks. In this case the PIC is programmed as a clock.

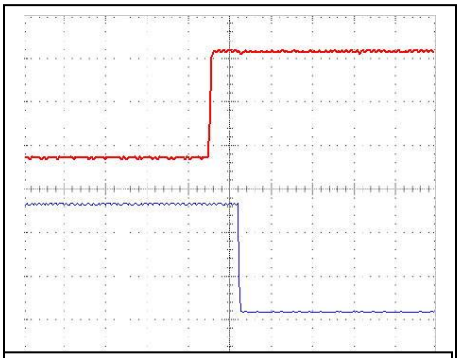


The 4MHz crystal is the oscillator source (the clock source) for the PIC. The PIC is programmed to count the number of pulses from the oscillator source and then use that count to compute and display the time. The capacitors C3 and C4 connected to the crystal are loading capacitors. A crystal is designed to operate at the specified frequency under a certain load condition. The designed load is 20pF of capacitance on each pin of the crystal. 20pF is not a common capacitance value therefore two 10pF capacitors are connected in parallel to come up with the specified capacitance of 20pF.



The PIC has a limited number of input/output (IO) resources and therefore some of the IO pins are shared and perform double duty. There is also are current handling limits for individual pins of the PIC and consequently additional components between the PIC and the display LEDs are required to deal with the current limitations (more about this later).

The LED displays are made up of 7 LED segments that are turned on as needed for form the digits of time. To display the 4 digits of a 24-hour time would require 28 LED segments (4*7), this number far exceeds the 12 IO lines available on the PIC. To deal with this limitation, the 7 associated LED segments on each digit are connected together and the common cathode of each LED digit are connected to switching transistors thus requiring 11-IO pins. There is also a decimal point on the LED display that is used to make a colon between the hours and minutes of the time display and these decimal points are connected together and use the final IO resource pin. Once the time is computed by the PIC software, the individual digits of the time are converted into a lighting sequence for the individual LED segments that will make up the number. The IO lines are put in a high state (5-volts) and the digit is turned on with the digit control IO pin connected to the common cathode for approximately 4 mSec. The digit is then turned off, the next digit LED segments IO lines are set to high, and the digit is turned on for 4 mSec. The digits are tuned on from right to left (single minute to tens of hour digits) and the process repeated so fast that you will not be able to detect any flicker (but you can see the switching on an oscilloscope display). This process is call multiplexing and the IO pins connected to the bank of 7-segement LEDs is called a data buss.

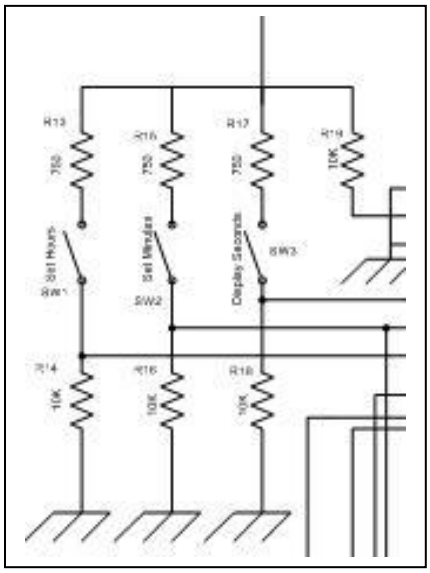


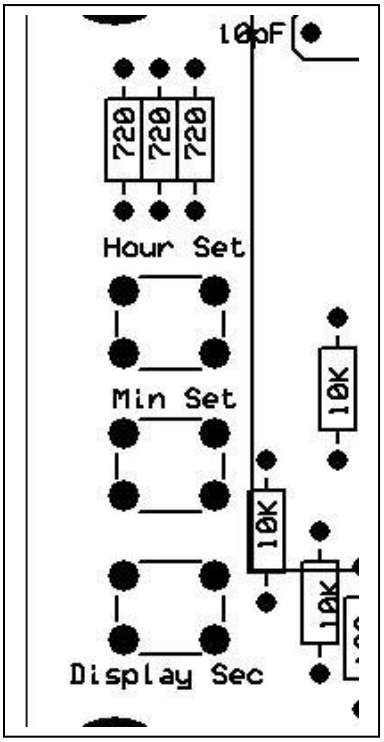
The blue trace is the 1s minute digit, red trace is the 10s minute digit. Time between 1s being turned off and 10s being turned on is 37uSec.

There is a time interval between when the time digits are turned on of approximately 37uSec. The PIC uses this time to look at 3 IO pins that are connected to switches that allow you to display seconds, and to set the hours and minutes. If a switch is detected being pressed during the 37uSec interval, the program in the PIC jumps to a subprogram to accomplish the desired action (change time or display seconds). When the switch is released, the PIC program resumes the computation and display of time.

Time Setting Switches

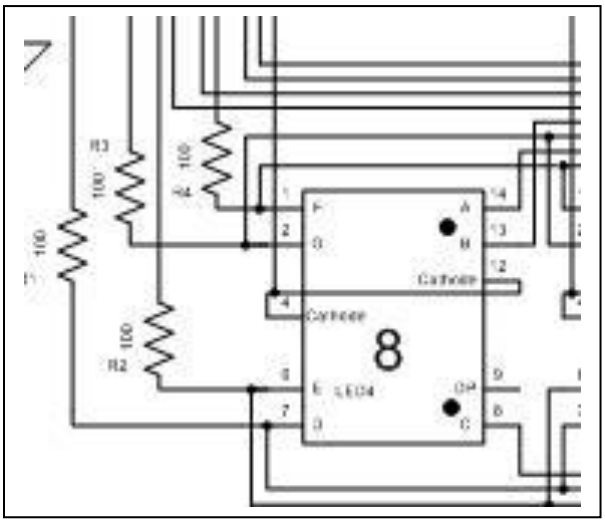
The time setting switches, SW1-3, are SPST momentary switches that connect 5 volts to the associated IO pin when the switch is pressed. The resistors in series with each switch are current limiting and voltage dividing resistors so that the appropriate voltage and current level is applied to the IO pin while not drawing excessive current away from the LED segment that shares the IO pin.

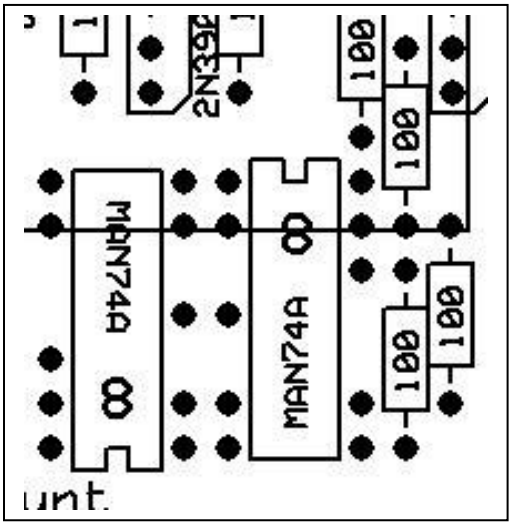




LED Digits

The 100 ohm resistors are connected to the individual LEDs within the 7-segment display to provide current limiting. The associated segment in each digit is connected together. Notice that the 10s digit of the minute display is installed upside down. This is a neat way of using the decimal points of the 10s digit of the minute display and the 1s digit of the hour display to form a colon to separate the hours numbers from the minutes numbers. The decimal points are programmed to flash at 1 second intervals.





LED Digit Turn-on Transistors

The PIC sets up the 7-segment LEDs to display the required number and then the appropriate digit of the display is "flashed" to display the digits from right to left. The current required to illuminate all 7-segments exceeds the current handling capability of a single IO pin. The transistors Q1-4 serve as electronic switches that are turned on and off by the IO pins thereby handling the amount of current.