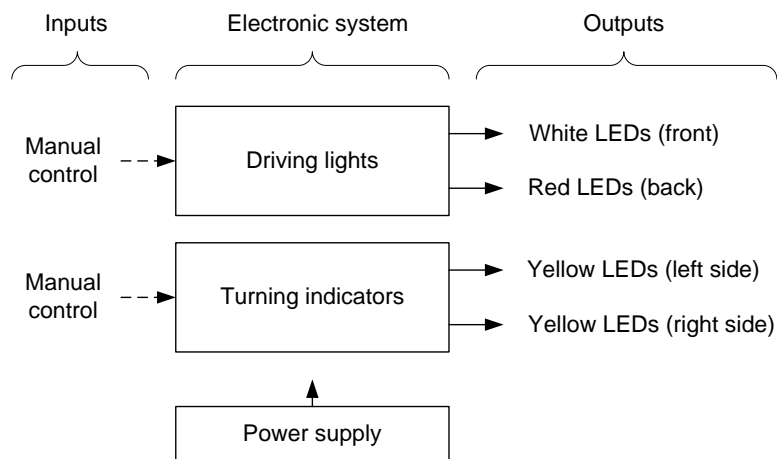
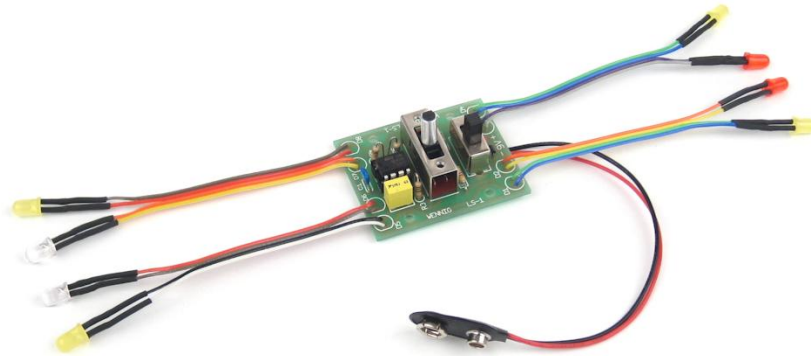


LED Sled - lighting system for model vehicles



| Part | Contents | Page |
|------|---|------|
| 1 | Assembly guide | 2 |
| 2 | Driving lights | 4 |
| | Circuit diagram (schematic) | 4 |
| | Circuit design and measurements | 5 |
| | Test points, links, reference symbols | 7 |
| 3 | Turning indicators | 8 |
| | Circuit diagram | 8 |
| | Circuit design | 9 |
| | Expected battery life | 12 |
| 4 | Reference material | 13 |
| | Fundamental laws and formulas | 13 |
| | Preferred values for passive components | 14 |
| | Electrical power and heat | 15 |
| | Battery data | 16 |

Part 1 Assembly guide

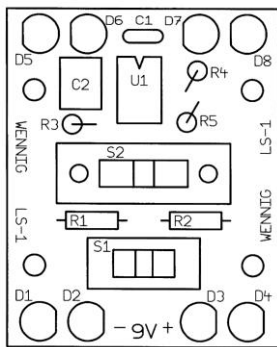
Before assembly

Wash hands before handling components. Contamination will affect solderability and long-term reliability of the assembly.

During assembly

- Wear eye protection, particularly when cropping wires. Flying offcuts injure eyes
- When bending the lead-wire of a component, grip the wire with small pliers and bend the free end of the wire – so the pliers isolate the component package from bending forces
- After loading wire-leaded components onto the PCB, semi-clinch (45° bend) and crop the wires to about 1.5mm from the board surface
- Use a fume extractor when soldering.

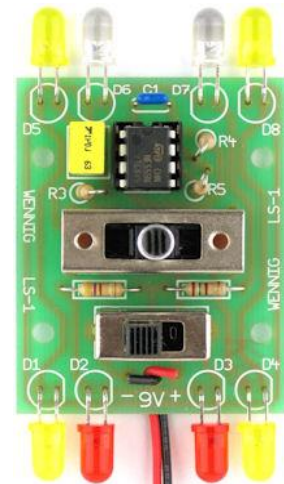
Assembly sequence (refer to parts list in LS-1 kit)



LED connections:

LEDs can be soldered directly to the PCB as shown here, or can be wired back to the PCB as shown on page 1.

Two-pin headers (straight or 90°) can also be soldered into the LED holes on the PCB, with matching sockets wired to the LEDs.



| Component | Comment |
|--------------------|--|
| R1, R2 | Before switches limit access. |
| U1 socket | Before switch S2 and other surrounding components limit access. |
| C1, C2, R3, R4, R5 | Before switch S2 limits access. |
| S1, S2 | <ul style="list-style-type: none"> • Both switches are a firm press fit into the board, providing more mechanical support than the solder joints alone. Check pin alignment with PCB holes before applying pressure • The switch connections and mounting pins/tabs are quite thick, requiring plenty of heat to solder. Flux will help solder flow. |

| | |
|----------------------------|---|
| 9V battery snap | <ul style="list-style-type: none"> • If intending to mount the battery close to the PCB, trim the battery-snap leads to the desired length • To reduce mechanical stress on the solder joints due to movement of the battery-snap leads, pass both leads through the support hole provided between the 9V +/- solder pads before soldering in place. |
| D1 – D4 then D5 – D8 | <ul style="list-style-type: none"> • Check LED polarity (see diagrams in kit sheet) • If soldering LEDs directly to the PCB, bend the leads 4mm from base of LED. A bending jig can be made by cutting a 10 mm long slot into a piece of 4mm plastic sheet with hacksaw blade. Slide the LED leads into the slot, press the LED body firmly down onto the plastic sheet, bend the leads at 90° against the other side of the sheet, and slide the LED out. • If wiring the LEDs to the PCB with the supplied rainbow cable, insulate the cable/LED solder joints with short lengths of the supplied heat-shrink tubing (as shown on page 1). |

After assembly

- In a well ventilated area, clean resin from the completed assembly with isopropyl alcohol and a small flux brush
- Buff the soldered side of the cleaned assembly with a clean, stiff-bristled paint brush - a 25mm wide paint brush with bristles cut back to about 20mm length is ideal
- Visually inspect all solder joints, and re-work / re-clean where necessary
- Wash hands to remove resin and solder residues

Part 2 Driving lights

'Physical' circuit diagram (as provided with LS-1 kit)

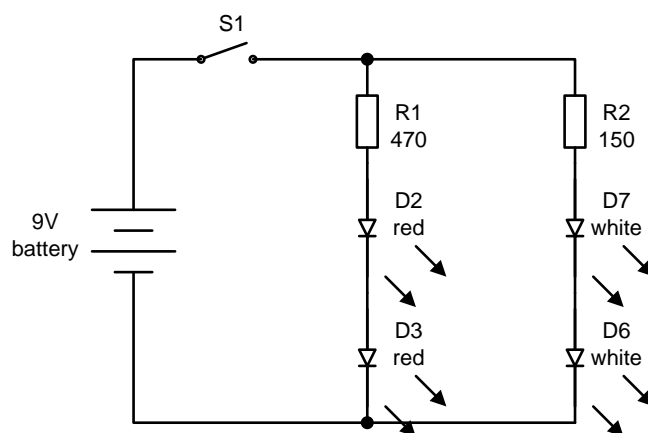
The circuit diagram (or schematic) places the light-emitting diode (LED) symbols in the general positions the LEDs would occupy on a vehicle. It also uses a switch symbol that reveals the inner workings of the double-pole double-throw (DPDT) slide switch S1. Such physical detail is usually avoided to keep circuit diagrams as simple as possible, but is provided in this introductory project to help link the physical hardware with the more abstract circuit diagram.



Functional circuit diagram

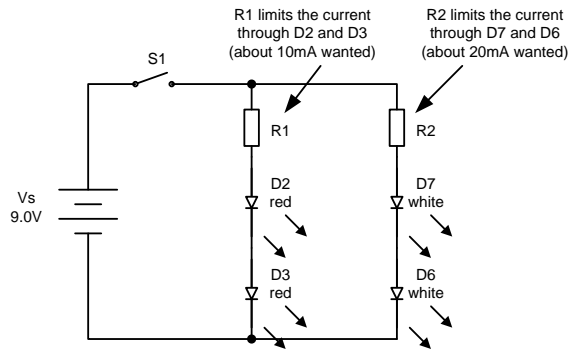
Complex circuit diagrams are best drawn to present circuit concepts as clearly as possible. For example, if the 'physical' circuit above is re-arranged as below, it is easier to see that:

- Switch S1 is either open (battery disconnected) or closed (battery connected)
- R1, D2 and D3 are connected in **series** (they share a common current)
- R2, D7 and D6 are connected in **series** (they share a common current)
- The series-connected component groups R1-D2-D3 and R2-D7-D6 are connected in **parallel** (they share a common voltage)
- When S1 closes, the battery is also in parallel with R1-D2-D3 and R2-D7-D6.

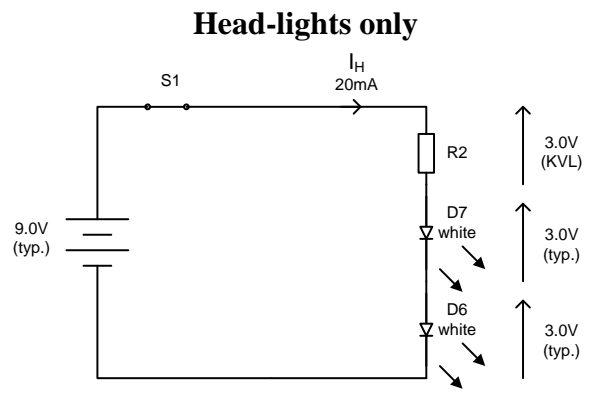
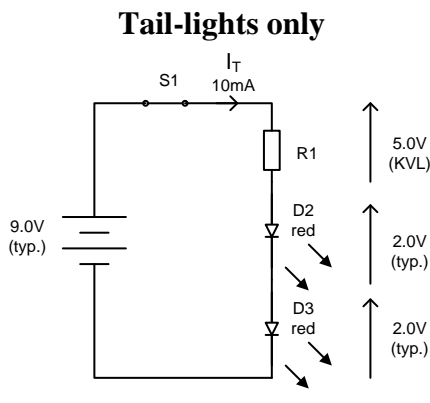


Driving lights – design

General circuit



Desired currents, and expected voltage distribution



Current-limiting resistor calculations

$$R1 = \frac{5.0V}{10mA} = 500\Omega$$

470Ω is nearest value in E12 range.
The diode current will rise slightly:

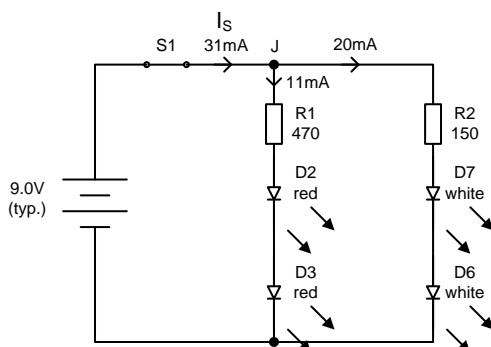
$$I_T = \frac{5.0V}{470\Omega} = 11mA \text{ (acceptable)}$$

$$R2 = \frac{3.0V}{20mA} = 150\Omega$$

150Ω is a preferred value in the E12 range.
The diode current will be as intended:

$$I_H = \frac{3.0V}{150\Omega} = 20mA$$

Final circuit, with current distribution

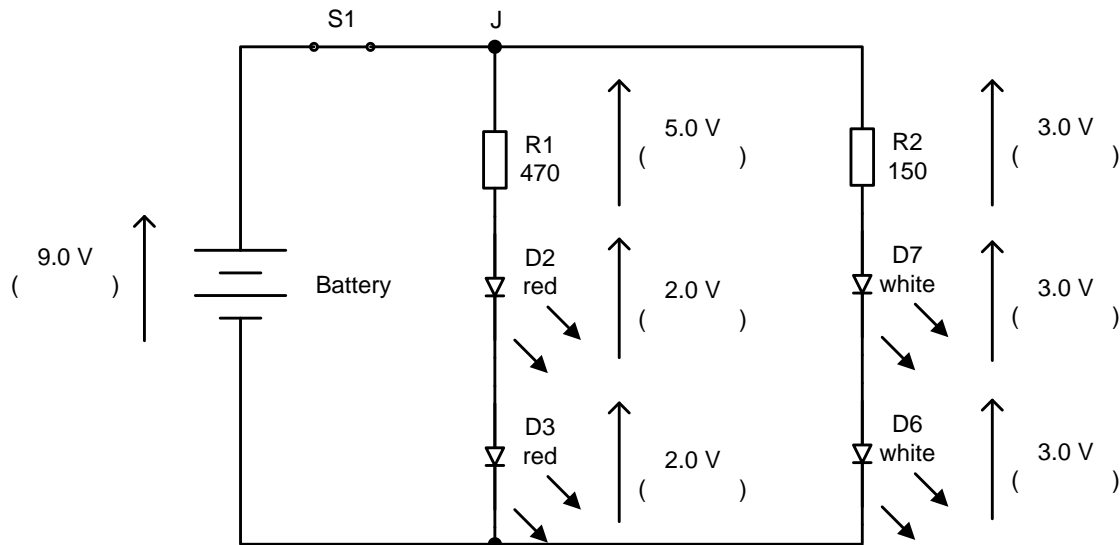


The total power supply current (I_S) can be calculated by applying Kirchhoff's current law (KCL) at junction **J**:

$$\begin{aligned} I_S &= I_T + I_H \\ &= 11mA + 20mA \\ &= 31mA \end{aligned}$$

Driving lights – measurements

Comparison between expected and measured (in brackets) voltages



Comparison between expected and measured currents

The three current measurements require opening (or ‘breaking’) the circuit to insert an ammeter. Alternatively, the circuit voltages across R1 and R2 can be measured and used with Ohm’s law and Kirchoff’s current law to **indirectly** find these values – as follows:

Expected: $I_T = 11 \text{ mA}$

Indirectly measured:

$$I_T = \frac{(V_{R1})}{R1}$$

$$= \frac{(\quad \text{V})}{470 \Omega}$$

$$= \dots\dots\dots \text{ mA}$$

Expected: $I_H = 20 \text{ mA}$

Indirectly measured:

$$I_H = \frac{(V_{R2})}{R2}$$

$$= \frac{(\quad \text{V})}{150 \Omega}$$

$$= \dots\dots\dots \text{ mA}$$

Expected: $I_S = 31 \text{ mA}$

Indirectly measured:

$$I_S = I_T + I_H$$

$$= \dots\dots\dots \text{ mA}$$

Sources of error

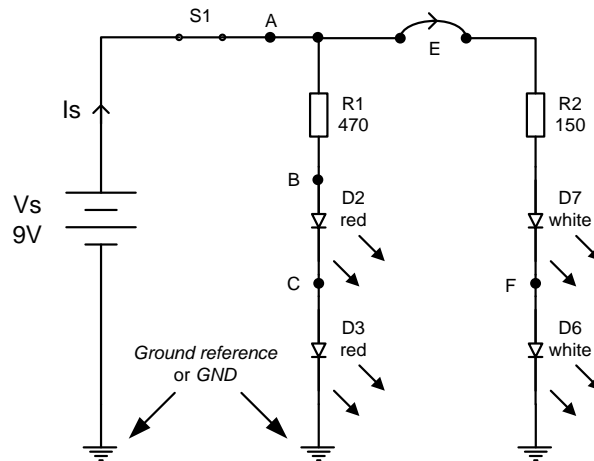
1. **Typical voltages** are assumed for the battery and LEDs. More accurate values can be found from manufacturers’ technical data or tests at the desired current values
2. **5% tolerance** carbon film resistors. Usually acceptable, but error can be reduced by using resistors with smaller tolerances (e.g. metal film resistors with 2% or 1% tolerance)
3. **Meter loading.** This is usually only significant when measuring voltage in a high-resistance circuits, or measuring current in a low-resistance circuit.

Test points, links, and reference symbols

Example schematic with test points, a link, and ground reference symbols

Note:

The example component values used here are from the **LED Sled**, but the test points and link shown are not marked or included on the **LED Sled** assembly.



Example test measurement table

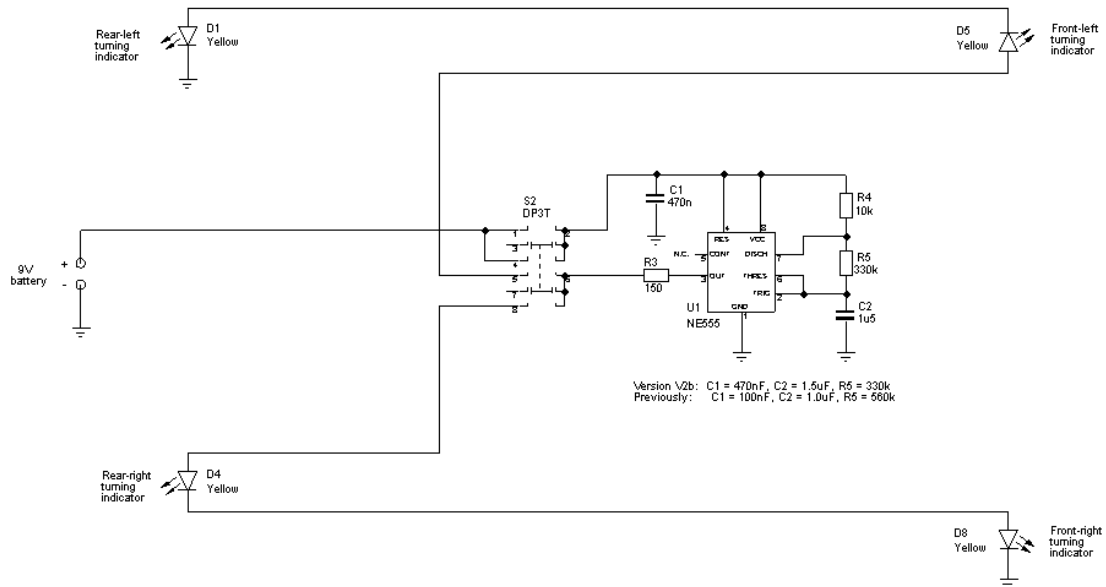
All expected values quoted in this table are from the **LED Sled** design

| Item | Measured value | Expected value | Comment |
|----------|----------------|----------------|---|
| V_A | | 9.0 V | Voltage at A relative to ground reference (GND). The polarity of measurement is implied. |
| V_{D2} | | 2.0 V | Voltage across D2 (no polarity specified) |
| V_{BC} | | 2.0 V | Voltage at B relative to C (polarity specified) (Note: $V_{BC} = V_B - V_C$) |
| V_{CB} | | -2.0 V | Voltage at C relative to B (polarity specified) (Note: $V_{CB} = V_C - V_B$) |
| V_{FB} | | -1.0 V | Voltage at F relative to B (polarity specified) (Note: $V_{FB} = V_F - V_B$) |
| I_E | | 20 mA | Current through link E (the arrow specifies positive direction – so when an ammeter replaces the link, it would be connected positive to left, and negative to right) |
| I_{D6} | | 20 mA | Current through D6 (no polarity specified – and the circuit will have to be opened at one end of D6 to connect an ammeter into the current path) |
| I_S | | 31 mA | Power supply current (the arrow specifies positive direction). An easy way to measure this current is to open switch S1, and connect an ammeter across the open switch terminals – the ammeter will complete the circuit again. |

Part 3 Turning indicators

'Physical' circuit diagram (as provided with LS-1 kit)

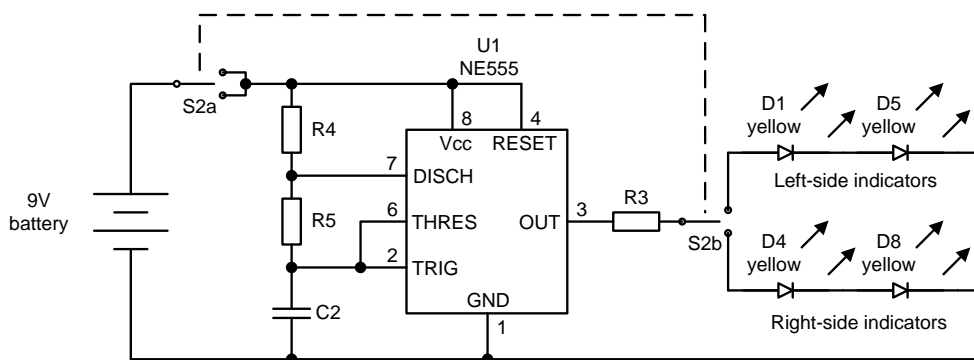
As with the driving lights, the circuit diagram (or schematic) places the turning indicator circuit components in positions similar to those physically occupied by the components on the printed circuit board. It also uses a switch symbol that reveals the inner workings of the double-pole triple-throw (DP3T) slide switch S2.



Functional circuit diagram

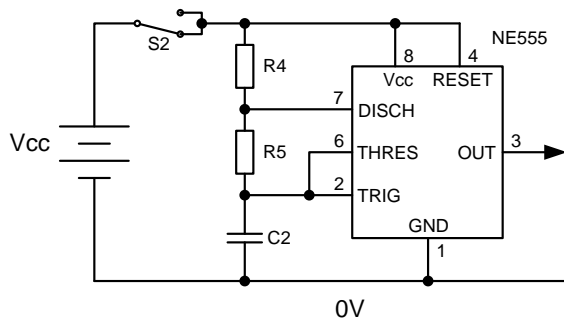
The following circuit diagram shows more clearly that:

- Control and signal flow is from left to right
- The moving contact in switch S2a connects the battery into the circuit when **up** (left turn) or **down** (right turn), and disconnects it in the **centre** (off) position
- The moving contact in S2b connects resistor R3 to LEDs D1 and D5 when **up** (left turn) or to D4 and D8 when **down** (right turn), and disconnects it in the **centre** (off) position
- R4, R5 and capacitor C2 control the timing of the NE555 voltage pulses from pin 3 (OUT) to flash the LEDs. Signal flow is from left to right.

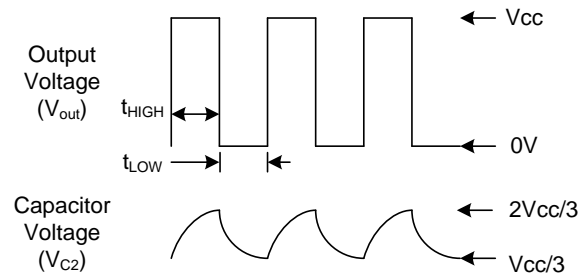


Turning indicators - design

General astable circuit



Typical astable waveforms

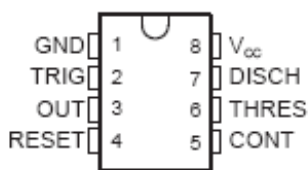


The NE555 integrated circuit produces these waveforms by alternately charging and discharging capacitor C2 through resistors R4 and R5. The voltage across C2 (V_{C2}) is used to determine when to switch between charge and discharge:

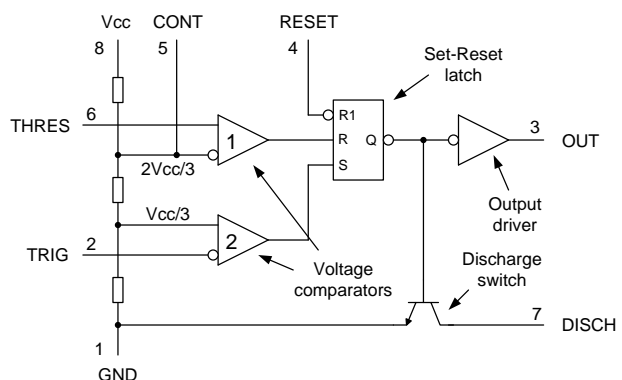
- When V_{C2} falls below $V_{cc}/3$ (sensed by the **TRIG** input), the NE555 open-circuits the **DISCH** pin to allow current to flow through R4 and R5 to charge C2
- When V_{C2} rises above $2V_{cc}/3$ (sensed by the **THRES** pin), the NE555 connects the **DISCH** pin to **GND**, forcing C2 to discharge through R5
- As the NE555 switches between these two conditions, it also switches the voltage at the **OUT** pin between V_{cc} and $0V$, as shown in the waveform diagrams above.

This timing sequence is detailed on the following page, with reference to the various electronic functions within the NE555 – as identified in the block diagram below.

NE555 IC pinout



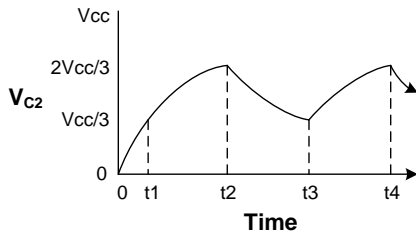
NE555 internal functions



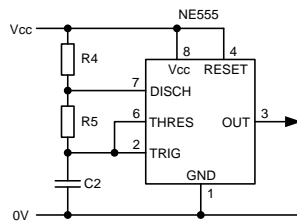
In electrically noisy environments, or where the circuit is assembled on a breadboard using long connecting wires, circuit operation may suffer from electrical interference. A small filter capacitor (10nF or greater) connected between **CONTROL** pin 5 and **GND** pin 1 of the NE555 will reduce the electrical noise that reaches the sensitive voltage comparators.

Turning indicators – NE555 timing sequence

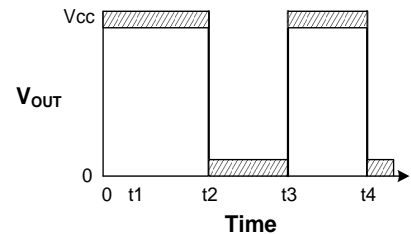
Capacitor voltage



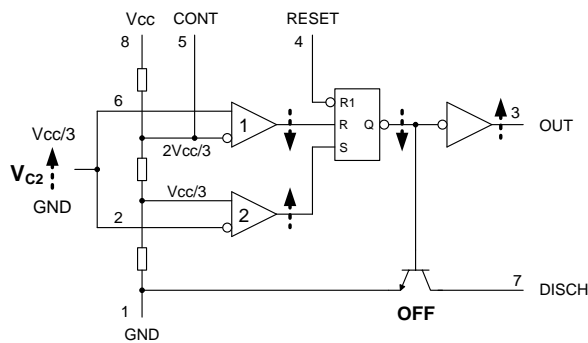
Astable circuit



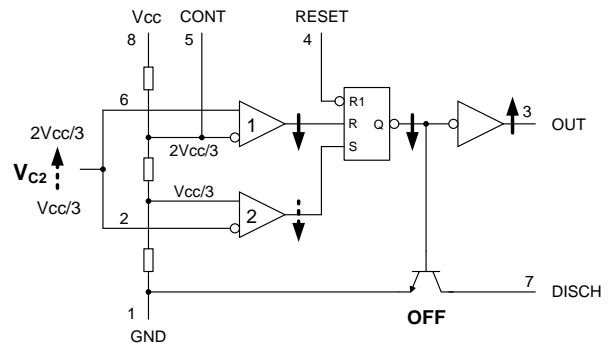
Output voltage



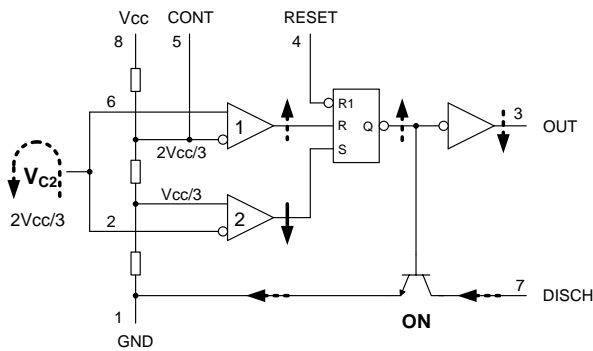
Time 0 – t1: $V_{C2} < V_{cc}/3$ and rising



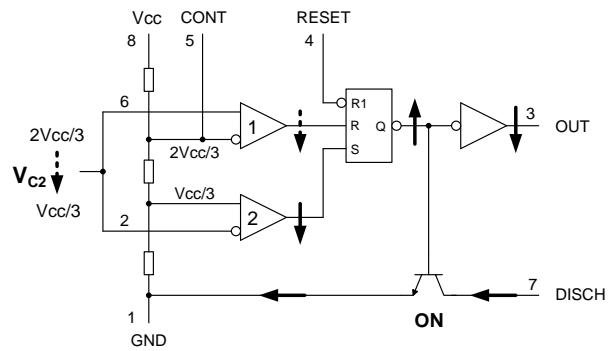
Time t1 – t2: $V_{cc}/3 < V_{C2} < 2V_{cc}/3$



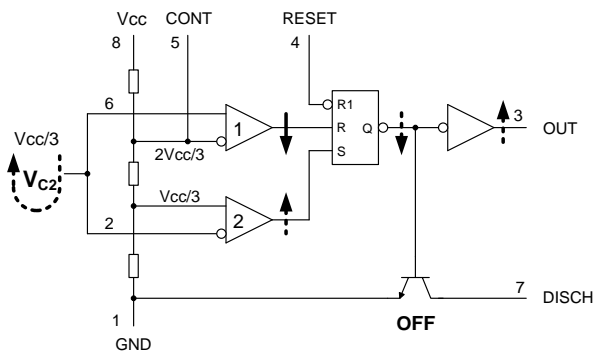
Time t2: $V_{C2} > 2V_{cc}/3$ momentarily



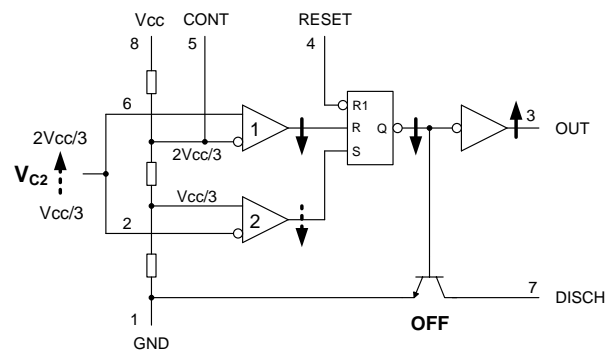
Time t2 – t3: $V_{cc}/3 < V_{C2} < 2V_{cc}/3$



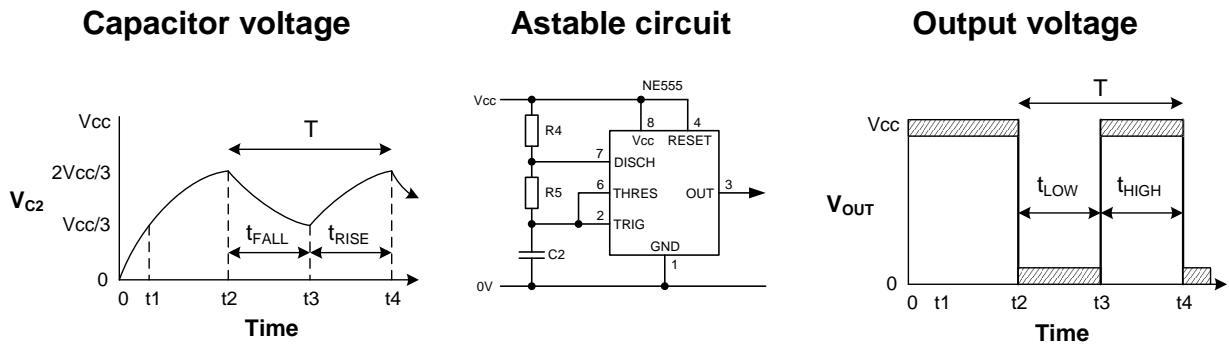
Time t3: $V_{C2} < V_{cc}/3$ momentarily



Time t3 – t4: Repeats sequence from t1



Turning indicators - RC timing calculations

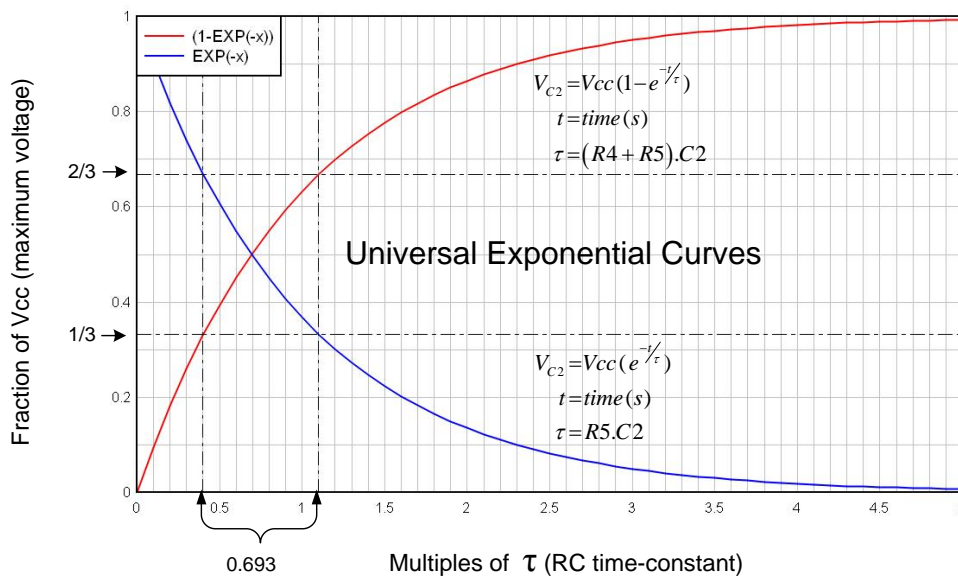


Turning indicators are required to flash at a rate between 1 and 2 flashes per second, so the flash period ($T = 1/f$) must lie between 1 s and 500 ms. The LED Sled circuit produces a flash period near 700 ms, so the flash rate is about 1.4 Hz.

$C2 = 1.5 \mu\text{F}$ (polyester) This is a compromise between size, stability and cost.

$R5 = 330 \text{ k}\Omega$ With $C2$, this produces a t_{FALL} of 343 ms (see calculations below)

$R4 = 10 \text{ k}\Omega$ With $R5$ and $C2$, this produces a t_{RISE} of 353 ms (see calculations below)



V_{C2} rises from $1/3V_{CC}$ to $2/3V_{CC}$ in a time of:

$$\begin{aligned}
 t_{\text{RISE}} &= 0.693(\tau_{\text{charge}}) \\
 &= 0.693(R4 + R5)C2 \\
 &= 0.693(340 \times 10^3)(1.5 \times 10^{-6}) \text{ s} \\
 &= 353 \text{ ms} \\
 &\Rightarrow t_{\text{HIGH}}
 \end{aligned}$$

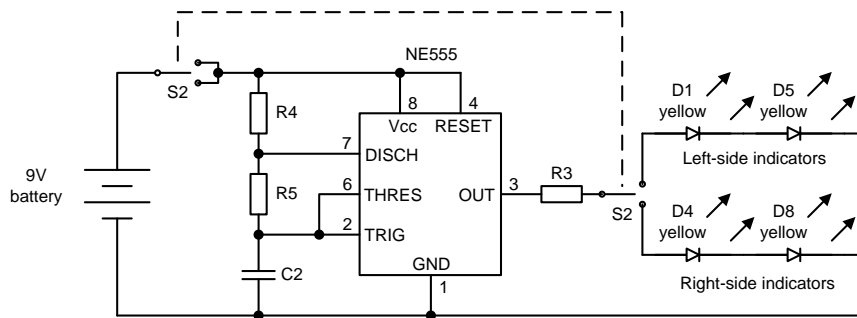
V_{C2} falls from $2/3V_{CC}$ to $1/3V_{CC}$ in a time of:

$$\begin{aligned}
 t_{\text{FALL}} &= 0.693(\tau_{\text{discharge}}) \\
 &= 0.693(R5)C2 \\
 &= 0.693(330 \times 10^3)(1.5 \times 10^{-6}) \text{ s} \\
 &= 343 \text{ ms} \\
 &\Rightarrow t_{\text{LOW}}
 \end{aligned}$$

The resulting **Vout** waveform is almost a square-wave ($t_{\text{HIGH}} \approx t_{\text{LOW}}$) with an amplitude approaching 9.0 V(pp), a period ($T = t_{\text{HIGH}} + t_{\text{LOW}}$) of 696 ms, and a frequency ($f = 1/T$) of 1.44 Hz. This waveform drives the yellow indicator LEDs via current limiting resistor $R3$.

Turning indicators – LED drive current

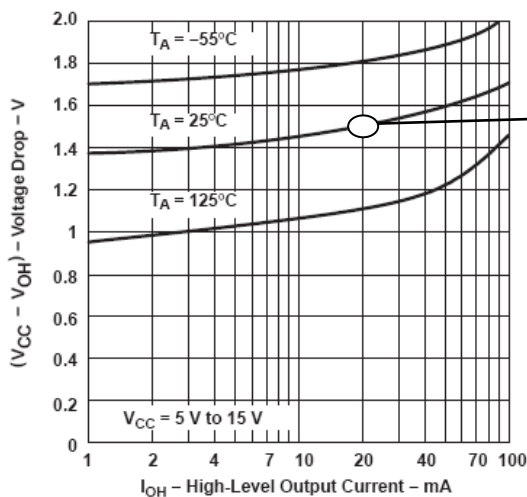
General circuit



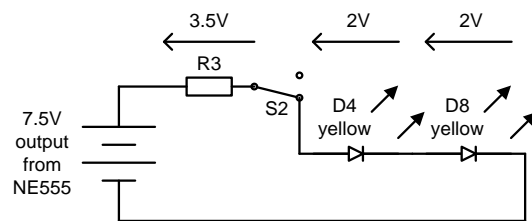
NE555 voltage loss @ 20 mA

Current limiting resistor

DROP BETWEEN SUPPLY VOLTAGE AND OUTPUT
vs
HIGH-LEVEL OUTPUT CURRENT



Find voltage across R3 (use KVL):



Calculate R3 to limit current to 20 mA:

$$R3 = \frac{3.5V}{20mA} = 175\Omega$$

Nearest preferred E12 values are 180 Ω and 150 Ω . To ensure at least 20 mA LED current with variation in practical battery and LED voltages, the lower resistance value of 150 Ω is used.

Expected battery life

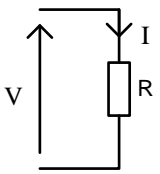
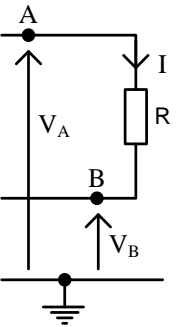
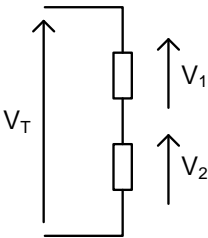
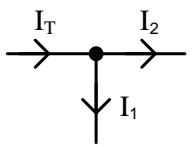
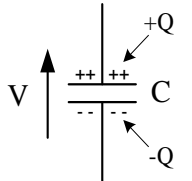
With all lights operating, the total current drain from the battery is approximately:

| | |
|----------------|-----------------|
| Headlights: | 20 mA |
| Tail-lights: | 10 mA |
| Indicators: | 10 mA (average) |
| NE555 IC: | 6 mA (typical) |
| Total : | 46 mA |

Assuming a battery capacity of 200mAh, the approximate operating time will be:

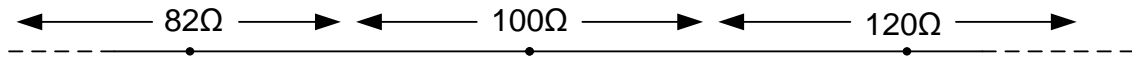
$$t(h) = \frac{Q(Ah)}{I(A)} = \frac{200 \times 10^{-3} Ah}{46 \times 10^{-3} A} = 4.3h$$

Fundamental laws and formulas

| Topic | Symbol | Formula | Note |
|--------------------------------------|--|---|--|
| |  | $I = \frac{V}{R}$ $V = I \cdot R$ $R = \frac{V}{I}$ | The resistor is assumed to be operating within its power rating |
| Ohm's law |  | $I = \frac{(V_A - V_B)}{R}$ $(V_A - V_B) = I \cdot R$ $R = \frac{(V_A - V_B)}{I}$ | $V_{AB} \equiv (V_A - V_B)$ Both imply: <i>the voltage at A relative to the voltage at B</i> |
| Kirchhoff's voltage law (KVL) |  | $V_T = V_1 + V_2$ | The total voltage across any number of series-connected devices equals the sum of the voltages across the individual devices |
| Kirchhoff's current law (KCL) |  | $I_T = I_1 + I_2$ | For any number of connections to a junction, the sum of currents in equals the sum of currents out |
| Capacitors |  | $C = \frac{Q}{V}$ $Q = C \cdot V$ $V = \frac{Q}{C}$ | If a constant current I flows to the capacitor for a time t, then: $Q = I \cdot t$ |
| Related topics | Series and parallel resistors. Resistive voltage and current dividers. Series-parallel resistive circuits. Series and parallel capacitors. | | |
| Reference | Thomas Floyd, <i>Principles of Electric Circuits</i> , Prentice Hall | | |

Preferred values for passive components

The EIA 'E' series specify the preferred values for resistors, capacitors and inductors based on manufacturing tolerances (imperfections). For example, the following three resistors have manufacturing tolerances of $\pm 10\%$, so are spaced about 20% apart to avoid value overlap.



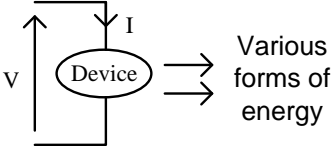
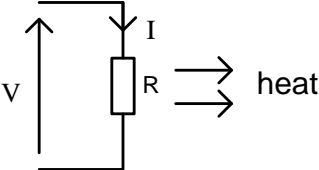
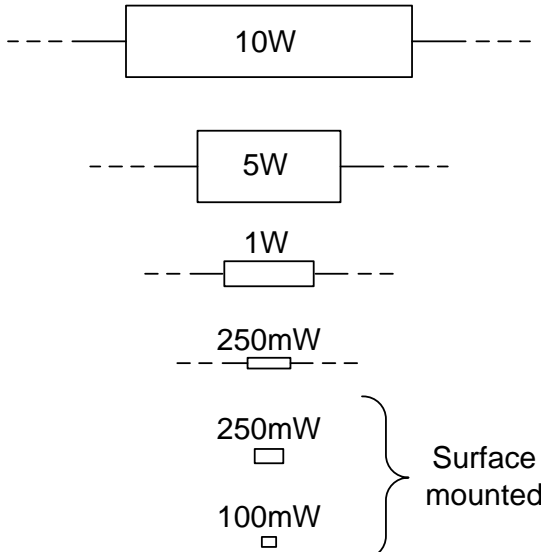
When all other values in this 10% tolerance range are spaced by about 20% there will be 12 possible values within each decade – as shown in the E12 column below.

The two-digit numbers in the table repeat with each decade, and are multiplied or divided by powers of 10 to achieve larger or smaller values.

The ranges within the 'E' series currently extend from E6 (20% tolerance) to E196 (approaching 0.1% tolerance) – the first three are shown below. Not all ranges are available for capacitors and inductors.

| E6 (20% tolerance) | E12 (10% tolerance) | E24 (5% tolerance) |
|------------------------------|-------------------------------|------------------------------|
| 10 | 10 | 10 |
| | | 11 |
| | 12 | 12 |
| | | 13 |
| 15 | 15 | 15 |
| | | 16 |
| | 18 | 18 |
| | | 20 |
| 22 | 22 | 22 |
| | | 24 |
| | 27 | 27 |
| | | 30 |
| 33 | 33 | 33 |
| | | 36 |
| | 39 | 39 |
| | | 43 |
| 47 | 47 | 47 |
| | | 51 |
| | 56 | 56 |
| | | 62 |
| 68 | 68 | 68 |
| | | 75 |
| | 82 | 82 |
| | | 91 |

Electrical power and heat

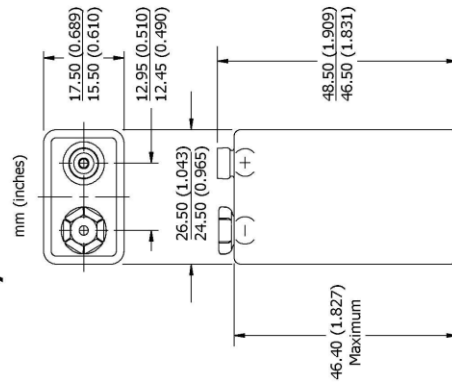
| Item | Symbol | Formula | Note |
|--|---|---|---|
| General power formula |  | $P = V \cdot I$ | Can be used with all electrical and electronic devices. |
| Power formulae for resistors |  | $P = V \cdot I$ $P = \frac{V^2}{R}$ $P = I^2 \cdot R$ | Can be used with all resistive devices, including wires and PCB tracks |
| Resistor power rating |  | | <p>Resistors convert electrical energy to heat, and transfer that heat to their surroundings. Their surface temperatures rise until the rate of heat loss equals the electrical power dissipated.</p> <p>The larger the surface area, the greater the rate of heat loss – and the higher the acceptable electrical power dissipation.</p> |
| Typical current ratings for copper conductors | <p>Single conductor (breadboard links) 1 x 0.5 mm diam. (100 mΩ/m) 2.0 A</p> <p>Multi-strand, plastic insulated cable 7 x 0.16 mm diam. (130 mΩ/m) 1.5 A 14 x 0.2 mm diam. (43 mΩ/m) 4.5 A</p> <p>PCB tracks, 35 μm thick (1 oz/ft²) 0.5 mm (20 th) wide 1.5 A 1.0 mm (40 th) wide 2.5 A 5.0 mm (200 th) wide 7 A</p> | | <p>Copper wires and PCB tracks are slightly resistive, and will dissipate power when current flows through them. Current ratings are usually based on an acceptable temperature rise.</p> <p>The current ratings quoted here for PCB tracks produce a temperature rise of about 10°C.</p> |

Battery data

ENERGIZER 522



Industry Standard Dimensions



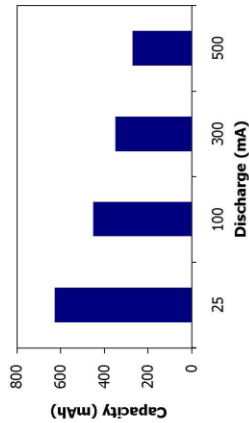
9V

Specifications

Classification: Alkaline
Chemical System: Zinc-Manganese Dioxide (Zn/MnO₂)
 No added mercury or cadmium
 ANST-1604A, IEC-6LR61
Designation: 9.0 volts
Nominal Voltage: -18°C to 55°C (0°F to 130°F)
Operating Temp: 45-6 grams (1.6 oz.)
Typical Weight: 21.1 cubic centimeters (1.3 cubic inch)
Typical Volume: Metal
Jacket: 5 years at 21°C (80% of initial capacity)
Shelf Life: Miniature Snap
Terminal:

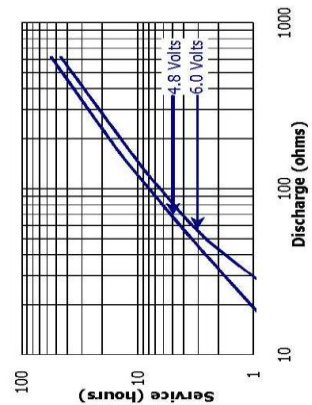
Milliamp-Hours Capacity

Continuous discharge to 4.8 volts at 21°C



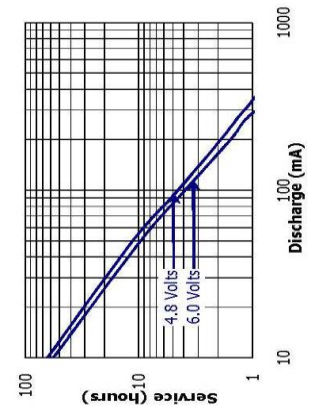
Constant Resistance Performance

Typical Characteristics (21°C)



Constant Current Performance

Typical Characteristics (21°C)



GP Batteries

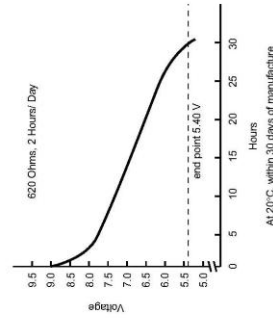
Data Sheet

Model No.: GP1604G

NO MERCURY ADDED

Description: Mercury Free Layer Built Extra Heavy Duty Battery
Chemical System: Carbon Zinc
Nominal Voltage: 9.0 Volts
Nominal Dimensions: 26.5 mm x 17.5 mm x 48.5 mm
Terminals: Standard snap fastener stud (+) and socket(-)
Jacket: Metal jacket
Applications: All electronic devices, e.g. toys, remote controls
Warranty Period: 24 months
Average Weight: 37.5g

| Estimated Service: | Discharge Condition | End Point Voltage | Service Life |
|--------------------|------------------------------|-------------------|--------------|
| 620 Ohms | 2 Hrs/ Day 7 Days/ Week | 5.40V | 30.0 Hrs |
| 180 Ohms | 30 Mins/ Day 7 Days/ Week | 4.80V | 8.6 Hrs |



Cross References:
 GP JIS IEC Eveready
 1604G 6F22 6F22 1222

Member Gold Peak Group
 Manufacturer reserves the right to alter or amend the design, model and specification without prior notice.
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