Searchlight Signal Driver Card (SSD)

The SMINI can drive directly 2-lead searchlight signal LEDs. However, for applications using an SUSIC-based Maxi-node some form of special driver circuit is required to control the polarity, including alternating the polarity, when driving 2-lead bi-color LEDs. One such circuit is the JLC provided Searchlight Signal Driver (SSD) which is designed specifically to produce red, yellow and green colors for use in searchlight signals using the 2-lead bi-color red/green LED. The SSD outputs one polarity to light the red LED, the opposite polarity to light the green LED and rapidly alternates the polarity to generate the yellow. The quality of the yellow is enhanced, for any given LED, by using a potentiometer to alter the duty cycle, i.e. the percentage of time that the red LED is illuminated versus the time that the green LED is illuminated. Fig. 1 illustrates the simplicity of the connections when using the SSD card.

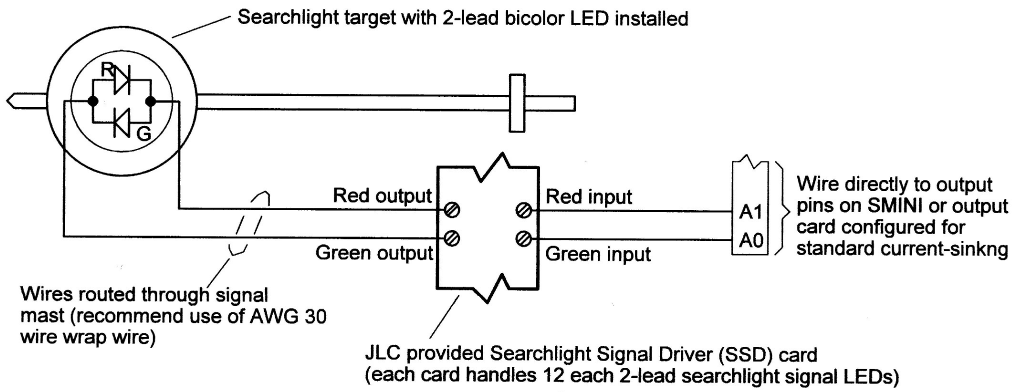

Fig. 1. Recommended connections driving 2-lead Searchlight LED using SSD card.

No external resistors or potentiometers are needed as everything required is built into the SSD. When software grounds the pin marked A0, the SSD causes current flow to light the green LED. Similarly, grounding pin A1 results in current flow to light the red LED. Grounding both A0 and A1 simultaneously tells the SSD card to alternate its output polarity to create the yellow aspect. The quality of the yellow aspect is enhanced by using a potentiometer built into the SSD's design to adjust the ratio of *green-time* to *red-time* when displaying the yellow aspect. When both A0 and A1 outputs are high, or open circuit, this results in the LED being dark.

Although we will see later that the SSD card can be used to drive 3-lead LED s, its specifically designed application is to drive 2-lead searchlight signals via the C/MRI when not using the SMINI. The SSD is easy to build and it extracts the best possible performance from bi-color LEDs. Even if you are not using the C/MRI, you still might want to use the SSD on your railroad. Here are a few of the important advantages gained by using the SSD:

1. It is a single-sided circuit board making assembly easy and with 12 circuits per board it provides a considerable cost savings over using other brands of searchlight signal driver cards.

2. It requires only two inputs per signal LED to control all four aspects: dark, red, green and yellow. By contrast most other drivers require three input lines per LED, i.e. one for each color aspect and the dark aspect is not provided. Therefore, the SSD provides added aspects at reduced cost. For example, by requiring only 2 and not 3 input lines, the SSD reduces your I/O cost by 33 percent.

3. Inputs are active low so that all you need to do is pull an input low, i.e. connect it to ground, to activate a signal aspect. Pulling neither input low results in the dark aspect and pulling both inputs low yields a yellow aspect.

4. Each card is capable of driving up to 12 different signal LEDs and each circuit works equally well with either two-lead or three-lead bi-color LEDs. No external resistors or diodes are required.

5. Built-in adjustment potentiometers enable easy optimization of each signal's yellow aspect including easy lifetime re-adjustment to account for any changing conditions over the life of the signal.

6. Each circuit has only one active component, an IC mounted in a socket, so it is easy to debug and maintain.

7. It requires only a single-ended +12Vdc supply. The polarity switching required to generate the red and green aspects as well as the alternating AC-type of signal required to achieve the yellow aspect are all generated internally by the circuit.

8. Its price is very reasonable. Assembling your own units it costs about $2.75 per signal LED for a medium size layout, i.e. quantity discounts apply.

SVOS operator, circuit designer and chief track layer, Kirk Wishowski designed the SSD. Its schematic is shown in Fig. 2.

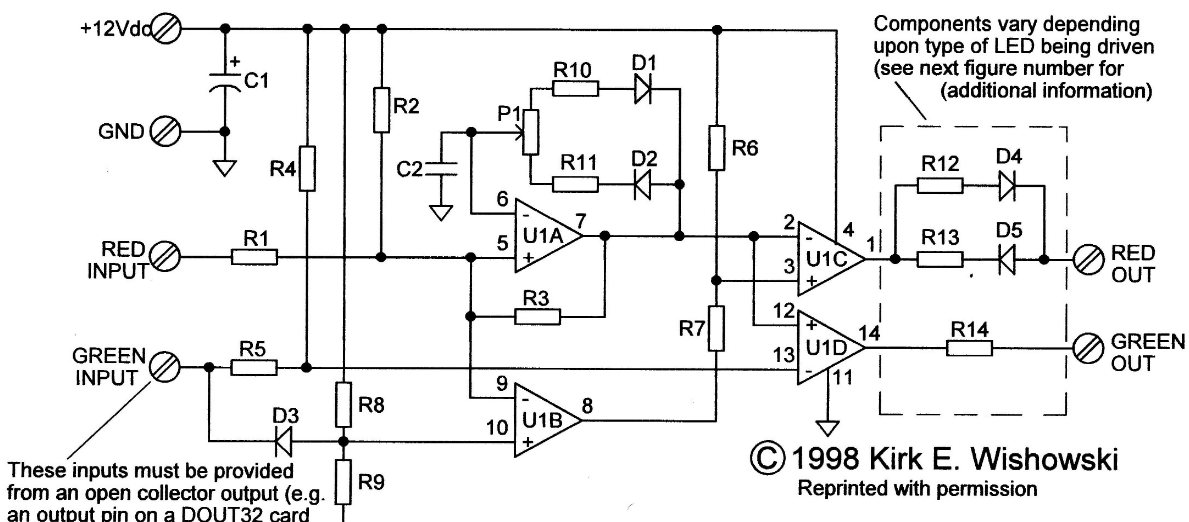

Fig. 2. Searchlight signal driver (SSD) schematic

Based on inputs from Kirk, here is a description of how the circuit functions. However, readers not interested in circuit theory may simply skip to Fig. 3 and its corresponding text. Fundamentally, the SSD is designed to interface directly with open collector devices such as the C/MRI's DOUT32 card, configured in the standard current sinking configuration. Using two inputs, four states can be selected: red, yellow, green and dark. With the last of these states, the C/MRI enables you to build in approach lighting, very easily.

The SSD's only active component is U1, an LM324 quad operational amplifier. Amplifier stages U1B, U1C and U1D are set up as voltage comparators. Anytime the voltage applied to the positive (+), or non-inverting, pin is greater in magnitude than the voltage applied to the negative (-), or inverting, pin, the output swings close to the +12Vdc supply voltage. By contrast, anytime the voltage applied to the negative pin has a greater magnitude than that applied to the positive pin, the outputs swings close to ground. Setting up the amplifiers as voltage comparators allows using them to perform logic gate functions.

The polarity of the current passing through the LED is controlled by the relative output voltages on pins 1 and 14 of the LM324 IC. When Pin 1 is high, close to +12Vdc and Pin 14 is low, close to ground, current flows from the red output through the LED and back in through the green output. By contrast, when Pin 14 is brought high and Pin 1 is low, current flows through the LED from green to red.

The inputs to U1C and U1D are interconnected so that when U1C output is high, U1D is low and vice versa. This circuit arrangement performs just like a DPDT switch, thereby providing the required polarity reversals for the 2-lead bi-color LED. R12 and R13 together with steering diodes D4 and D5 allow individual intensity adjustments of red and green. Resistor R14 is used only for the 3-lead LED case to set the green intensity and limit the current below the 20mA limit.

Stage U1A is set up as a gated oscillator. When the red input is held low, the output of U1A oscillates at approximately 220Hz – a frequency set by C2, P1, R10 and R11. The oscillation's duty cycle, the percentage of time the output is low versus high, is adjusted by P1. The limits of the on and off times are established by D1, D2, R10 and R11. When the red input is high, the output of U1A is forced high. This eliminates the alternating polarity output, allowing the selection of green or dark via the green input.

Stage U1B provides the logic gate function – green and not red – to the non-inverting (+) input of U1C. This logic function is used to force the output of U1C high for the input combination green = high and red = low. This prevents the oscillating output of U1A from being passed through U1C, thereby resulting in a maximized solid-green intensity that is unaffected by an adjustment of P1. Table 1 summarizes the relationships between the SSD circuit inputs and outputs for all four input combinations.

Table 1. Truth table for SSD circuit

Color LED	Red Input	Green Input	Red Output	Green Output	Oscillate Condition
Yellow	low	low	oscillates	oscillates	oscillates
Green	low	high	high	low	not oscillate
Red	high	low	low	high	not oscillate
Dark	high	high	low	low	not oscillate

The high and low entries refer to the voltage logic levels within the SSD circuit and not to the software variables used to drive the SSD. For example, pulling both the red and the green inputs low, i.e. connecting them to ground, causes the LED to display yellow. To make this happen via the C/MRI software you send out a variable defined as SIGNAL = YEL where the YEL aspect constant is defined as YEL = 3 which is a binary 11. Active high software activates the load by pulling the output line low. This inversion is automatically handled for you by the logic built into every C/MRI output. Resistors R12 through R14 along with diodes D4 and D5, are varied depending upon the type of LED being driven and to set the maximum value of desired LED current. Fig. 3 shows the recommended situation for connecting both the 2-lead and 3-lead LED types.

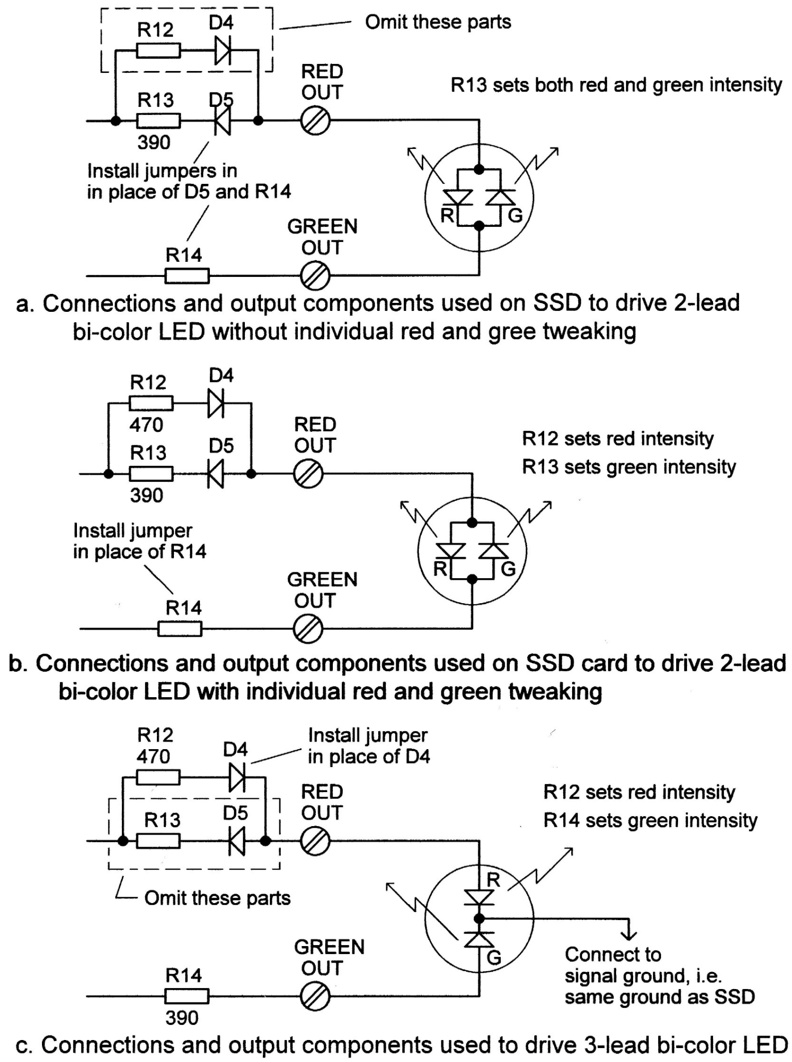

Fig. 3. Connecting LEDs and selecting output components for SSD

Fig. 3a shows the case for driving 2-lead bi-color LEDs where you are happy with the resulting standalone red and green intensities, and you only desire to be able to adjust the quality of the yellow. In this case, you eliminate parts R12 and D4 and install jumpers in place of D5 and R14. Resistor R13 is selected to limit the current flowing in both directions through the LED.

Fig. 3b shows the ultimate refinement case where you have separate control of the red and green intensities as well as control of the yellow. Resistor R14 is replaced with a jumper and you select R12 to set the red intensity and R13 to set the green intensity. Then, once you have the red and green set to your satisfaction, adjust P1 to optimize the quality of the yellow aspect.

Although it is entirely optional to do so, the SSD can be used to drive 3-lead bi-color LEDs using the connections indicated in Fig. 3c. One output drives the red LED and the other output drives the green LED. Yellow is produced by driving both the green and red LEDs simultaneously. The duty cycle of the red LED is adjusted to obtain the best yellow. Resistor R13 and diode D5 are omitted from the circuit and a jumper is installed in place if D4. Then resistors R12 and R14 are selected to balance the relative brightness of the red and green respectively. Once R12 and R14 are fixed, then P1 is adjusted to achieve the best yellow aspect.

In all cases of Fig. 3, I have included typical *starting values* for making the resistor selections. These values are based on powering the SSD with +12Vdc and testing a few dozen different LEDs. Do not hesitate to experiment to determine resistor values that provide you with the best intensity and color balance. However, resistor values less than about 370Ω should not be used. Going below this value results in excessive heating of the LM324 without providing any additional current output through the LED, i.e. the LM324 limits the current output to 20mA maximum. Thus you do not achieve anything by going below 370Ω except possibly damaging the LM324.

Fig. 4 shows the parts layout for the SSD. Ready-to-assemble SSDs are available from JLC Enterprises. Complete kits as well as fully assembled and tested cards can be ordered from EASEE Interfaces. Twelve circuits can be built on each card, and because all are identical I have repeated the parts nomenclature from circuit to circuit. The parts list quantities, see Table 2, are for a single signal LED. Therefore to assemble a complete SSD card you need to multiply the quantities by 12 and add 2 extra 4-40 screws and nuts for the card's power connections.

The order of parts assembly is not critical, but for the sake of having a plan, I recommend following the steps in order and check off the boxes as you complete each one. I have included a [+] after the symbol for each part where polarity of installation is important. As a further aid to assembly, the positive pad for polarity sensitive capacitors and Pin-1 of the IC socket are square. Also, the longer lead on these capacitors is the positive lead.

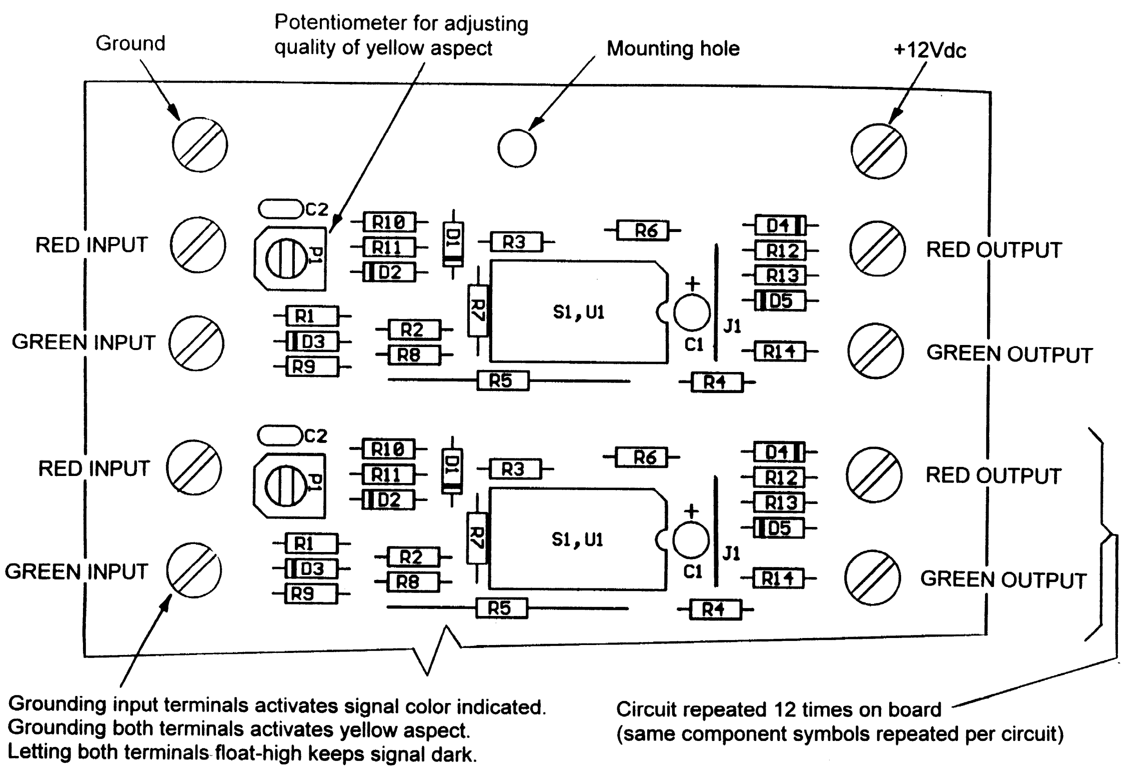

Fig. 4. Parts layout for Searchlight Signal Driver (SSD) card

Table 2. Searchlight signal driver (SSD) parts list.
(In recommended order of assembly)

Qnty.	Symbol	Description
4	-	4-40 nuts (Digi-Key H216)
4	-	4-40 x ¼-long pan head machine screws (Digi-Key H142)
1	J1	Jumper, make from no. 24 uninsulated bus wire (Belden no. 8022)
3	R1-R3	100KΩ resistors [brown-black-yellow]
4	R4-R7	1.0KΩ resistors [brown-black-red]
1	R8	6.8KΩ resistors [blue-gray-red]
1	R9	15KΩ resistor [brown-green-orange]
1	R10	18KΩ resistor [brown-gray-orange]
2	R11	13KΩ resistor [brown-orange-orange]
3	D1-D3	1A, 100V fast recovery diodes (Digi-Key 1N4934CT)
1	S1	14-pin DIP socket (Jameco 112213)
1	C1	1.0µF, 35V tantalum capacitor (Jameco 33662)
1	C2	.1µF monolithic capacitor (Jameco 332671)
1	P1*	50KΩ potentiometer (Digi-Key 3306F-503)
1	U1	LM324N quad op amp (Jameco 23683)

Select one of the following three options to complete card assembly:

If using circuit for 2-lead bi-color LED without separate red and green tweaking, install:

1	D4	Do not install, leave open circuit
1	D5	Install jumper in place of diode
1	R12	Do not install, leave open circuit
1	R13	390Ω resistor [orange-white-brown]
1	R14	Install jumper in place of resistor

If using circuit for 2-lead bi-color LED with separate red and green tweaking, install:

2	D4, D5	1A, 100V fast recovery diodes (Digi-Key 1N4934CT)
1	R12	470Ω resistor [yellow-violet-brown] (adjust to change red intensity)
1	R13	390Ω resistor [orange-white-brown] (adjust to change green intensity)
1	R14	Install jumper in place of resistor

If using circuit for 3-lead bi-color LED, then install:

1	D4	Install jumper in place of diode
1	D5	Do not install, leave open circuit
1	R12	470Ω resistor [yellow-violet-brown] (adjust to change red intensity)
1	R13	Do not install, leave open circuit
1	R14	390Ω resistor [orange-white-brown] (adjust to change green intensity

*Use potentiometer P1 built into the SSD card to adjust the quality of yellow aspect.

Above quantities are per signal LED. Multiply by 12 to assemble total card (12 signal LEDs).
Also, add in two additional nuts and screws, per card, for power supply connections.

Author's recommendations for suppliers given in parentheses above with part numbers where applicable.
Equivalent parts may be substituted. Resistors are ¼W, 5 percent with color codes given in brackets.

Once you have one SSD assembled and operating correctly, you can use it as a pattern for assembling additional cards. Here are the recommended assembly steps.

Terminal screws and nuts. Install the 4-40 screws and nuts with the nut on the circuit trace side of the board. Solder the nuts to the large pads surrounding each hole. Besides the four terminals for each circuit you also need to install those for the +12Vdc and ground power terminals.

J1. Using AWG 22 bus wire install, solder and trim.

R1-R11. Make 90-degree bends in the leads of each resistor so it is centered between its two holes and the leads just fit. Insert and solder while holding the part flat against the card, then trim the leads.

D1-D3[+]. Install same as resistors but make sure that the banded end of each diode is oriented as shown in Fig. 4.

S1[+]. Make certain that you have all 14 pins properly in their respective holes with the correct orientation for Pin 1, then hold the socket tight against the board as you solder the pins. As with any multi-pin part, solder only a couple of pins first, those on opposite corners of the socket. Reheat as necessary to make certain that the socket is firmly against the board, then solder the remaining pins.

C1[+]. Insert this capacitor standing perpendicular to the card. Make sure that the + lead goes into the + hole as shown in Fig. 4. Incorrect polarity will damage this capacitor. Solder and trim leads.

C2. Insert this capacitor standing perpendicular to the card, solder, and trim leads.

U1[+]. Insert the LM324 IC making sure you have the correct Pin-1 orientation and that all pins go into the socket.

P1. Install this trim potentiometer as in Fig. 4 and push the three prongs all the way into the holes as you solder.

Install remaining parts. Depending upon the type of LED you are going to drive, select one of three choices listed in Table 2. Based upon your selection follow the procedures noted previously for diodes and resistors to install the appropriate components for D4, D5, and R12 through R14.

Cleanup and inspection.

That completes the assembly steps for the SSD. The card layout uses wide traces and spacing between traces so soldering problems should be minimized. There is only one active component, the LM324, so debugging is easy, especially since the IC is in a socket. If you do have a problem in one or more of the circuits not driving LEDs correctly, compare the circuits that work with those that do not. Look for diodes inserted backwards, resistor values in the wrong locations and most importantly solder bridges or faulty solder joints.

For readers who might possibly have access to an oscilloscope, Fig. 5 shows the voltage waveform that should exist across Pins 1 and 14 of the LM324 for various inputs and settings of P1. Studying these waveforms helps clarify how the circuit functions. With both the red and green inputs pulled low, Fig. 5a, the output waveform is a square-wave with a period of about 4.6mS. This way both the green and the red LEDs are blinking on and off.

Because the blinking rate is approximately 220 times per second, calculated as 1 divided by the 4.6mS period, the combination of the green and red appears as a yellow aspect. Adjusting P1 changes the duty cycle, e.g. the relative length of time that the red LED is turned on compared to the total time per cycle. The range of the P1 adjustment is from almost all green to almost all red. Settings near the middle of the potentiometer should yield the best blend of green and red and therefore the best yellow.

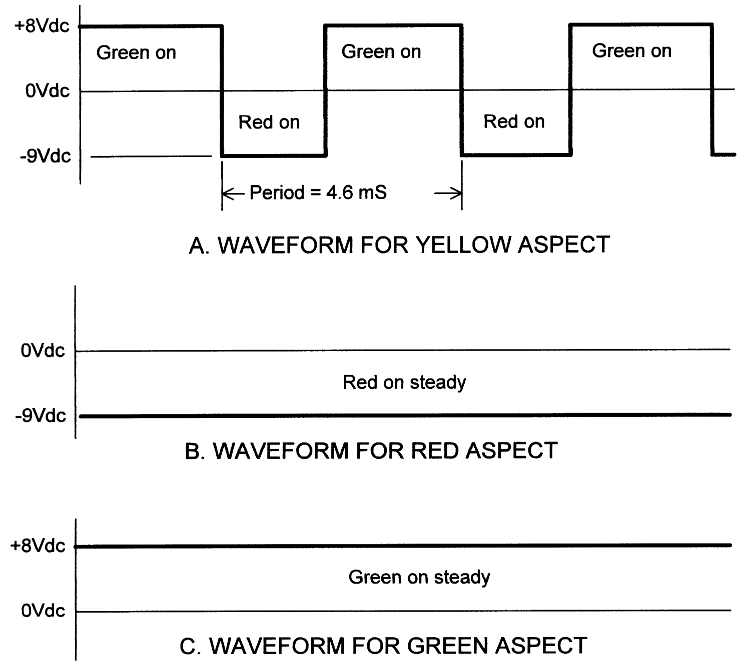

Fig. 5. Voltage waveforms out of LM324 as a function of SSD inputs and setting of P1.

With only the red input pulled low, Fig. 5b, the green portion of the waveform disappears and the red turns on steady. With only the green input pulled low, Fig. 5c, the red portion of the waveform disappears and the green LED turns on steady. With both inputs left to float high, neither LED is on and the signal aspect is dark

The SSD card can be driven directly from a DOUT card configured in the standard current sinking configuration or a COUT24 card. You can also drive the SSD inputs from any other logic circuit as long as the circuit outputs are open collector configuration. To test the SSD, you can simply connect clip leads between the input screws and ground to activate the appropriate LED color and leave the screw unconnected when not activating the color. Or you can replace the clip leads with two SPST toggles with one lead from each toggle connected to ground and the remaining lead from each toggle connected to one of the input screws on the SSD.

If you find that with your particular LEDs, the “best yellow” is achieved with P1 settings close to one end of the adjustment, consider altering the red intensity resistor, R12, to improve the green to red intensity balance before attempting to adjust the yellow. Selecting increasing values of R12 decreases the red intensity.