RailFun 2014
Basic Electronic circuits

Some simple circuits for animation on your layout.

Presented by Mike Wood

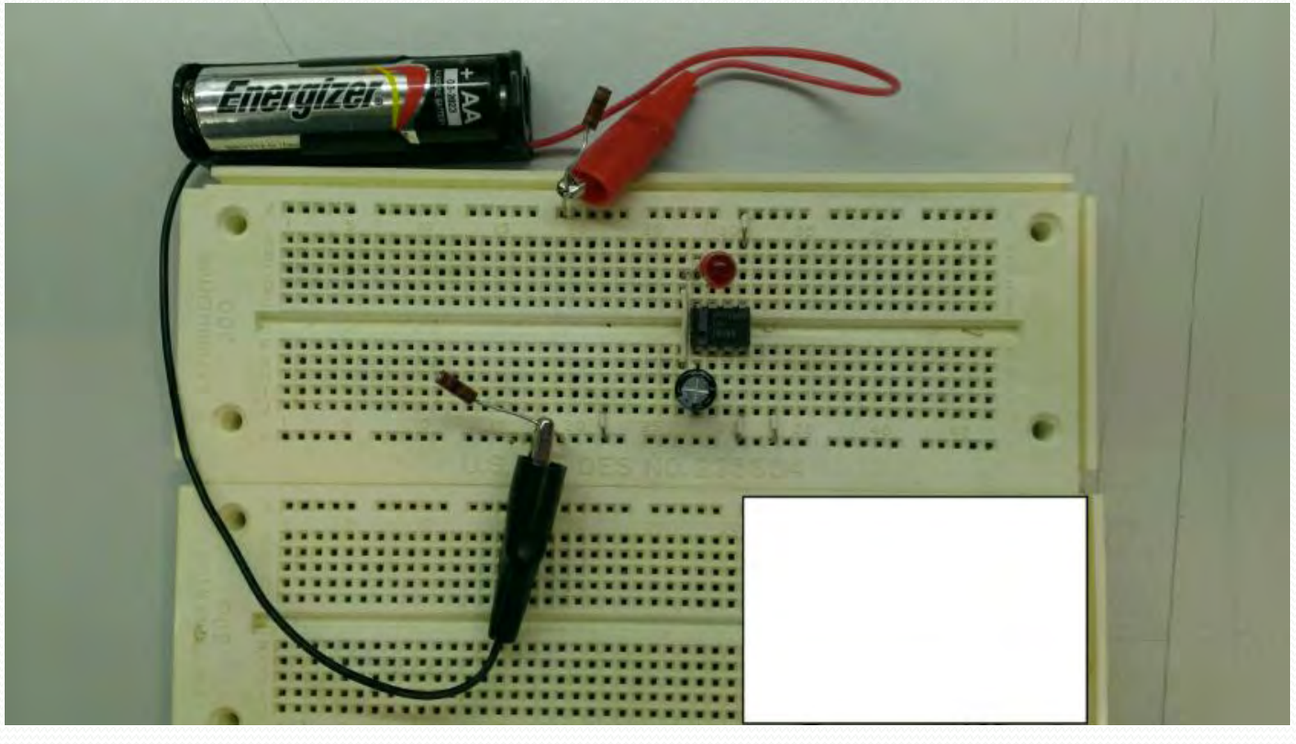
Rev 2. Nov 16 2014

Agenda

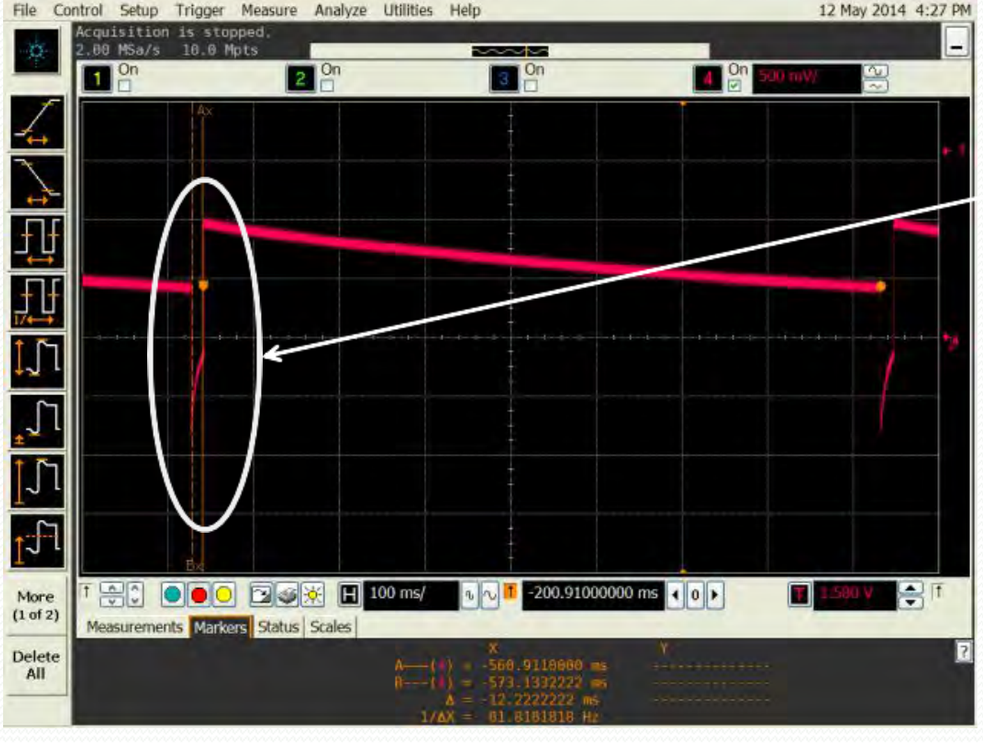
- Introduction and some basics
- Circuit 1: Low voltage (1.5 V dc) Flasher
- Circuit 2: Traffic light sequencer

Low voltage (15 V dc) Flasher

- Experimenters plug in board : no soldering required, great way to test things out.
- Parts list:
- Qty 1 LM3909 LED Flasher
- 220 uf 10V capacitor
- 15 Volt AA battery standard or alkaline



Low voltage (15 V dc) Flasher



- This is the output response of the Flasher LED at pin 8.
- This portion of the signal represents the amount of time that the LED is lit up.
- The "on" blink is roughly 10 to 40 ms and about 1 second off.

LM3909 data sheet and the low voltage flasher circuit

National Semiconductor

February 1995

LM3909 LED Flasher/Oscillator

LM3909 LED Flasher/Oscillator

General Description

The LM3909 is a monolithic oscillator specifically designed to flash Light Emitting Diodes. By using the timing capacitor for voltage boost, it delivers pulses of 2 or more volts to the LED while operating on a supply of 1.5V or less. The circuit is inherently self-starting, and requires addition of only a battery and capacitor to function as an LED flasher.

Packaged in an 8-lead plastic mini-DIP, the LM3909 will operate over the extended consumer temperature range of −25°C to +70°C. It has been optimized for low power drain and operation from weak batteries so that continuous operation life exceeds that expected from battery rating.

Application is made simple by inclusion of internal timing resistors and an internal LED current limit resistor. As shown in the first two application circuits, the timing resistors supplied are optimized for nominal flashing rates and minimum power drain at 1.5V and 3V.

Timing capacitors will generally be of the electrolytic type, and a small 3V rated part will be suitable for any LED flasher using a supply up to 6V. However, when picking flash rates, it should be remembered that some electrolytics have very broad capacitance tolerances, for example −20% to +100%.

Features

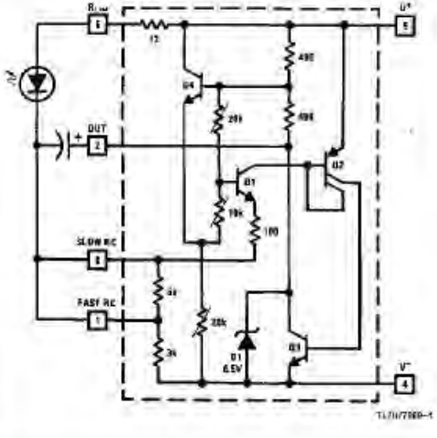
- Operation over one year from one C size flashlight cell
- Bright, high current LED pulse
- Minimum external parts
- Low cost
- Low voltage operation, from just over 1V to 5V
- Low current drain, averages under 0.5 mA during battery life
- Powerful, as an oscillator directly drives an 80 speaker
- Wide temperature range

Applications

- Finding flashlights in the dark, or locating boat mooring floats
- Sales and advertising gimmicks
- Emergency locators, for instance on fire extinguishers
- Toys and novelties
- Electronic applications such as trigger and sawtooth generators
- Siren for toy fire engine, (combined oscillator, speaker driver)
- Warning indicators powered by 1.4V to 200V

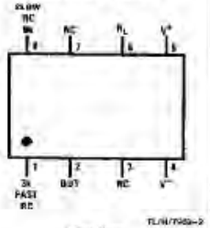
Schematic Diagram

Typical 1.5V Flasher



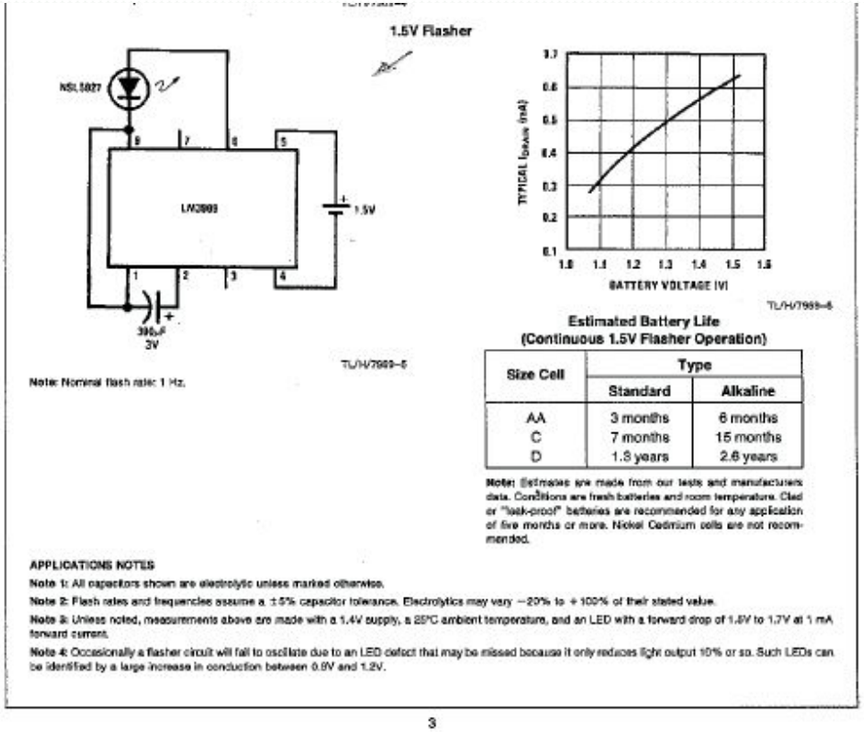
Connection Diagram

Dual-In-Line Package



Top View

Order Number LM3909N
See NS Package Number N08E



Note: Nominal flash rate: 1 Hz.

Estimated Battery Life
(Continuous 1.5V Flasher Operation)

Size Cell	Type	
	Standard	Alkaline
AA	3 months	6 months
C	7 months	15 months
D	1.3 years	2.6 years

Note: Estimates are made from our tests and manufacturers data. Conditions are fresh batteries and room temperature. Cad or "leak-proof" batteries are recommended for any application of five months or more. Nickel Cadmium cells are not recommended.

APPLICATIONS NOTES

Note 1: All capacitors shown are electrolytic unless marked otherwise.

Note 2: Flash rates and frequencies assume a ±5% capacitor tolerance. Electrolytics may vary −20% to +100% of their stated value.

Note 3: Unless noted, measurements above are made with a 1.4V supply, a 25°C ambient temperature, and an LED with a forward drop of 1.6V to 1.7V at 1 mA forward current.

Note 4: Occasionally a flasher circuit will fail to oscillate due to an LED defect that may be missed because it only reduces light output 10% or so. Such LEDs can be identified by a large increase in conduction between 0.6V and 1.2V.

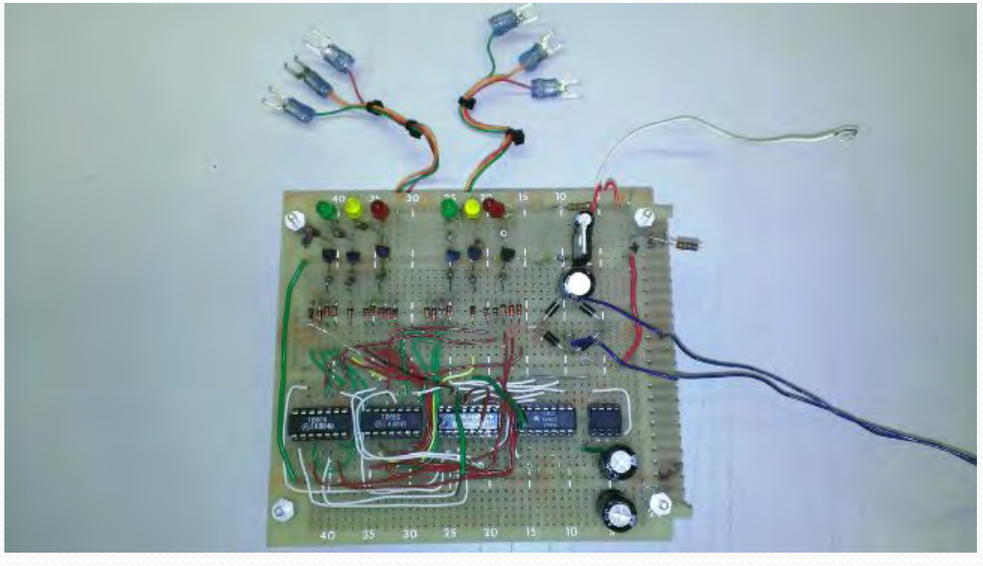
Low voltage (1.5 V dc) Flasher

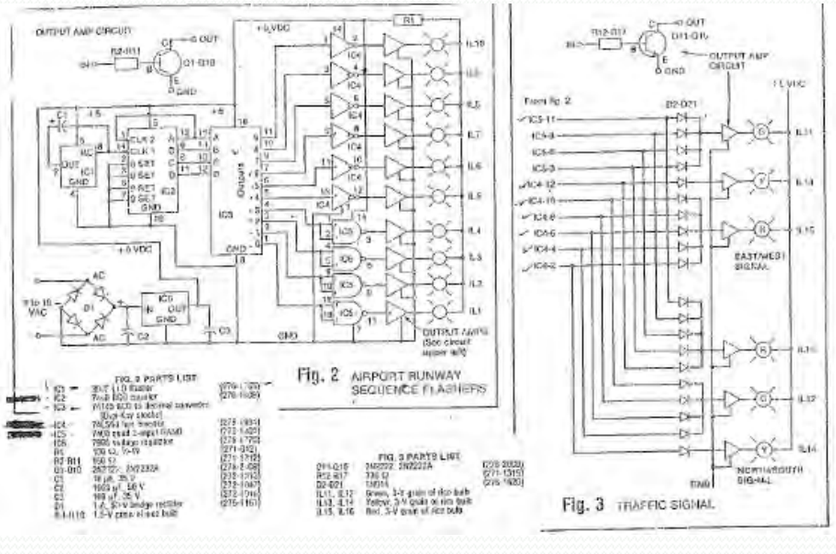
- How do you change the Flash rate of the LED?
- By decreasing the capacitor value, the output frequency of the flasher will increase and the LED will blink on and off at a faster rate. Note that some electrolytic capacitors have wide tolerance ranges on the order of -20% to +100%.
- If it flashes faster than about a 10 to 15 Hz rate, the on/off sequence of the LED will actually appear to be always lit, this is called persistence of vision, basically your eye cannot detect the flashing.
- If you want to more accurately control the flash rate you can use a potentiometer (variable resistor). The circuit changes a bit but the flash rate is now determined by the resistor capacitor and voltage. Other variations exist and are beyond the scope of this presentation.

Agenda

- Introduction and some basics
- Circuit 1: Low voltage (1.5 V dc) Flasher
- Circuit 2: Traffic light sequencer

Traffic light sequencer board





- The schematic diagram is an old Xeroxed copy from Model Railroader Magazine. May 1982.
- I'll attempt to simplify it for you with some graphics and allow you to see real time oscilloscope measurements within the circuit. An "under the hood" look if you will.

First, some basics

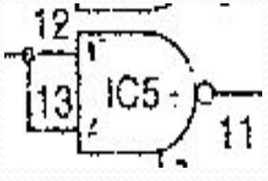
- Transistor : a device used to amplify and switch an electric signal. It has three terminals, base, emitter and collector. In our circuit we switch it on or switch it off by applying a voltage to its base .

- Diode : a component with 2 leads or electrodes, between which allows a transfer of current in one direction only.

- LED Light Emitting Diode: same concept as a diode, however the LED converts electricity to light.

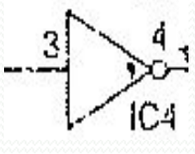
First, some basics

- NAND gate: a component that will take two inputs and provides a logic low output, if and only if both inputs are a logic high. Otherwise its output is a logic low.



INPUT 1	INPUT 2	OUTPUT
0	0	1
0	1	1
1	0	1
1	1	0

Inverter : As the name implies , this component will invert the state of it's input. If the input is a logic low signal (a zero) the output will switch to a logic high signal (a one). If the input is a logic high signal the output will switch to a logic low signal.



INPUT	OUTPUT
0	1
1	0

Traffic light sequencer schematic

May 1982 issue of Model Railroader magazine. Pages 82 - 85.

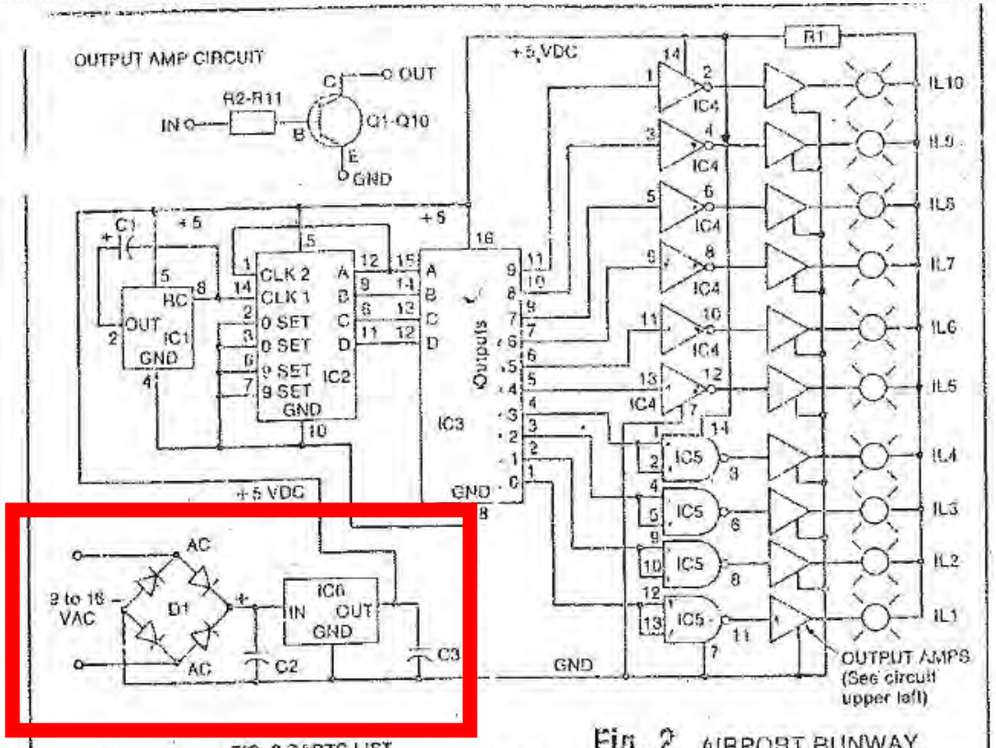


Fig. 2 AIRPORT RUNWAY SEQUENCE FLASHERS

FIG. 2 PARTS LIST

IC1	3909 LED flasher	(276-1105)
IC2	7490 BCD counter	(276-1108)
IC3	74145 BCD to decimal converter [Digi-Key stocks]	
IC4	74LS04 hex inverter	(276-1804)
IC5	7400 quad 2-input NAND	(276-1801)
IC6	7805 voltage regulator	(276-1770)
R1	100 Ω, ½-W	(271-012)
R2-R11	150 Ω	(271-1312)
Q1-Q10	2N2222, 2N2222A	(276-2009)
C1	10 µF, 35 V	(272-1013)
C2	1000 µF, 50 V	(272-1047)
C3	100 µF, 35 V	(272-1016)
D1	1-A, 50-V bridge rectifier	(276-1161)
IL1-IL10	1.5-V grain-of-rice bulb	

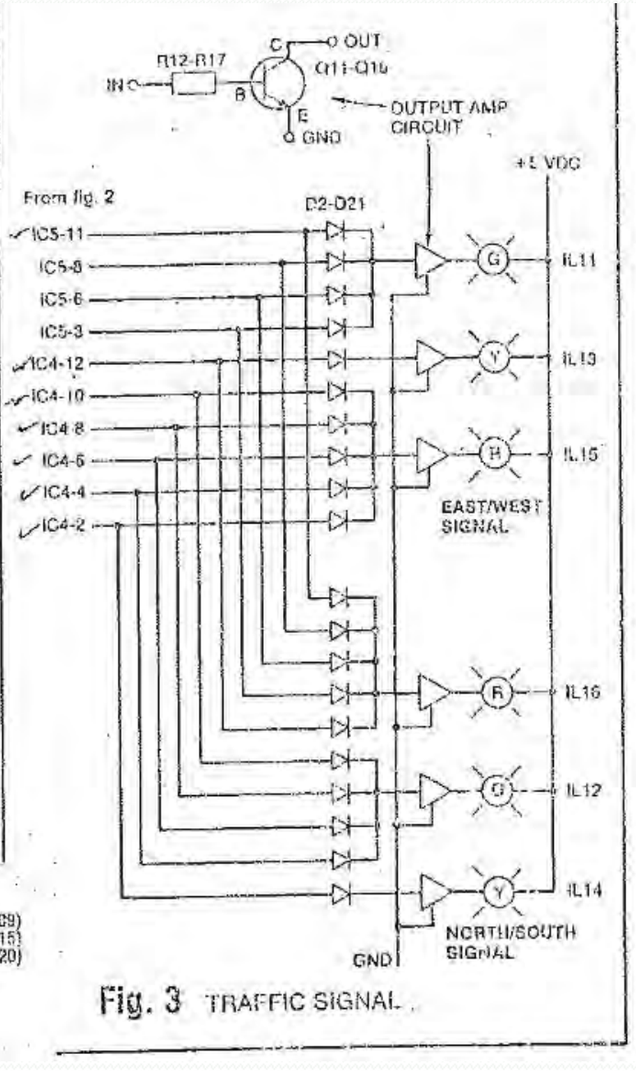
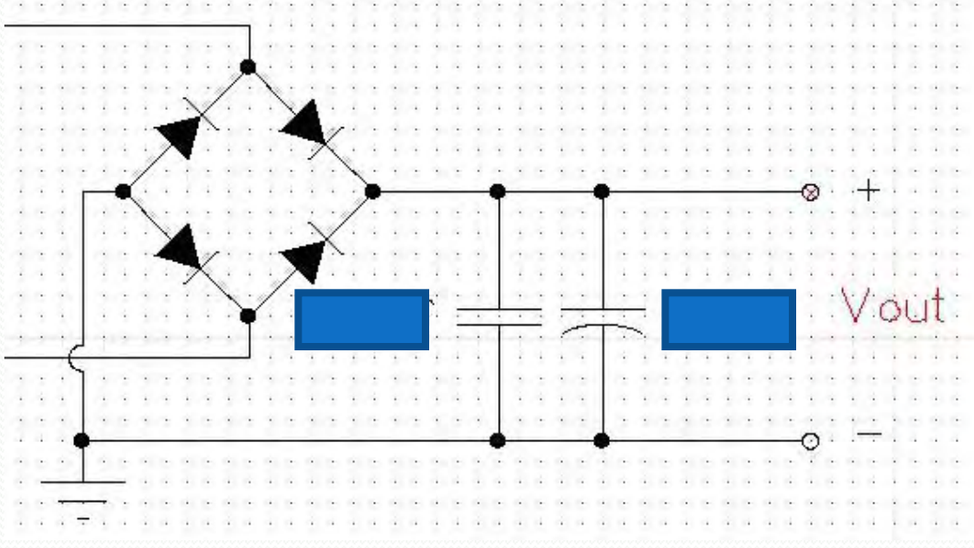


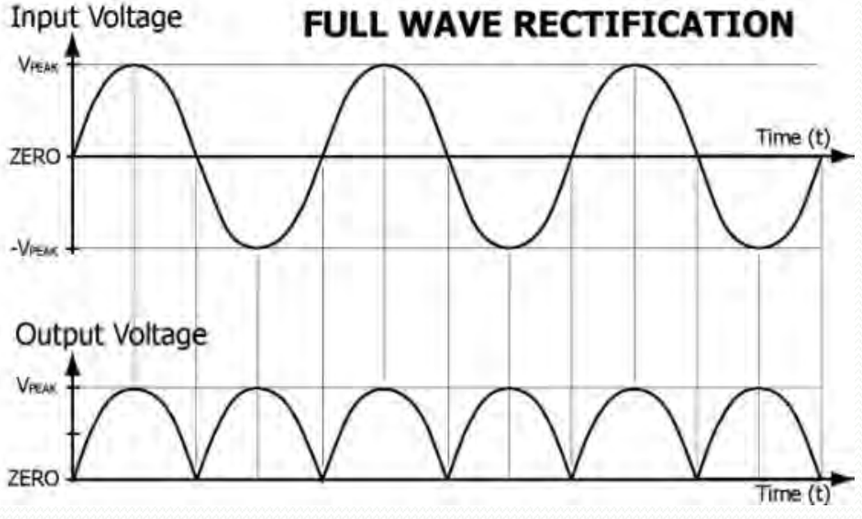
Fig. 3 TRAFFIC SIGNAL

FIG. 3 PARTS LIST

Q11-Q16	2N2222, 2N2222A	(276-2009)
R12-R17	330 Ω	(271-1315)
D2-D21	1N914	(276-1620)
IL11, IL12	Green, 3-V grain of rice bulb	
IL13, IL14	Yellow, 3-V grain of rice bulb	
IL15, IL16	Red, 3-V grain of rice bulb	

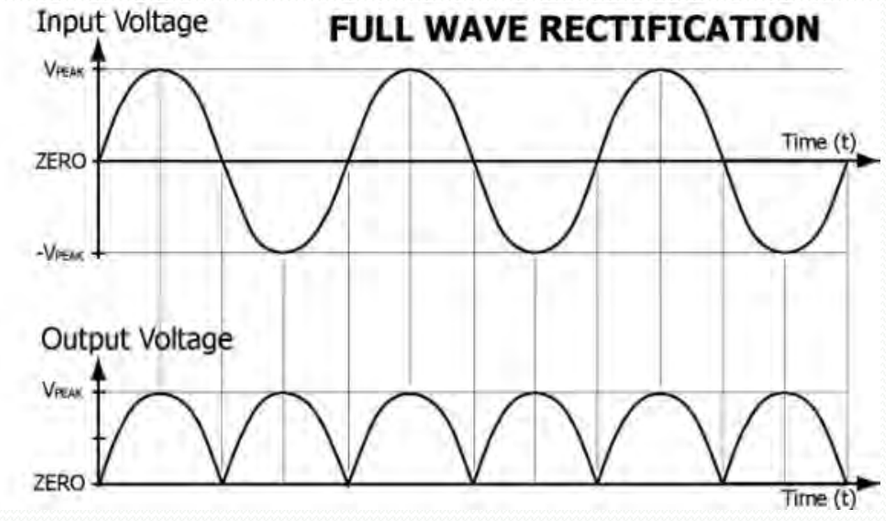
Power section: Full wave rectifier

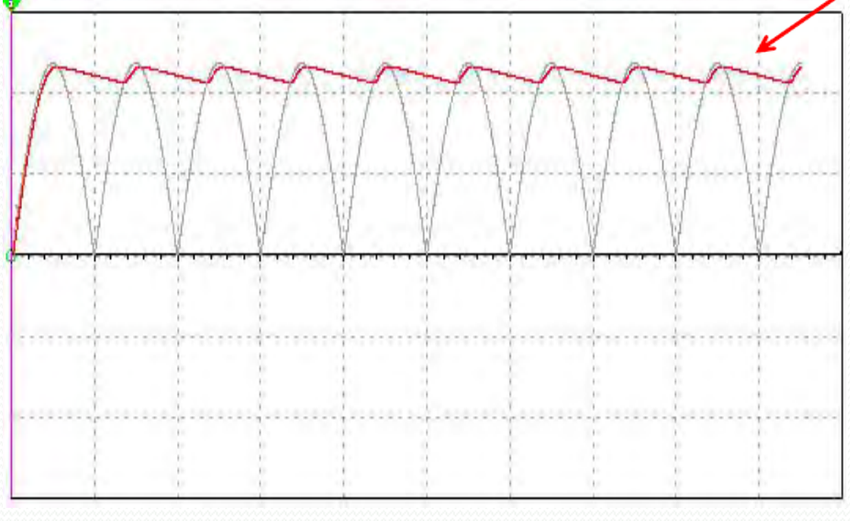




- The output of the rectifier is unfiltered and varies between zero and the peak voltage. We need to smooth it out. For that we will use a capacitor.

Full wave rectifier and filter capacitor

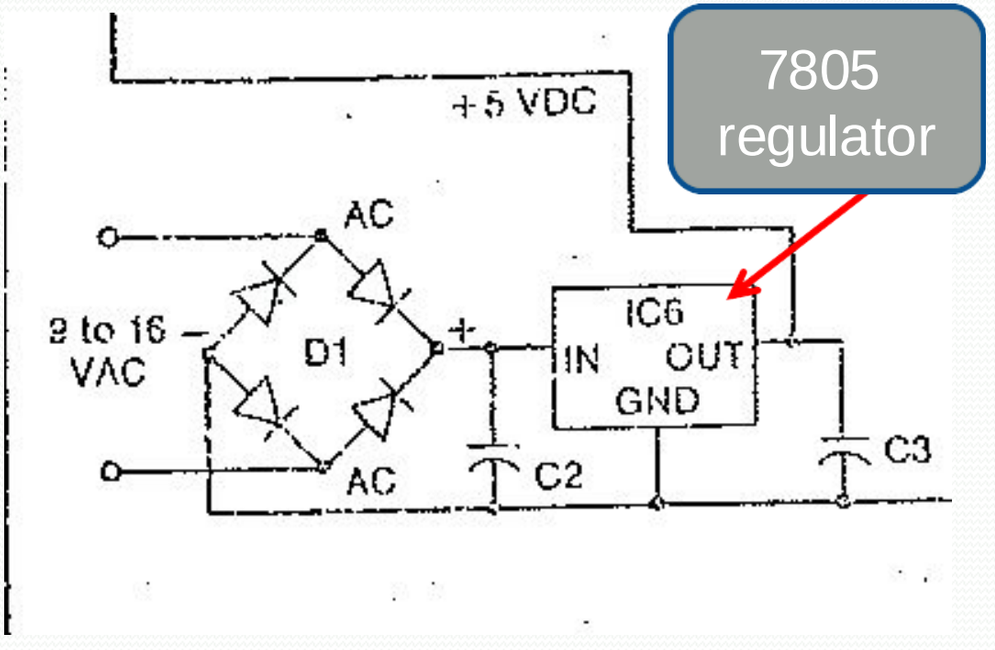




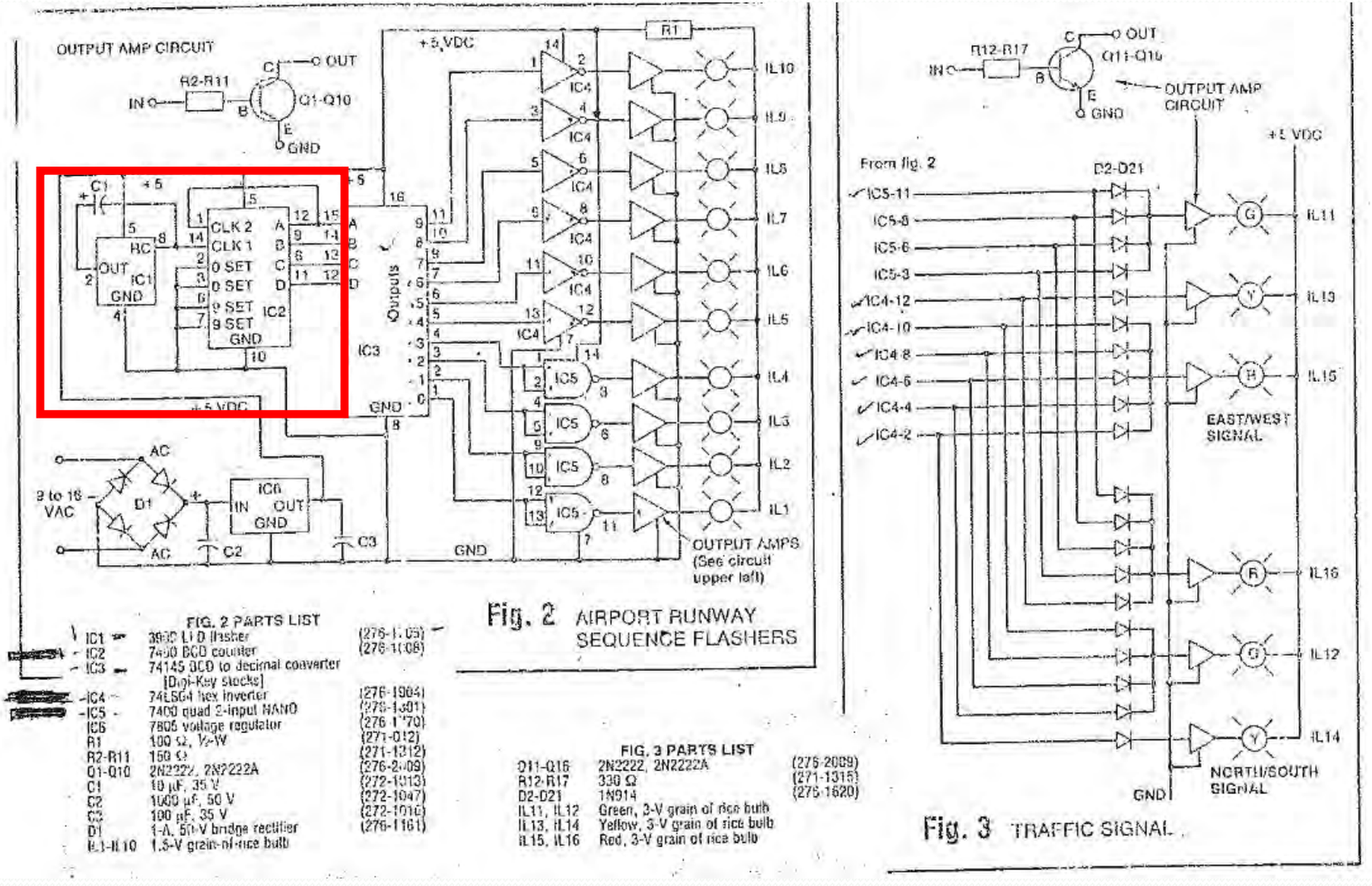
- The rectifier converts the AC signal into a full wave rectified DC output, the output side of the rectifier is where the capacitor (C2) sees the DC signal.
- The capacitor provides a filtering effect and attempts (charges up) to maintain the voltage at a constant level. The capacitor won't hold the charge forever and will begin to discharge.
- The "filtered" voltage is then applied to the voltage regulator IC6.

The 7805 Regulator

- The other IC's in this design require a clean 5Volt source in order to properly function. That's the job for the regulator (IC6).
- The 7805 regulator takes in a voltage from approximately 7 to 30 volts and regulates it down to 5 Volts (+/-0.2V).
- The input capacitor (C2) filters out voltage ripple from the rectifier.
- The output capacitor (C3) provides a load balance to ensure consistant voltage output from the 7805.
- IC-6 should have a heat sink to help dissipate the heat that results from the voltage drop across it.



LED Flasher and BCD counter



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IC2	7490 BCD counter	(276-1108)
IC3	74145 BCD to decimal converter [Digi-Key stocks]	
IC4	74LS04 hex inverter	(276-1904)
IC5	7400 quad 2-input NAND	(276-1801)
IC6	7805 voltage regulator	(276-1770)
R1	100 Ω, ½-W	(271-012)
R2-R11	150 Ω	(271-1312)
Q1-Q10	2N2222, 2N2222A	(276-2009)
C1	10 µF, 35 V	(272-1013)
C2	1000 µF, 50 V	(272-1047)
C3	100 µF, 35 V	(272-1016)
D1	1-A, 50-V bridge rectifier	(276-1161)
IL1-IL10	1.5-V grain-of-rice bulb	

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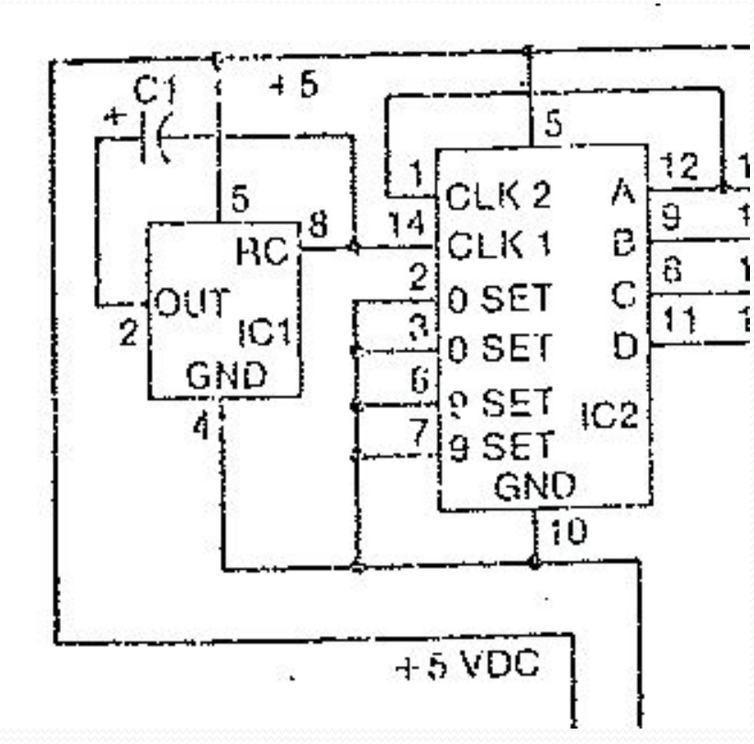
Fig. 3 TRAFFIC SIGNAL

LED Flasher and BCD counter section



- IC 1 is an LED Flasher , its purpose is to generate a continuous series of pulses (1s' and 0 s' ie a series of logic high and logic low pulses) .
- The frequency of these alternating 1s' 'and 0 s' is determined by the value of capacitor C1.
- The output of the flasher IC is passed from pin 8 over to pin 14 of the BCD counter (IC2).

What is BCD ?

- BCD or Binary Coded Decimal is a type of binary encoding format where each decimal digit is represented by a fixed number of bits, usually four or eight.
- BCD takes advantage of the fact that any one decimal numeral can be represented by a four bit pattern. Each decimal digit has a corresponding four bit binary value.
- In the following example we will work with 4 bits.

Decimal numbers and place holders

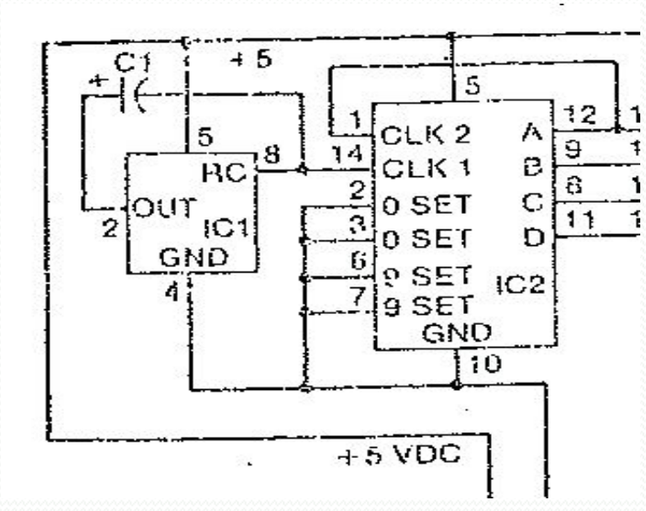
Decimal number
0
1
2
3
4
5
6
7
8
9
10

Place holders	Place holders	Place holders	Place holders
Thousands	Hundreds	Tens	Ones
			0
			1
			2
			3
			4
			5
			6
			7
			8
			9
		1	0

Decimal numbers in BCD "8421" format

Decimal number	Place holder value 8	Place holder value 4	Place holder value 2	Place holder value 1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

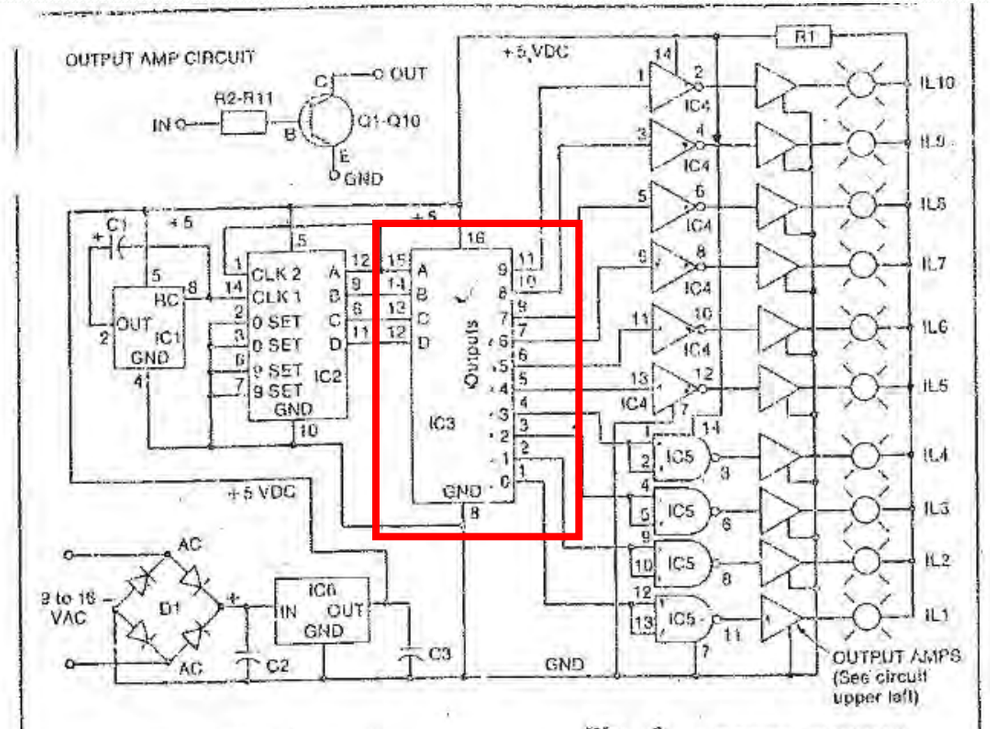
LED Flasher and BCD counter section



Number	Place holder value D=8	Place holder value C=4	Place holder value B=2	Place holder value A=1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

- The pulse train output from IC1 is passed into IC2. The counters job (IC-2) is to count from 0 to 9 and then repeat.
- By counting from 0 to 9 we can control up to ten LED's. IC-3 will take care of that.
- The output of the counter (IC-2) is represented to the BCD table shown here.
- Note the output pins of the BCD counter , they are labeled A,B,C and D.
- We can apply those letters to each place holder .

The BCD to decimal converter



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IC4	74LS04 hex inverter	(276-1904)
IC5	7400 quad 2-input NAND	(276-1901)
IC6	7805 voltage regulator	(276-1770)
R1	100 Ω, ½-W	(271-012)
R2-R11	150 Ω	(271-1312)
Q1-Q10	2N2222, 2N2222A	(276-2009)
C1	10 µF, 35 V	(272-1013)
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D1	1-A, 50-V bridge rectifier	(276-1161)
IL1-IL10	1.5-V grain-of-rice bulb	

Fig. 2 AIRPORT RUNWAY SEQUENCE FLASHERS

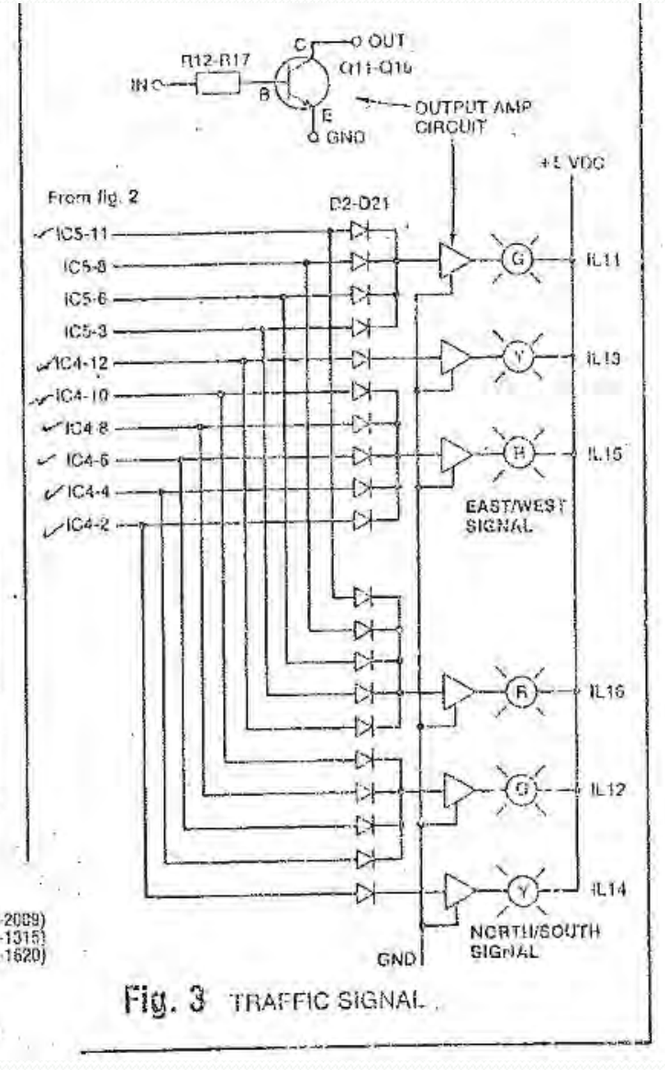

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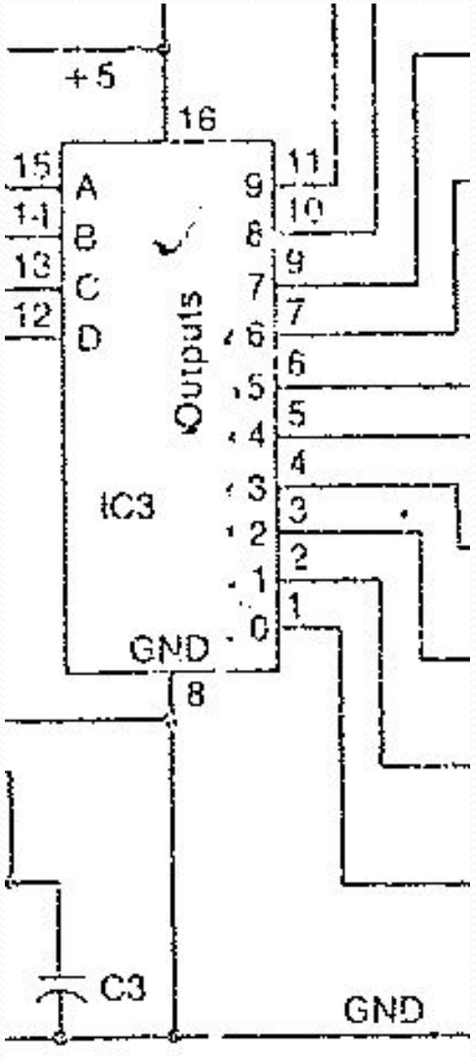
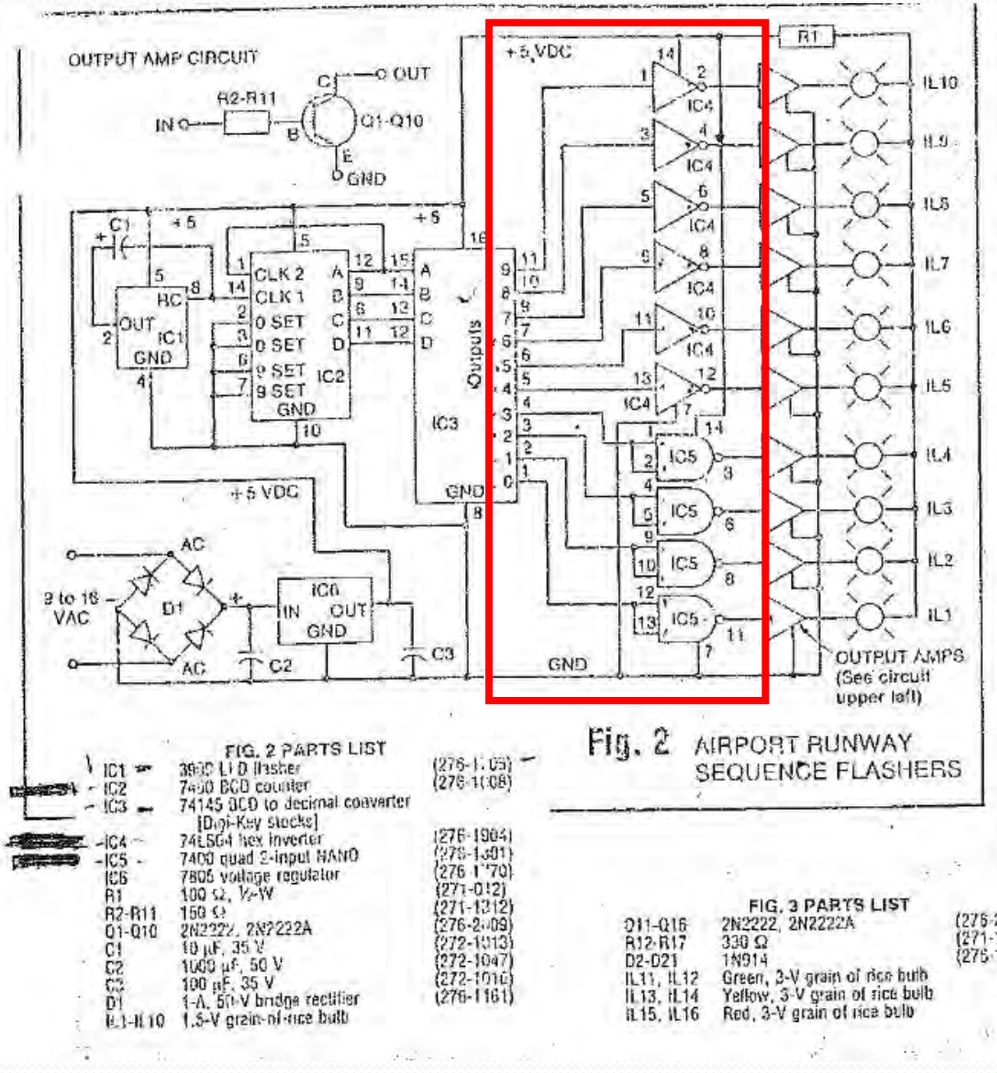
Fig. 3 TRAFFIC SIGNAL

The BCD to decimal converter



- The BCD to decimal converter is IC3. It's job is to take the BCD output from IC2 and convert it into a sequential output.
- In doing so, only one of the output pins will be active low (0 volts) at any time. All of the other output pins will be active high (~5V).
- This active low output is opposite of the signal levels desired to drive the output amplifiers.
- We need to invert the outputs of IC3.....

Inverters IC4 and IC5 will do this.



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IC5	7400 quad 2-input NAND	(276-1901)
IC6	7805 voltage regulator	(276-1770)
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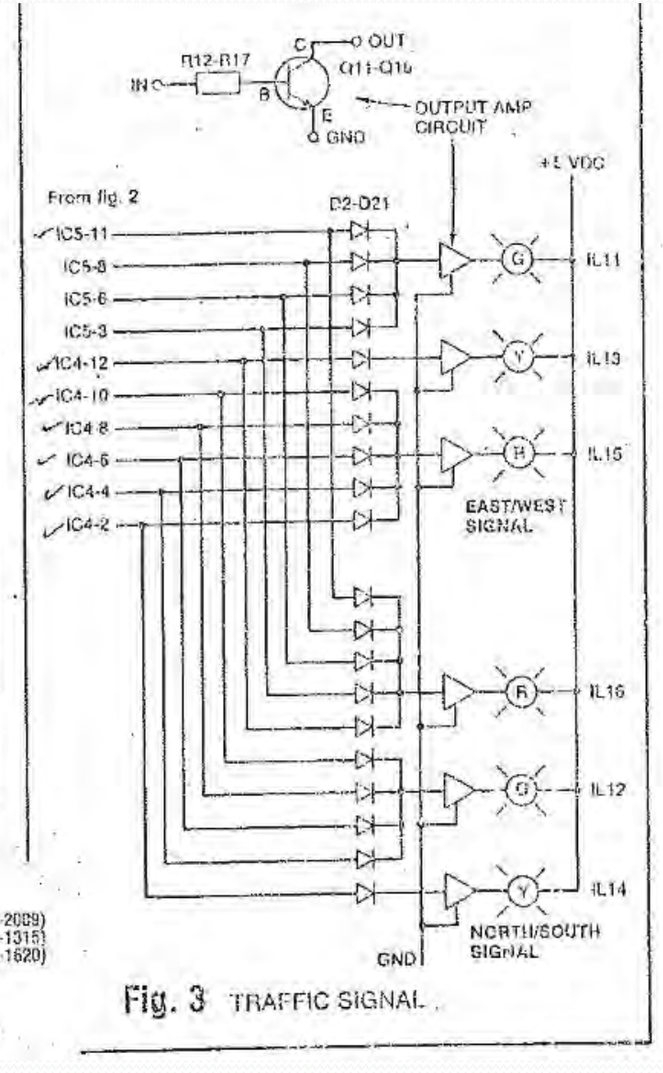
IL1-IL10	1.5-V grain-of-rice bulb	



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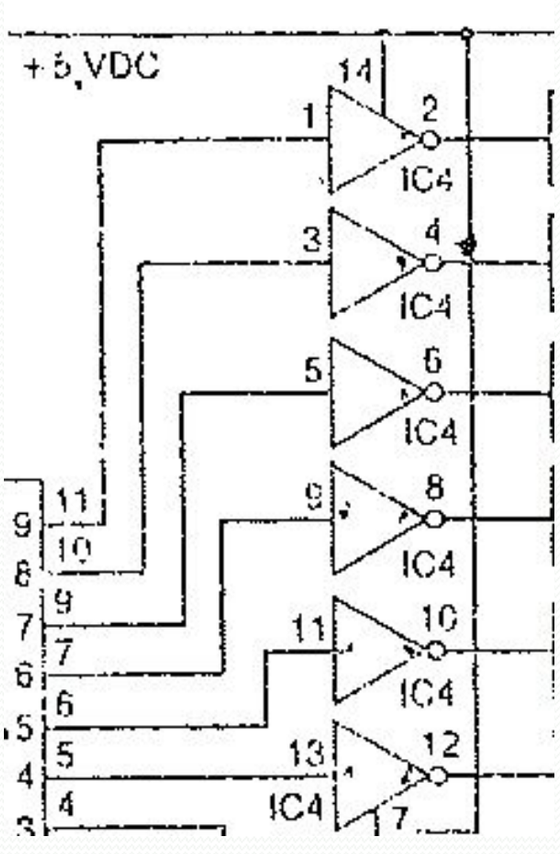
IL15, IL16	Red, 3-V grain of rice bulb	

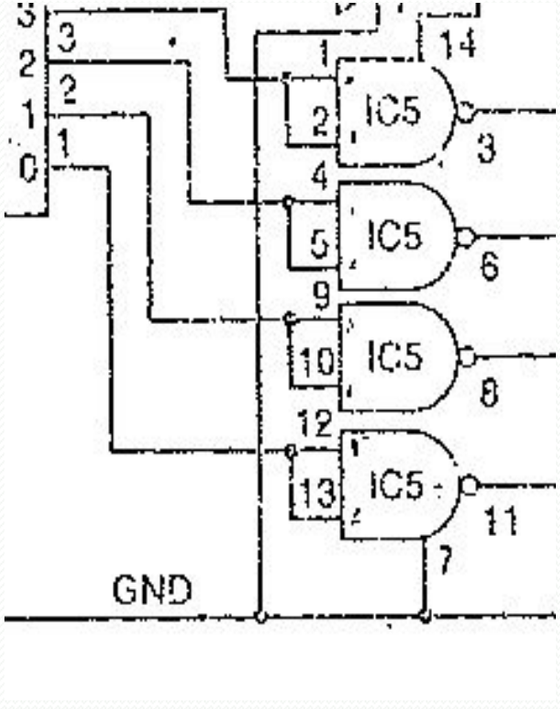
IC4 and IC5 will invert the outputs of IC3



- IC 4 is an inverter. There are six individual inverters in one package.
- Its job is simple.
- If the input is a logic low signal (a zero) output will switch to a logic high signal (a one). If the input is a logic high signal the output will switch to a logic low signal.

INPUT	OUTPUT
0	1
1	0

IC4 and IC5 will invert the outputs of IC3



- IC5 is a logic NAND gate. It takes two inputs and provides a logic high output if and only if both inputs a logic high. Other wise its output is a logic low.

INPUT 1	INPUT 2	OUTPUT
0	0	1
0	1	0
1	0	0
1	1	0

- Notice that if we tie the inputs together on NAND gate we have the equivalent function of an inverter.

The outputs of IC4 and IC5 will drive the LED circuits

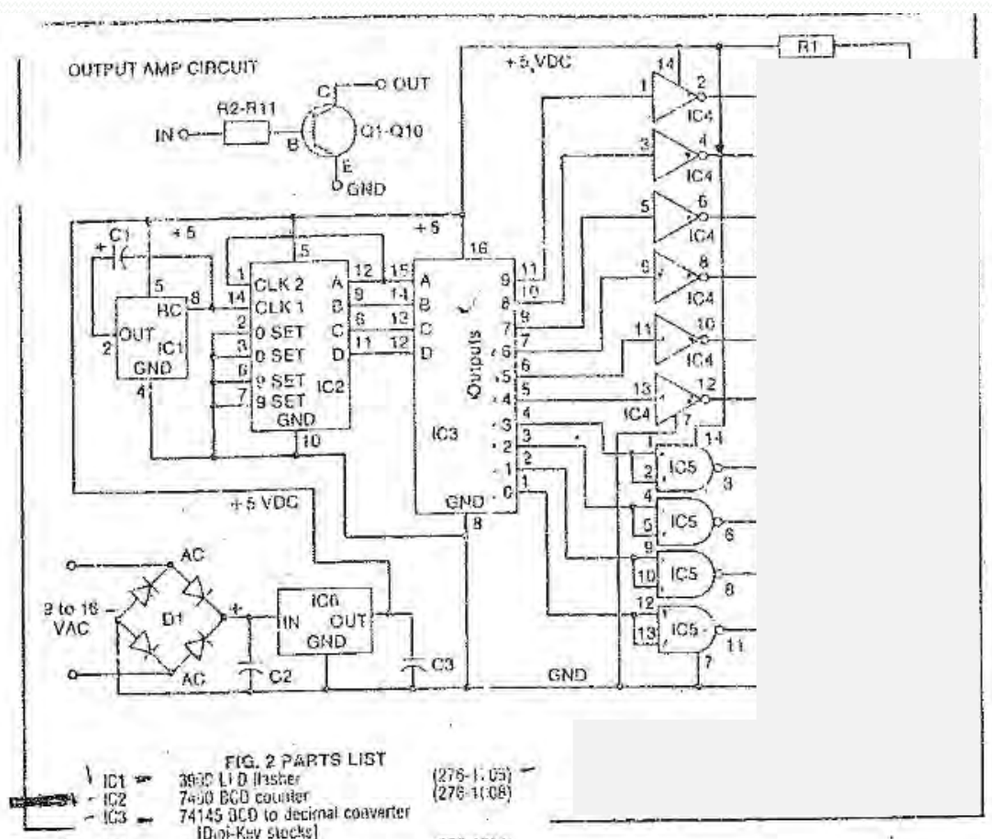


FIG. 2 PARTS LIST

IC1	3900 LED flasher	(276-1105)
IC2	7490 BCD counter	(276-1108)
IC3	74145 BCD to decimal converter [Digi-Key stocks]	
IC4	74LS04 hex inverter	(276-1904)
IC5	7400 quad 2-input NAND	(276-1901)
IC6	7805 voltage regulator	(276-1770)
R1	100 Ω, ½-W	(271-012)
R2-R11	150 Ω	(271-1312)
Q1-Q10	2N2222, 2N2222A	(276-2009)
C1	10 µF, 35 V	(272-1013)
C2	1000 µF, 50 V	(272-1047)
C3	100 µF, 35 V	(272-1016)
D1	1-A, 50-V bridge rectifier	(276-1161)
IL1-IL10	1.5-V grain-of-rice bulb	

FIG. 3 PARTS LIST

Q11-Q16	2N2222, 2N2222A	(276-2009)
R12-R17	330 Ω	(271-1335)
D2-D21	1N914	(276-1620)
IL11, IL12	Green, 3-V grain of rice bulb	
IL13, IL14	Yellow, 3-V grain of rice bulb	
IL15, IL16	Red, 3-V grain of rice bulb	

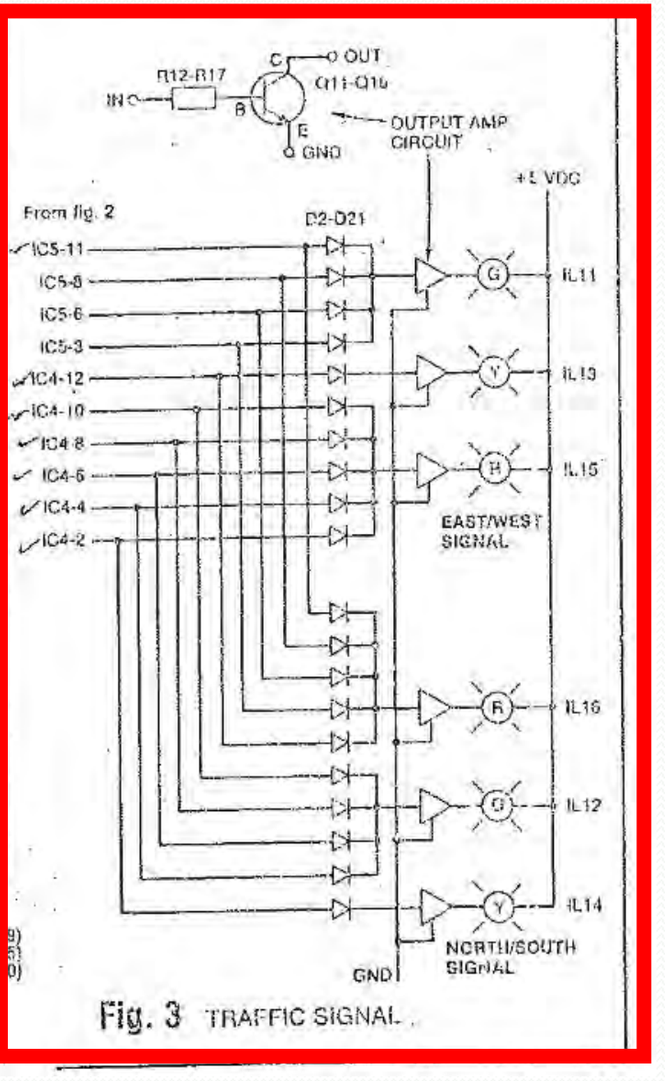


Fig. 3 TRAFFIC SIGNAL

Lets walk thru the full sequence

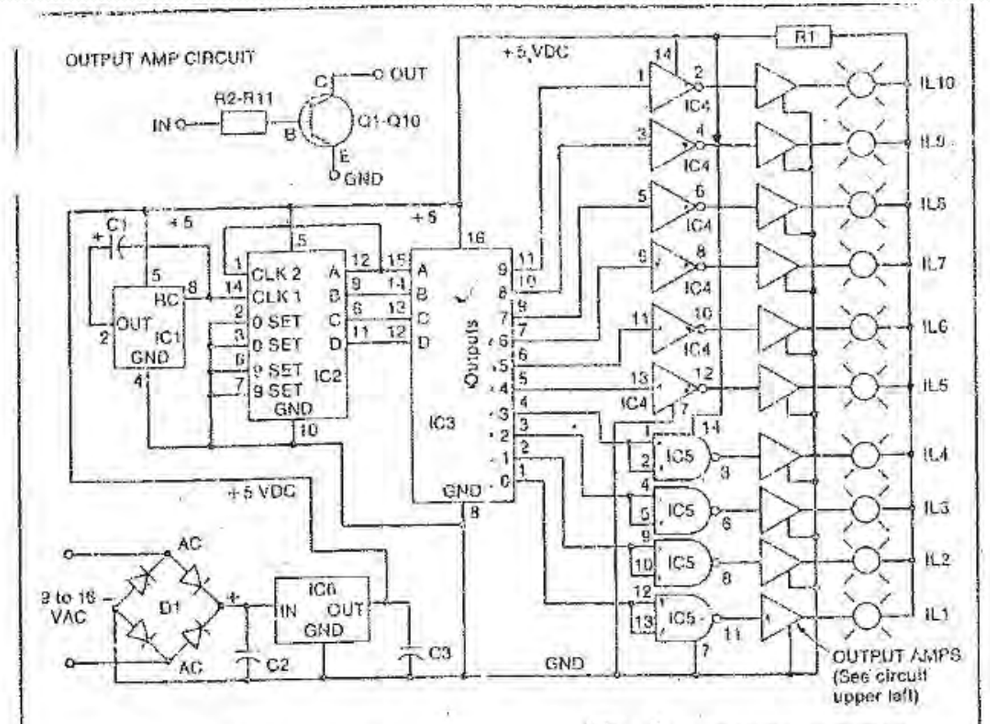


Fig. 2 AIRPORT RUNWAY SEQUENCE FLASHERS

FIG. 2 PARTS LIST

IC1	3909 LED flasher	(276-1165)
IC2	7490 BCD counter	(276-1108)
IC3	74145 BCD to decimal converter [Digi-Key stocks]	
IC4	74LS04 hex inverter	(276-1904)
IC5	7400 quad 2-input NAND	(276-1901)
IC6	7805 voltage regulator	(276-1770)
R1	100 Ω, ½-W	(271-012)
R2-R11	150 Ω	(271-1312)
Q1-Q10	2N2222, 2N2222A	(276-2009)
C1	10 µF, 35 V	(272-1013)
C2	1000 µF, 50 V	(272-1047)
C3	100 µF, 35 V	(272-1016)
D1	1-A, 50-V bridge rectifier	(276-1161)
IL1-IL10	1.5-V grain-of-rice bulb	

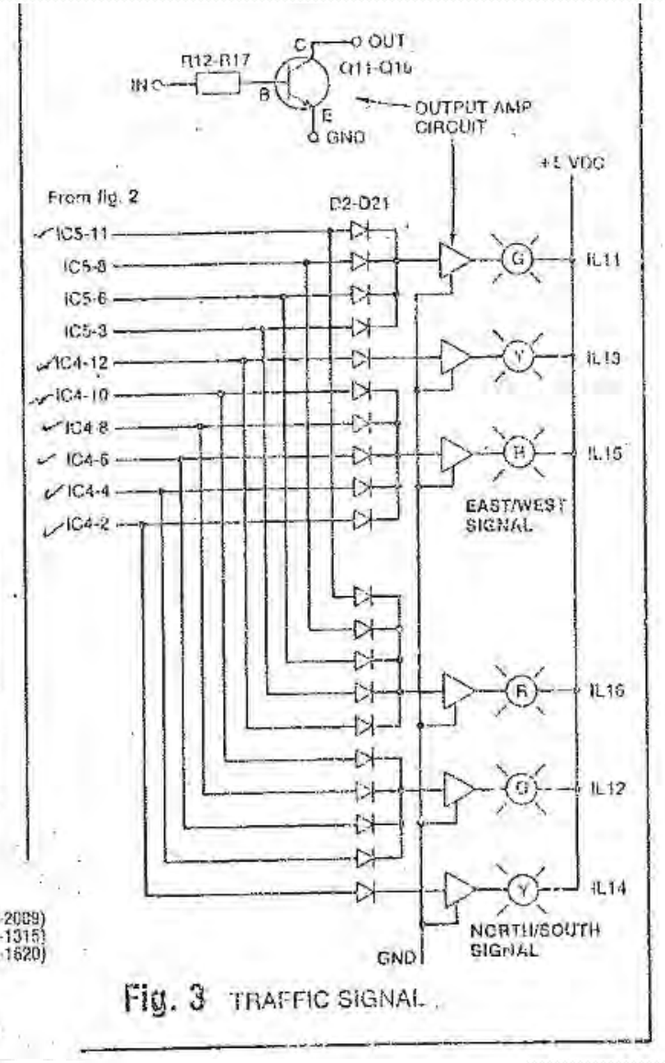
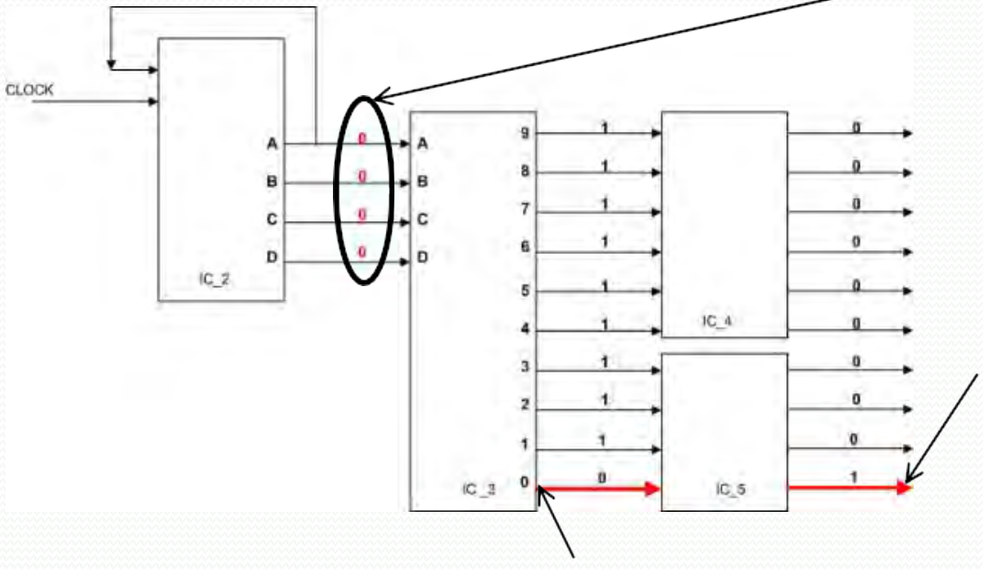


Fig. 3 TRAFFIC SIGNAL

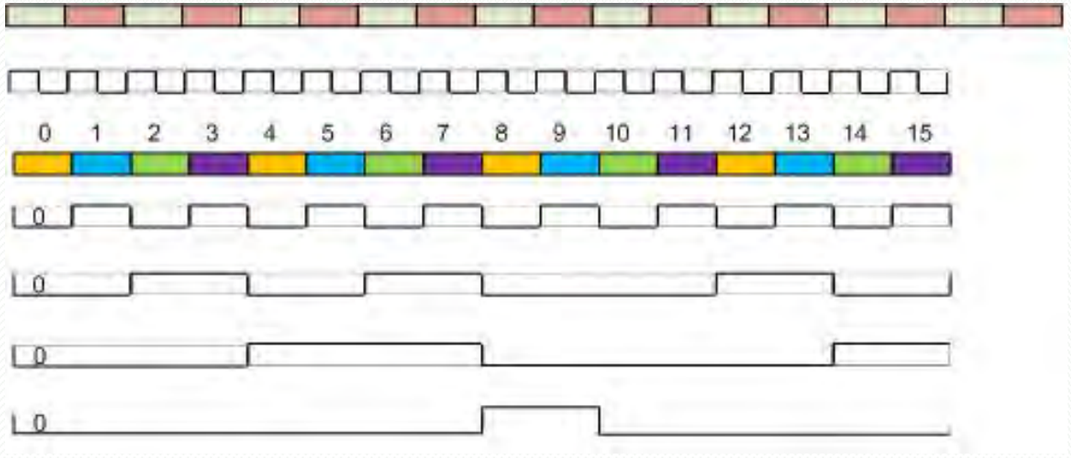
FIG. 3 PARTS LIST

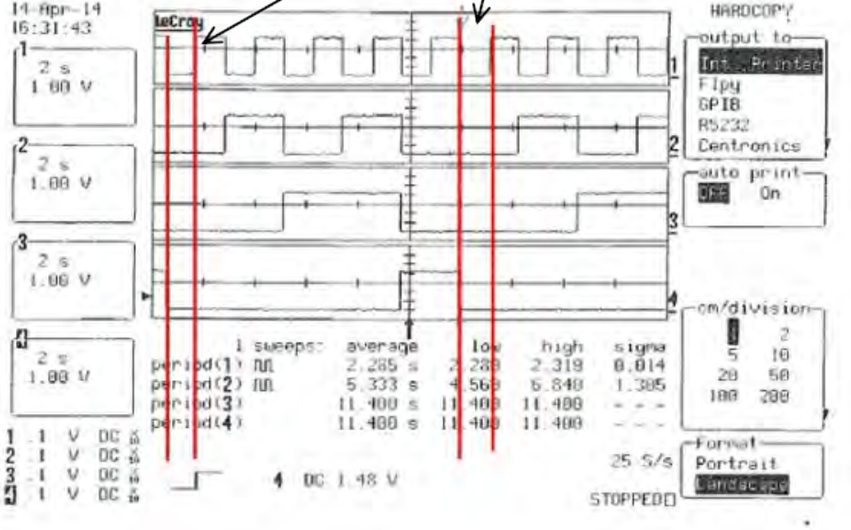
Q11-Q16	2N2222, 2N2222A	(276-2009)
R12-R17	330 Ω	(271-1315)
D2-D21	1N914	(276-1620)
IL11, IL12	Green, 3-V grain of rice bulb	
IL13, IL14	Yellow, 3-V grain of rice bulb	
IL15, IL16	Red, 3-V grain of rice bulb	

Traffic light sequencer East - West signal



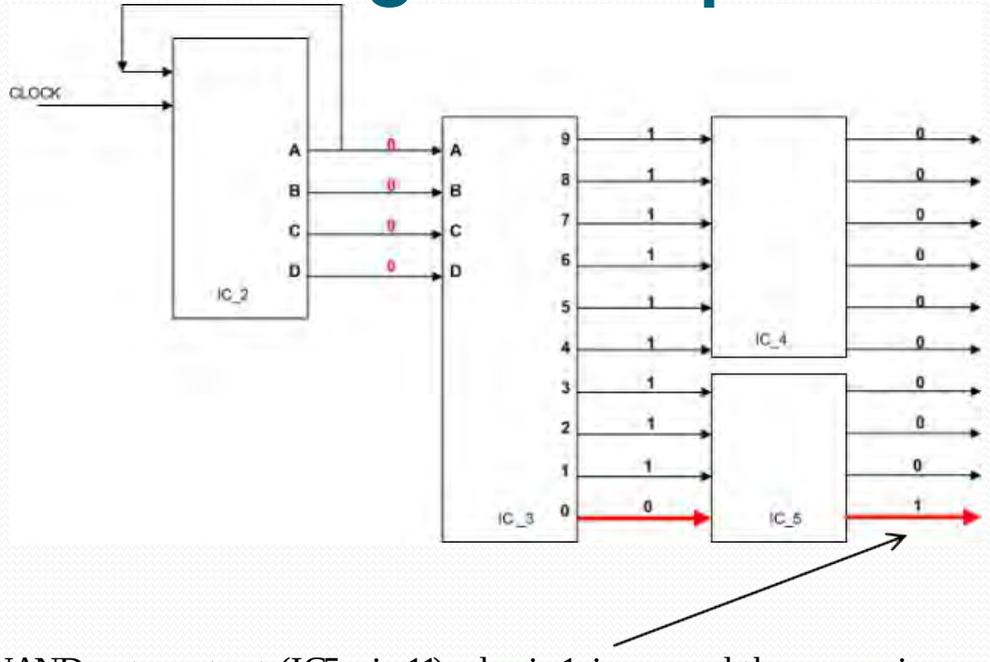
- The BCD counter (IC2) outputs a 0000 pattern.
- The BCD to decimal converter (IC3) receives it and converts the 0000 BCD input to a 0 output . IC3 pin 1 (output 0) switches low.
- Logic NAND gate IC_5 receives the low input and inverts it to a logic 1 at its output (pin 11).
- The NAND gate output will pass the signal onto the transistor LED driver circuit.
- The oscilloscope plot shows the full count cycle pattern from 0000 to 1001 and repeats (red vertical lines show the 0000 count).

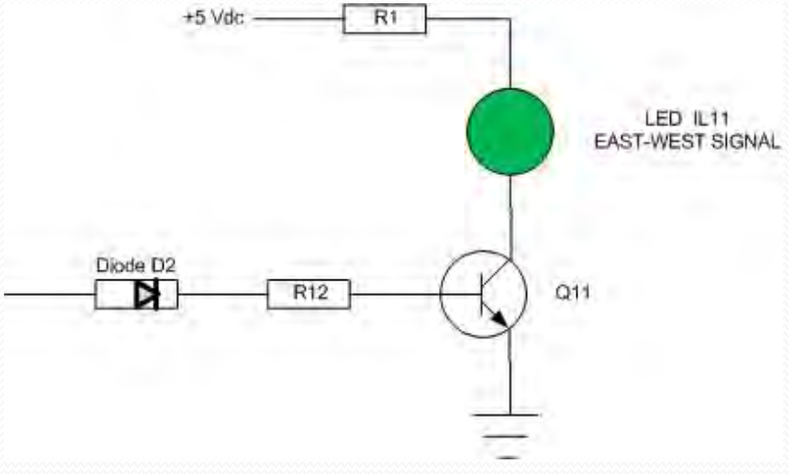




Traffic light sequencer

East –West signal only



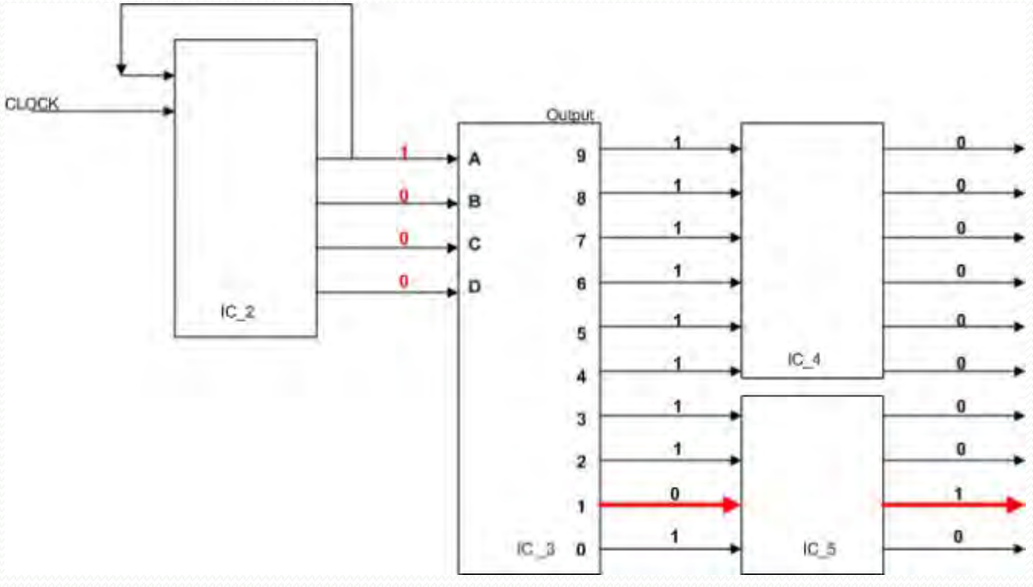


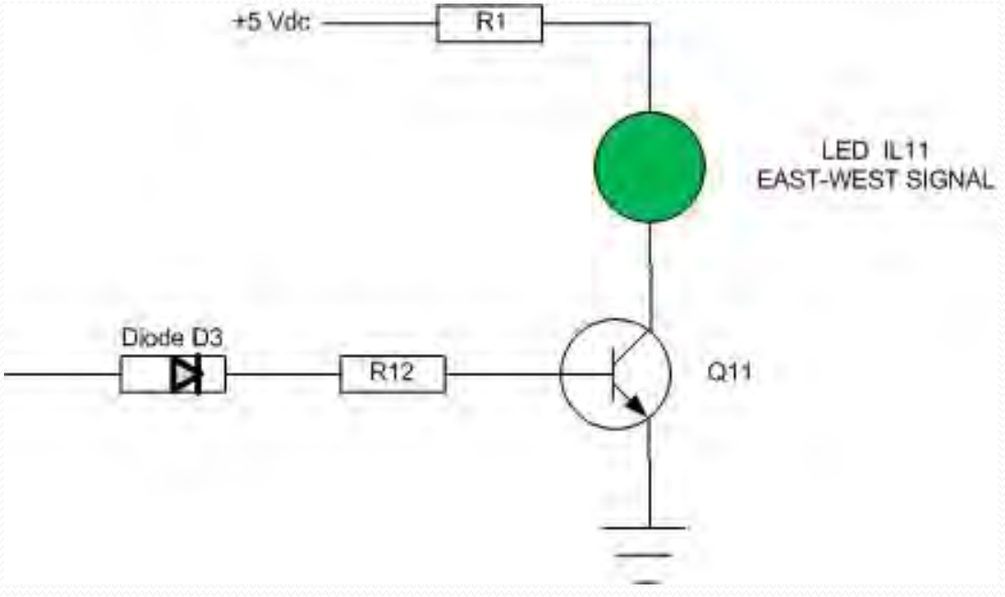
- The NAND gate output (IC5 pin 11) a logic 1, is passed thru a series diode D2. The diode passes the signal into the LED driver transistor circuit.

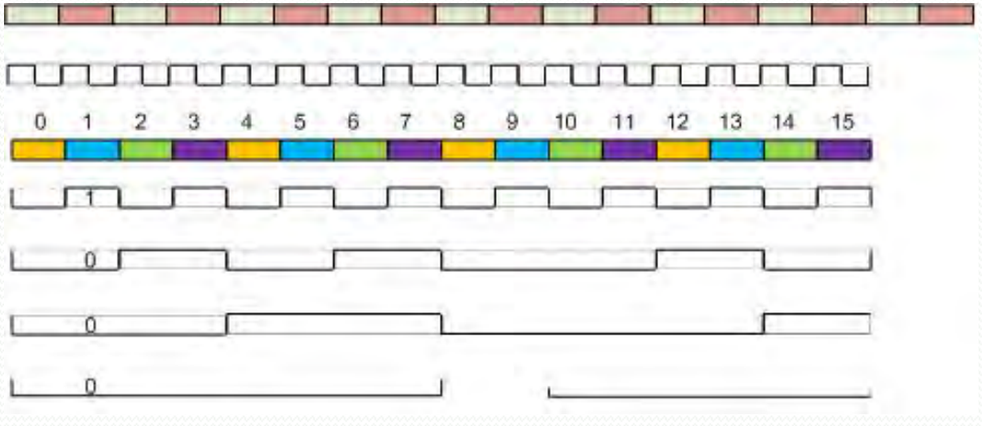
- The transistor acts as a switch. When the voltage at the base of the transistor reaches about 0.7V the transistor turns on. This means that current passes from the +5V dc supply, thru the limiting resistor R1 , thru the LED, and thru transistors collector to its emitter (which is tied to ground). In this example the East –west Green light is lit.

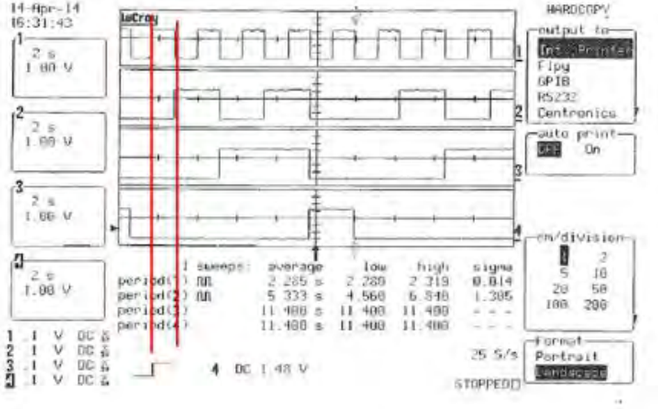
- Meanwhile, the North south traffic Red LED will be lit. This circuit segment is not shown.

Traffic light sequencer East - West signal

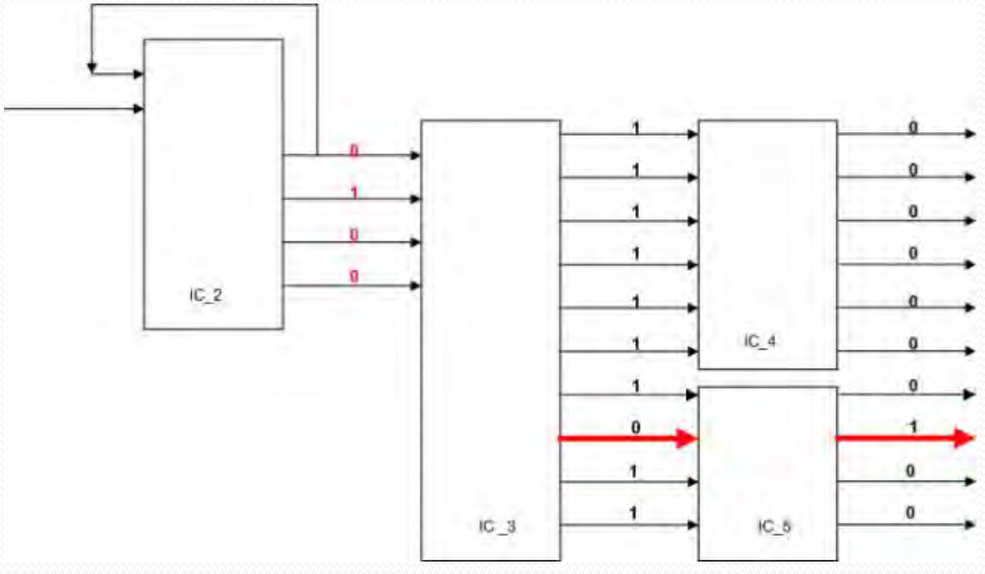


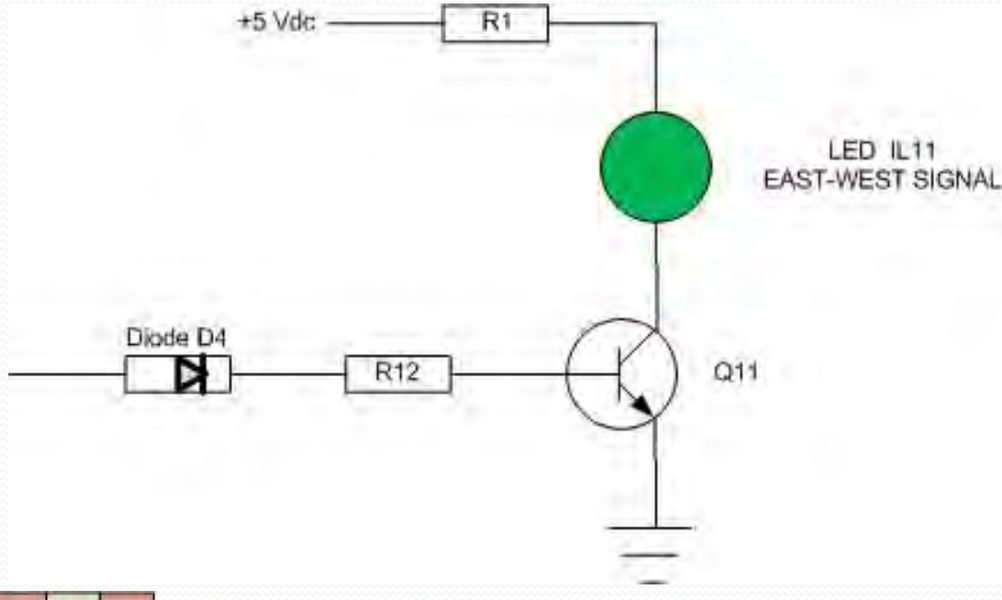


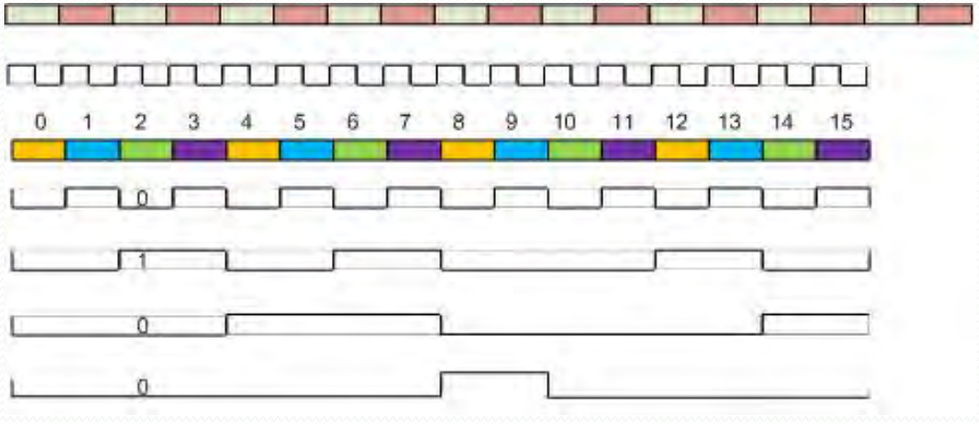




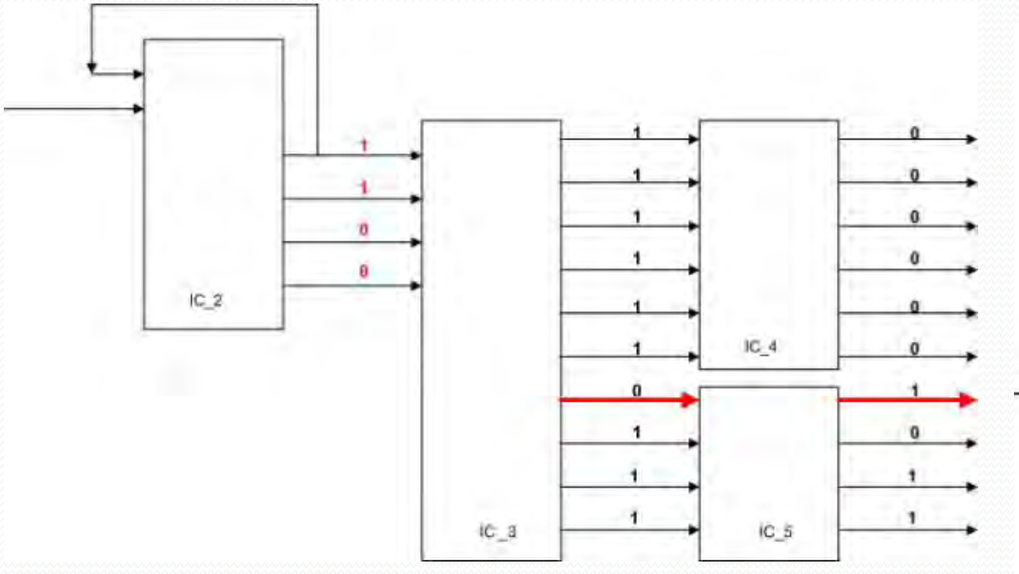
Traffic light sequencer East - West signal

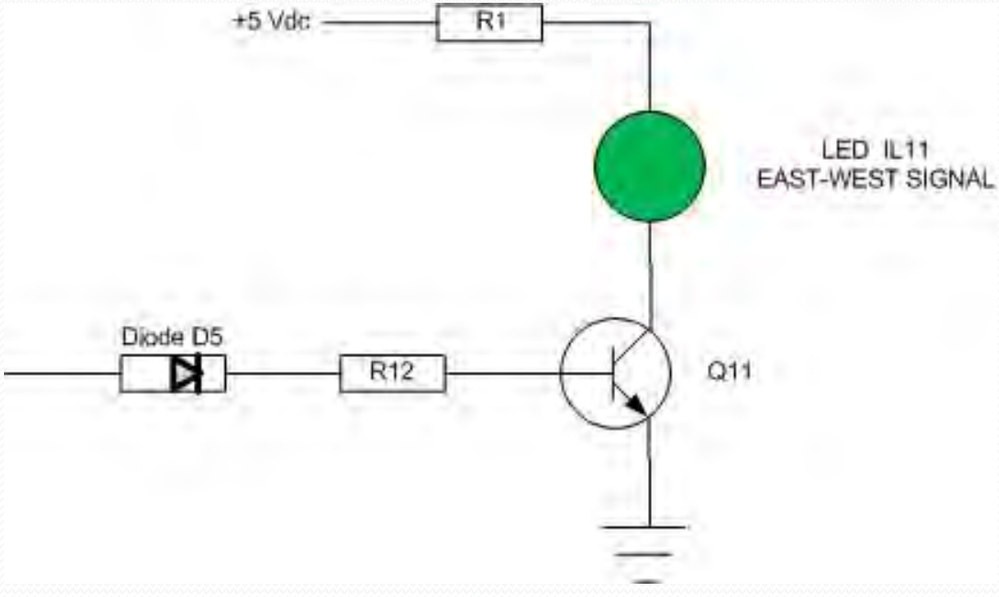


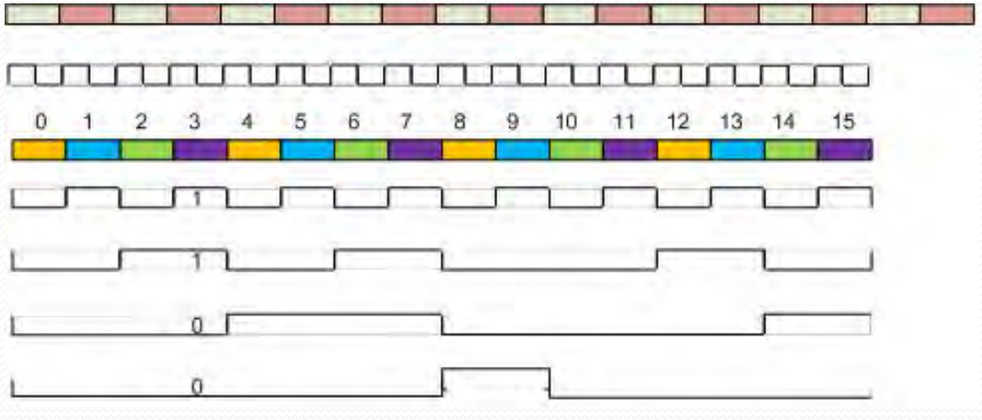




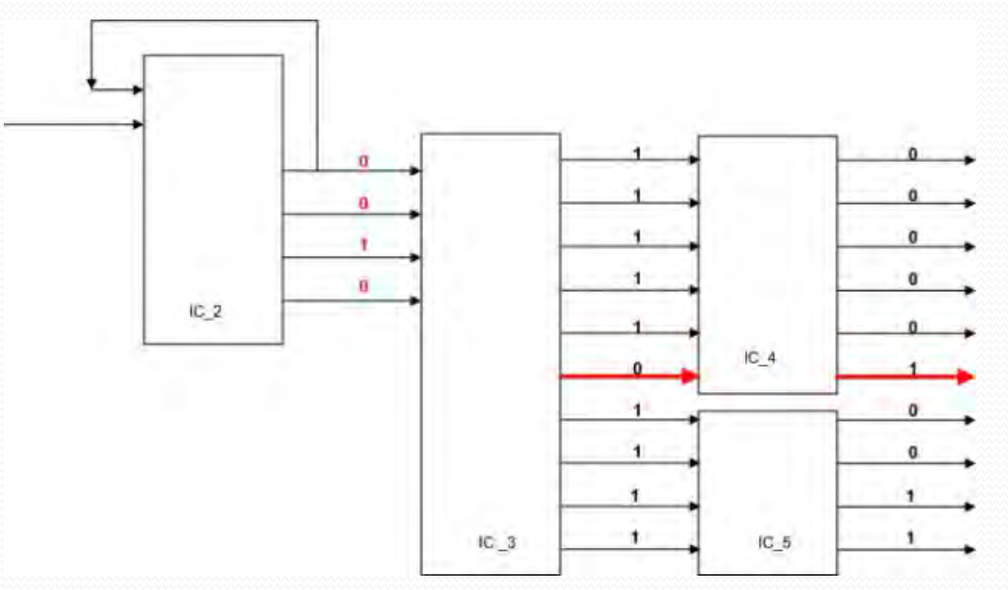
Traffic light sequencer East - West signal

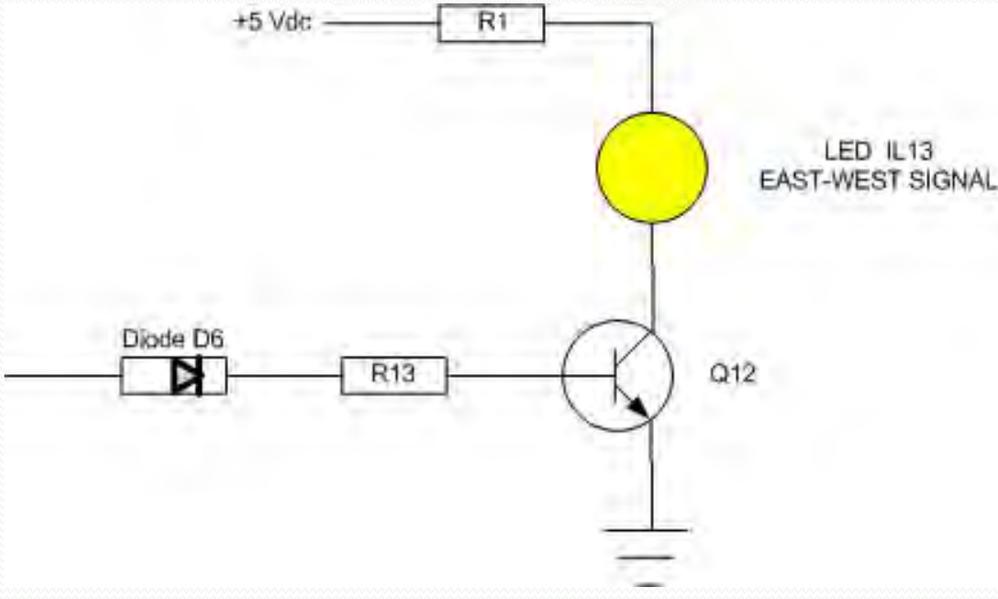


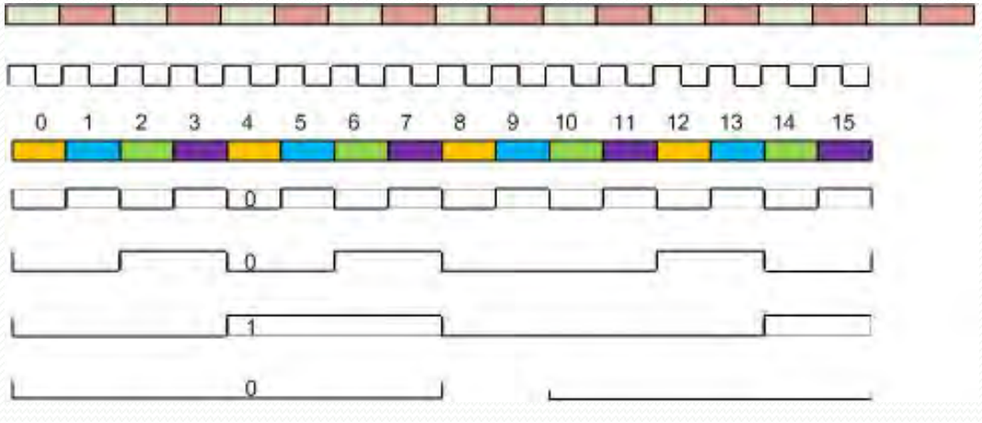




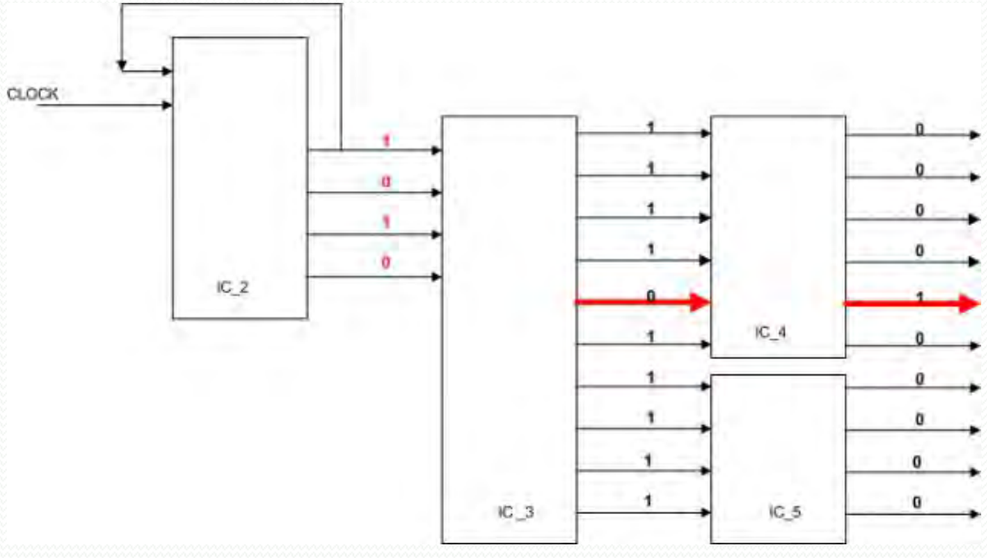
Traffic light sequencer East - West signal

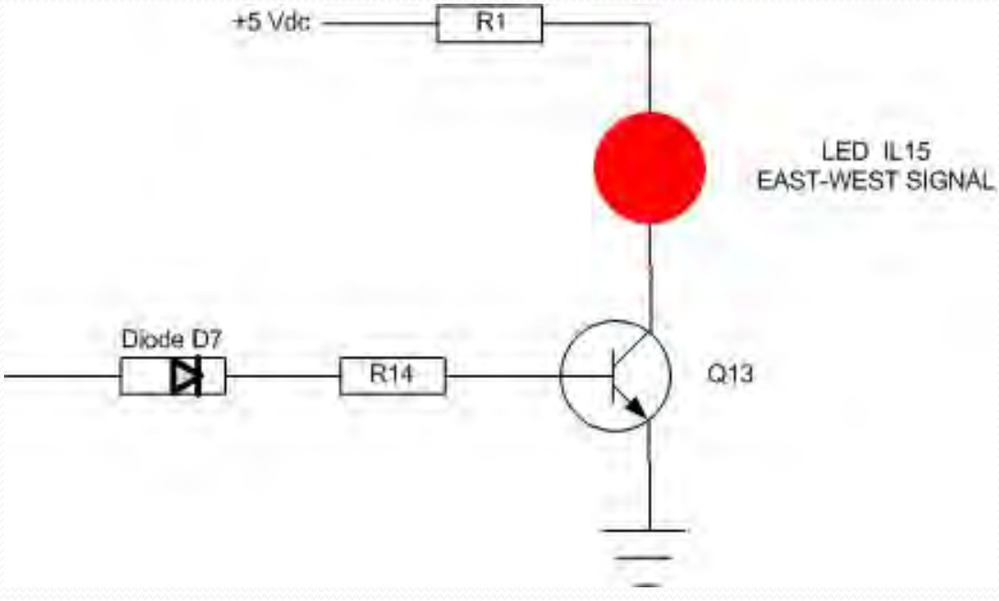


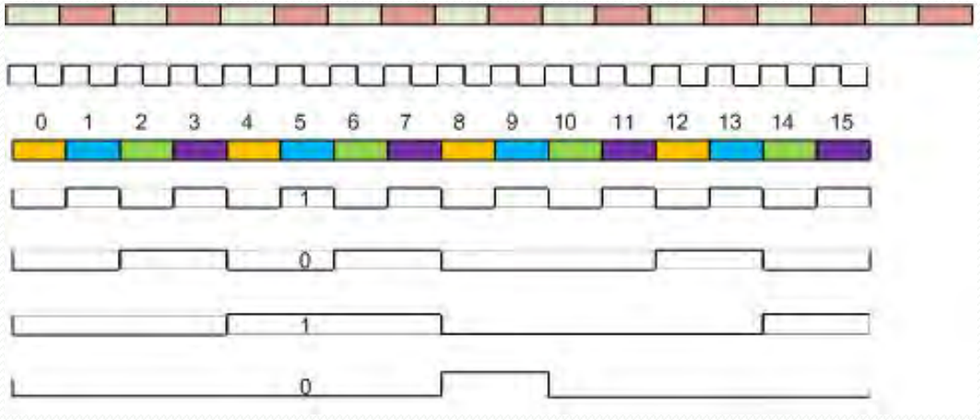




Traffic light sequencer East - West signal

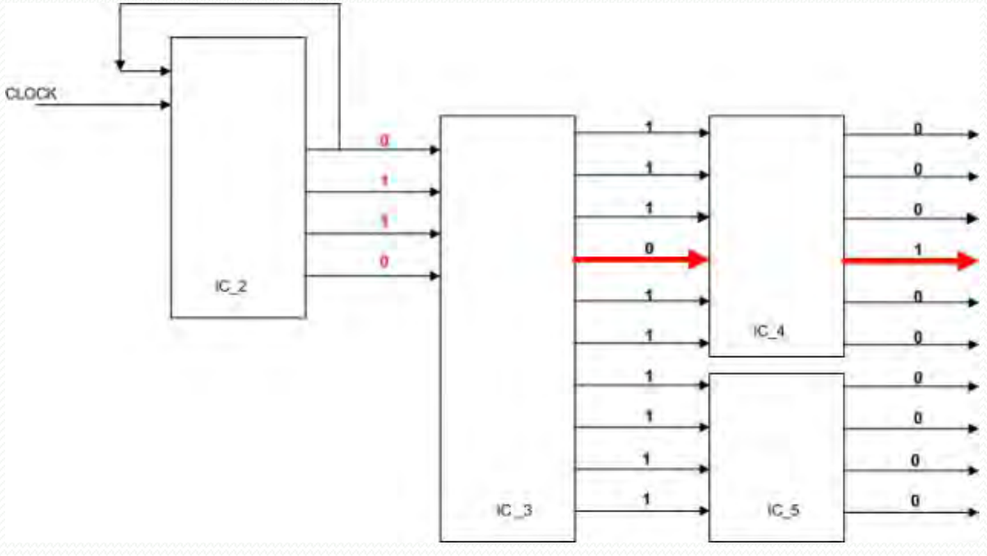


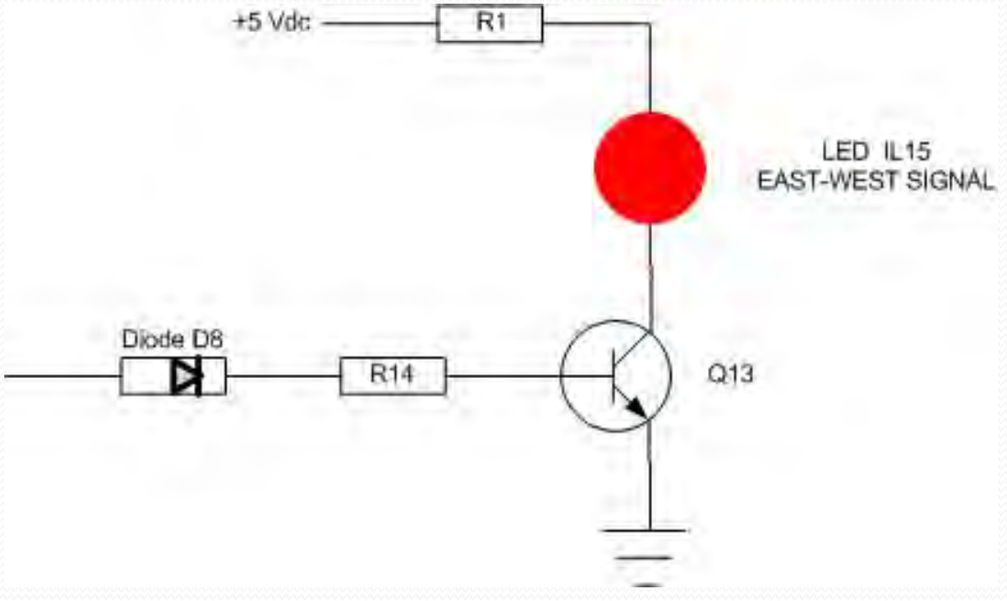


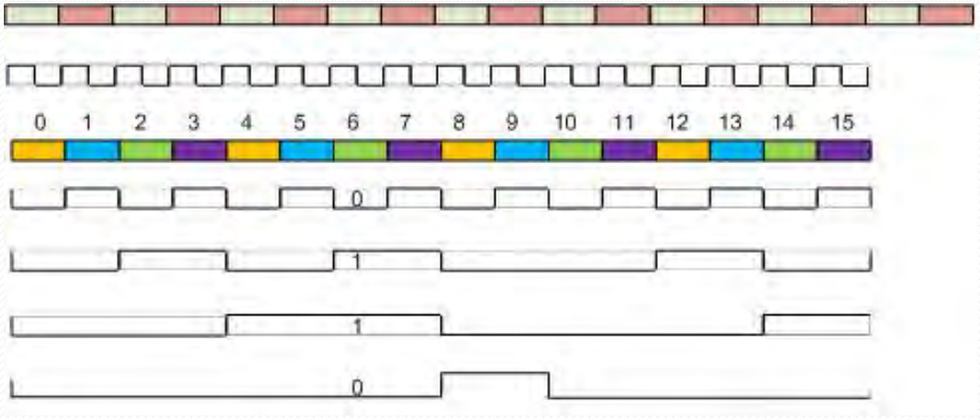


Traffic light sequencer East - West signal

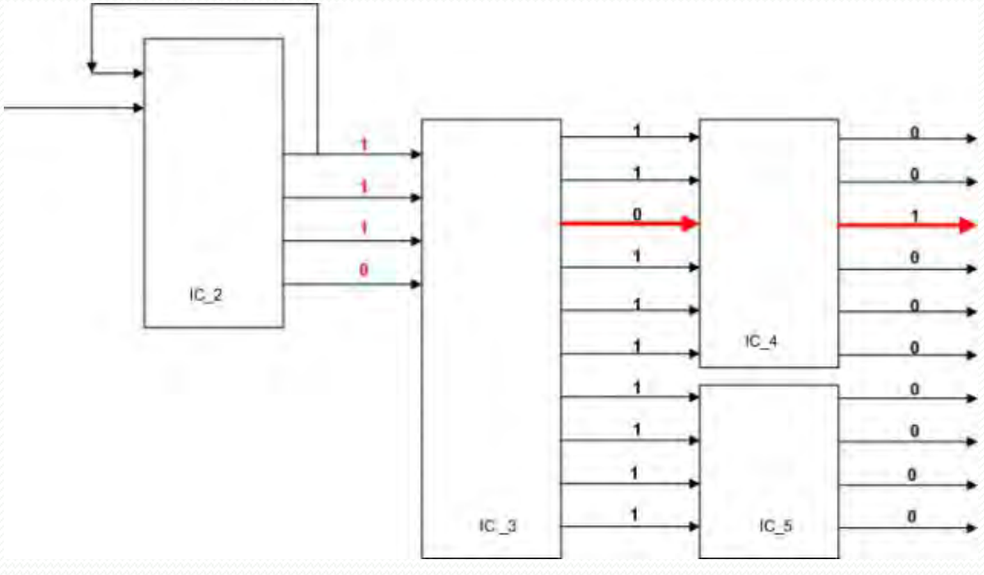
East - West signal

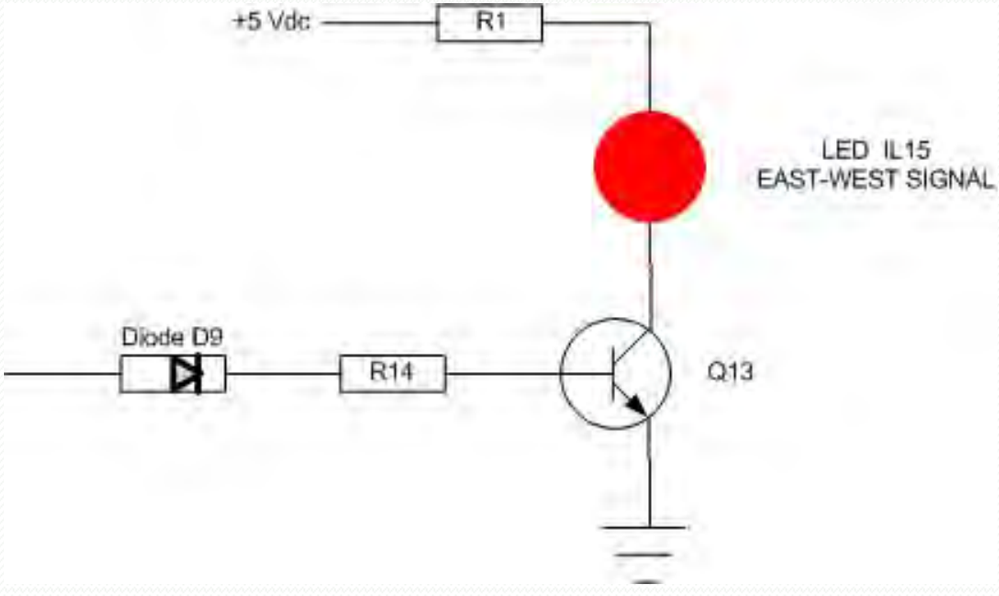


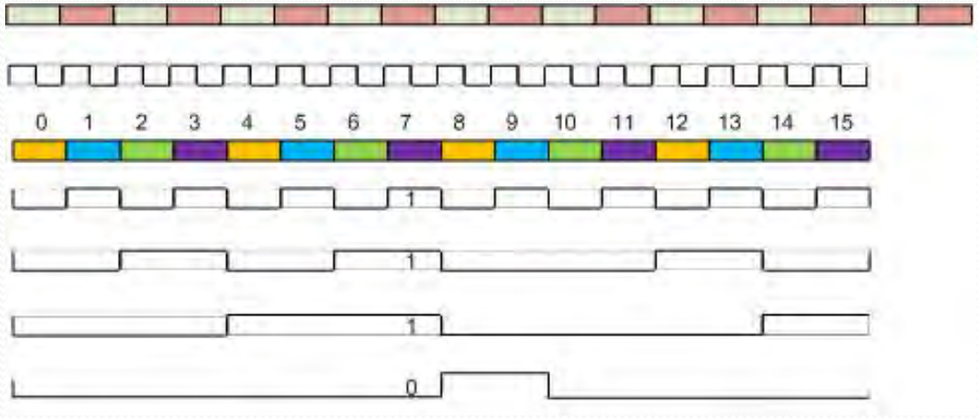




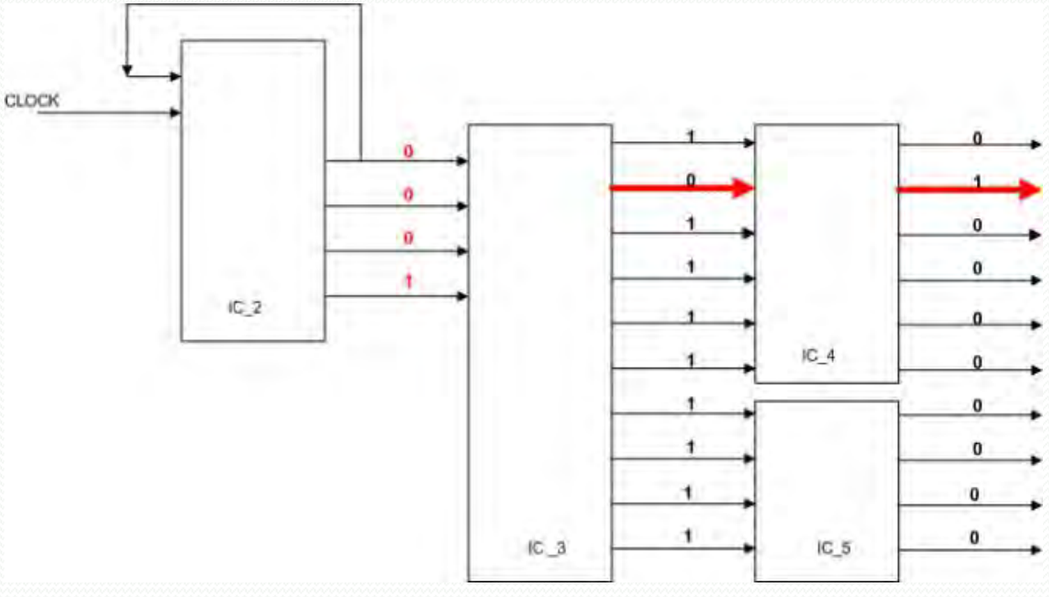
Traffic light sequencer East - West signal

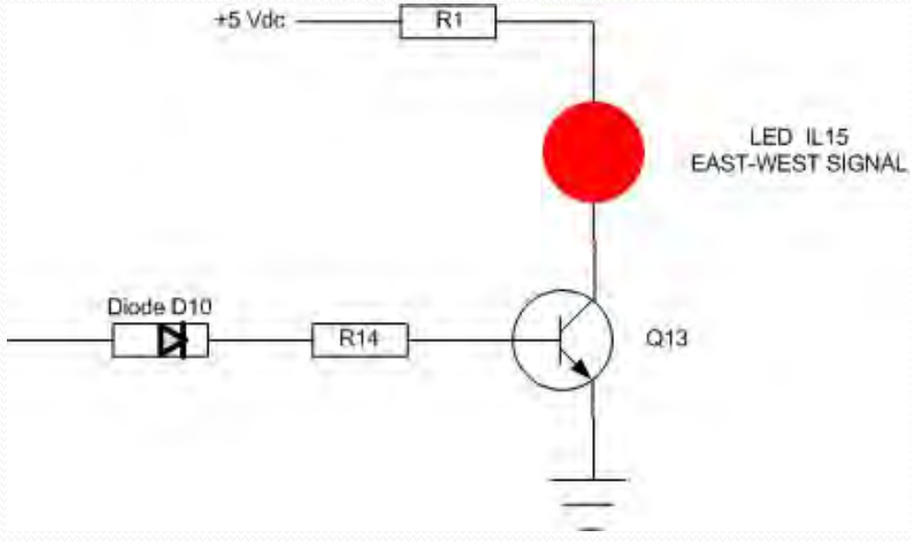


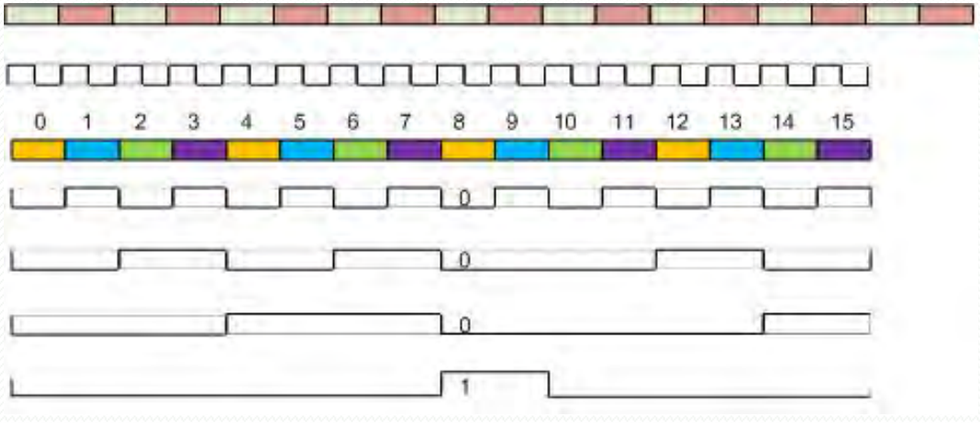




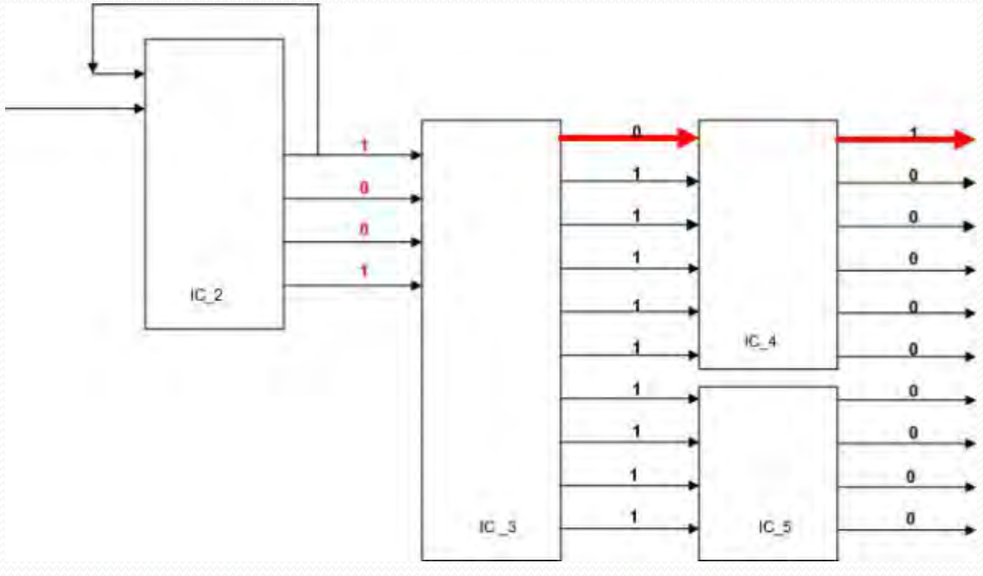
Traffic light sequencer East - West signal

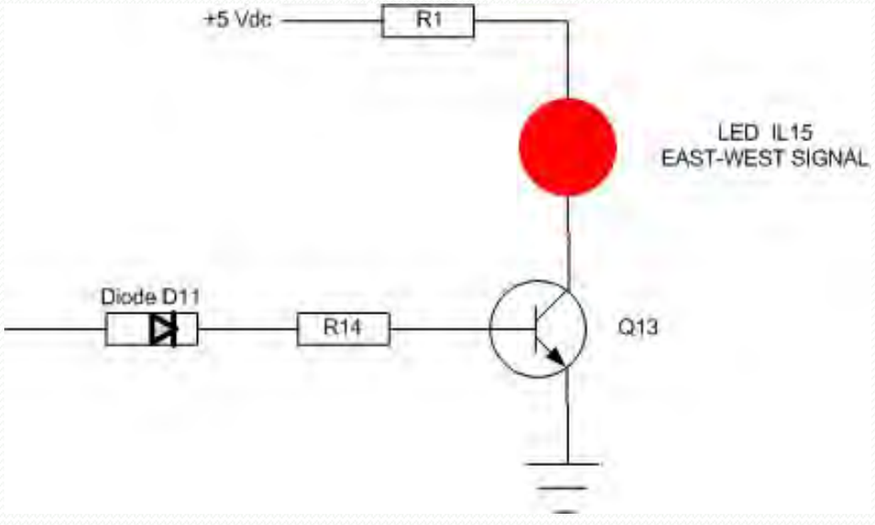


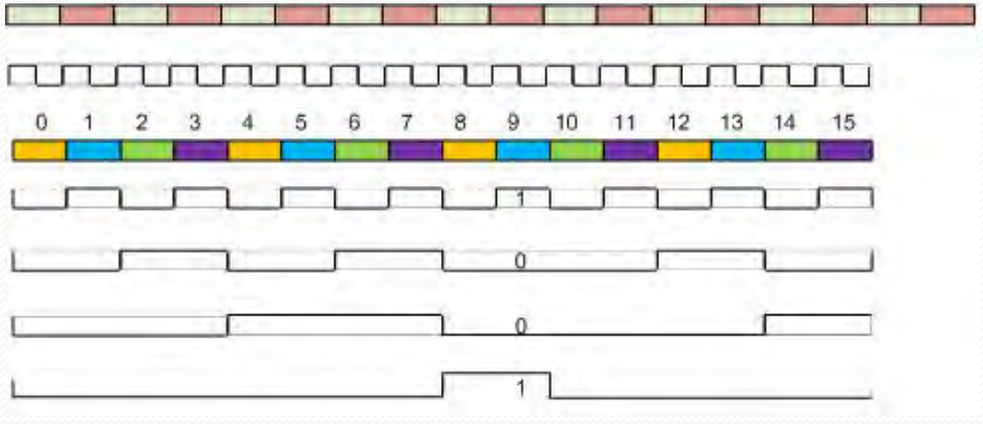




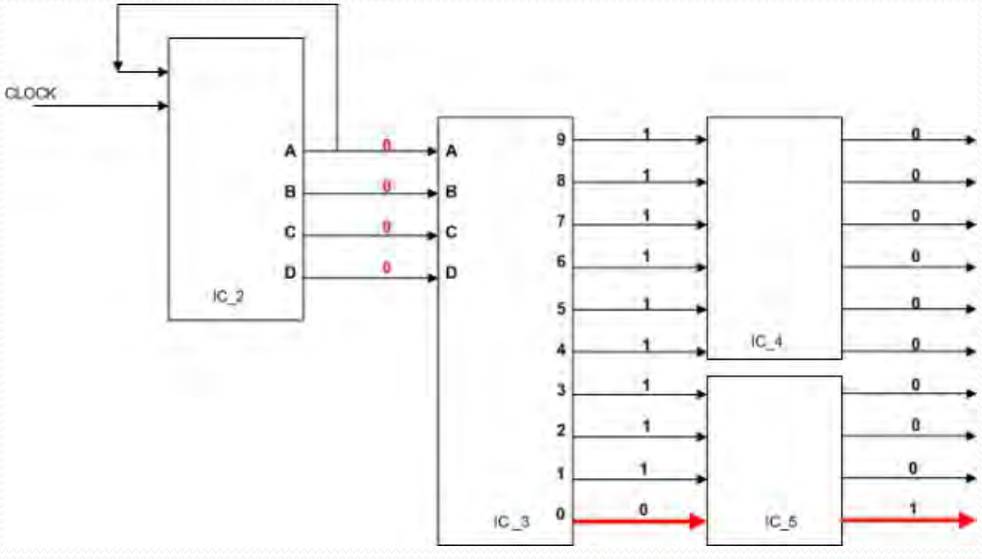
Traffic light sequencer East - West signal





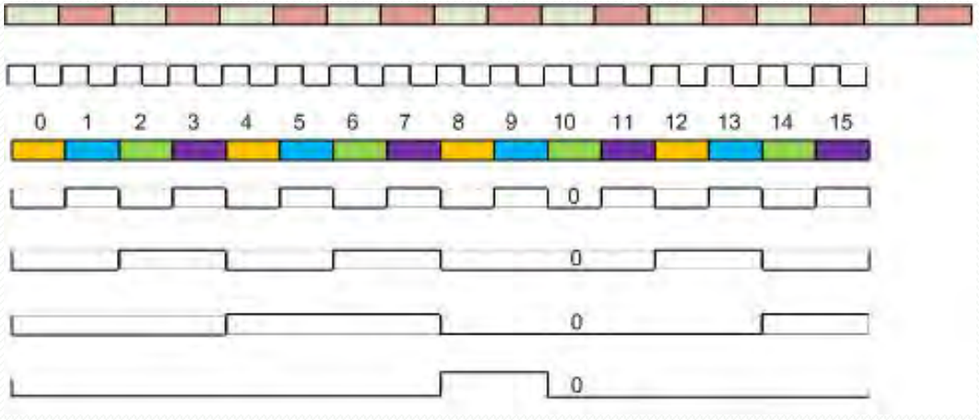


Traffic light sequencer East - West signal



At this point he BCD counter has completed one count cycle from 0000 to 1001.

On the next clock pulse from the Flasher LED IC 1, the BCD counter will begin a new count sequence starting at 0000.



Credit and thanks to…..

- Thanks to the staff at Kalmbach Publishing for allowing me to reference the article in the May 1982 issue of magazine.

- Thanks to the staff of RailFun and to the Fox Valley Division of the NMRA for allowing me to make my first presentation at a regional convention in May and to you today.

Reference materials:

- National Semiconductor LM3909 Data sheet (Now part of Texas Instruments).
- Sound Light and Music Projects for the LM3909 by Delton Horn, TAB Books, ISBN 0-8306-3801-6
- Model Railroader Magazine ; Kalmbach Publishing, May 1982 article, Symposium on Electronics pages 82-85
- Wikipedia.org for terminology definitions and wave form images

Come up and see the circuits in operation !

- Thank you!

- Any questions?