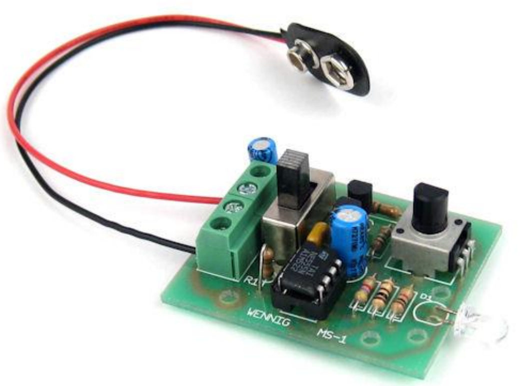
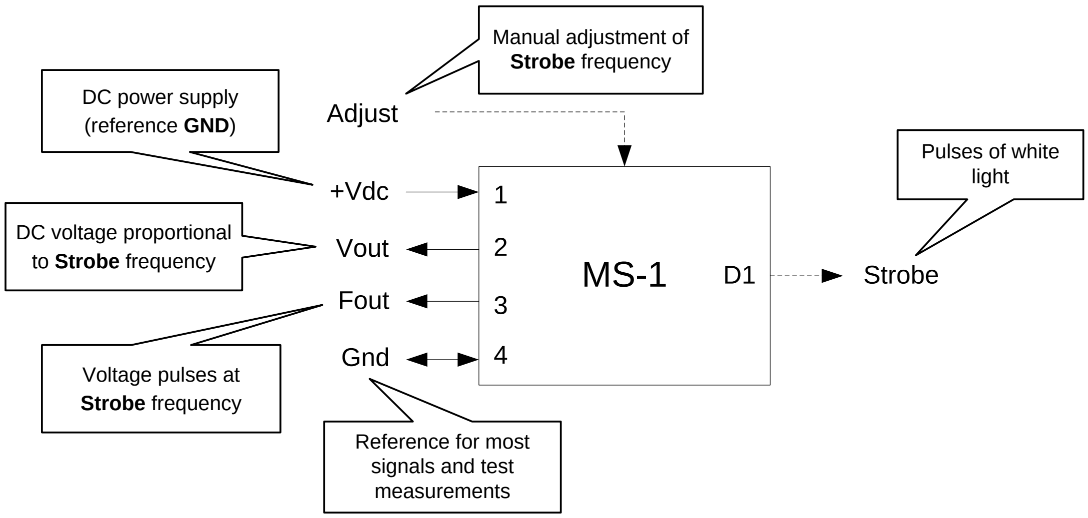
Micro-Strobe (Kit MS-1)

This miniature stroboscope aids in the study of rotating or vibrating objects like fan blades, motor shafts, guitar strings and loudspeaker diaphragms. The device is hand-held and battery powered, and makes no physical contact with the object under study.



Caution!
Be considerate of people who are sensitive to flashing lights.



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Part 1 Assembly guide

Before assembly

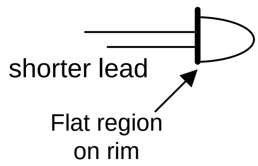
Wash hands before handling components. Contamination will affect solderability and long-term reliability of the assembly.

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 PCB detail and parts list in MS-1 kit)

Component	Comment
R2, R3, R4, R5, R6	Non-polarised, but for ease of reading colour codes, load resistors with gold tolerance bands toward the top edge or right hand side edge of PCB
R1	Non-polarised, so load for most convenient reading of colour code
Q1, Q2	The hole spacing in the PCB is a compromise between the various lead-wire spacings available with TO-92 plastic packages. Gently bend the transistor lead-wires to suit the holes in the PCB, and load each transistor so the package is about 4mm clear of the board surface – the 4mm of lead-wire provides stress-relief.
C2	Non-polarised, so load either way around.
C1, C3	Polarised, so insert positive polarity lead-wires (longer) into the holes marked '+', and negative polarity lead-wires (shorter, and aligned with negative marking on capacitor body) into the unmarked holes. On the copper side of the PCB, square pads indicate positive polarity, and round pads indicate negative polarity.
U1 socket	Place onto the PCB, and bend pins 1 and 5 to hold socket in place while soldering. After soldering all pins, carefully insert the NE555 IC into the socket.
S1	The package is a firm press fit, so check pin and tab alignment with PCB holes before applying pressure. Plenty of heat is required to solder the heavy mounting tabs – flux will assist solder flow.
J1	Check orientation before soldering.

RV1	The package is a firm ‘snap’ fit. Position the pins and mounting tabs over the PCB holes, and squeeze the metal sides of the package while pushing firmly downward. The sprung mounting tabs will lock the package in place, requiring little solder on the tabs – outside edges only.
D1	• Check LED polarity (see sketch) • If mounting D1 to face outward rather than upward, bend the lead-wires by 90° at about 4mm from the package. A bending jig helps: **Bending jig:** With a hacksaw blade, cut a 10mm long slot into a piece of 4mm thick plastic sheet. Slide the LED leads into the slot, press the LED package firmly down onto the plastic sheet, and bend the leads at 90° against the other side of the sheet. Slide the LED out. 

After assembly

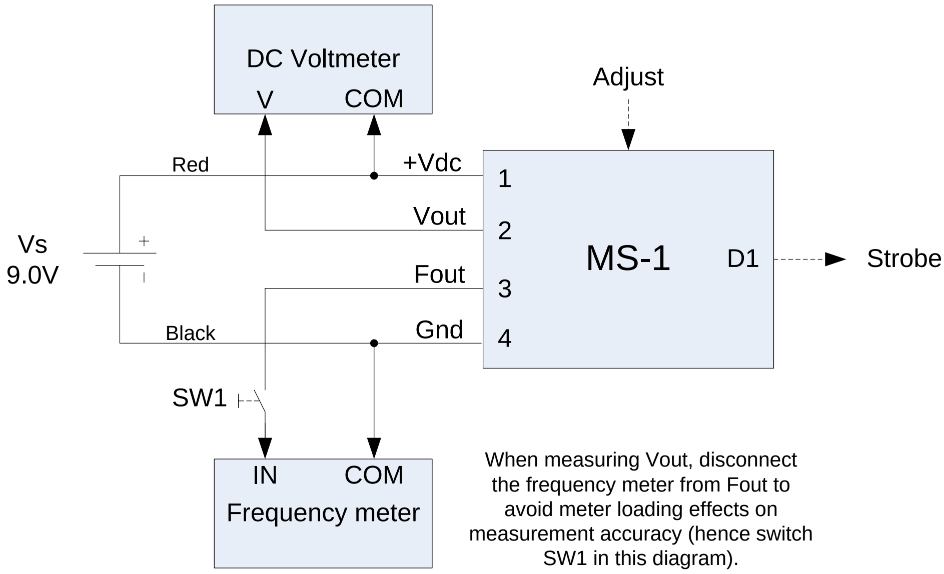
- In a well ventilated area, clean resin from the completed assembly with isopropyl alcohol and a small flux brush
- Buff the soldered side of the cleaned assembly with a clean, stiff-bristled paint brush - a 25 mm wide paint brush with bristles cut back to about 20 mm length is ideal
- Visually inspect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

Part 2 Test and calibration

Required equipment

- 9 V battery and snap connector, or suitable DC power supply
- Digital multimeter
- Frequency meter (audio frequency range)
- Momentary action switch (optional – clip leads can be used instead)
- Connecting wires
- Hand tools

Test setup



Notes: 1. The DC voltmeter uses the +Vdc terminal as its voltage reference, so it must be electrically isolated from the frequency meter. A battery powered digital multimeter is ideal for this measurement.

2. Apart from the DC voltmeter, any other test equipment connected to the MS-1 can be battery or AC mains powered, and should use the Gnd terminal as voltage reference.

Test procedure

Take the following actions, and make the observations and/or measurements listed. Where an MS-1 exhibits significantly different characteristics from those suggested in the procedure (with allowance for manufacturing tolerances), check all components associated with the function under test for:

- correct values and ratings
- correct orientation on the PCB
- solder joint integrity

Frequency adjustment range

Lowest strobe frequency

Actions	Observations / measurements
• Adjust RV1 fully anti-clockwise • Switch ON the MS-1	• Nothing happens for a few seconds as C2 initially charges from 0V • D1 then flashes at approximately 1.0 Hz • **Fout** frequency (F_o) measures approximately 1.0 Hz

Highest strobe frequency

Actions	Observations / measurements
• Adjust RV1 fully clockwise	• D1 appears to be continuously illuminated • $F_o \geq 100$ Hz • Absolute **Vout** voltage $\lvert V_o \rvert \geq 2.8$ V Note that V_o is a negative voltage, but only the magnitude is considered here

Vout calibration

Actions	Observations / measurements
• Adjust RV1 until F_o is 20Hz • Disconnect the frequency meter, and observe the V_o reading	• V_o will take a few seconds to settle • Record V_o in Table 2-1 • Re-connect the frequency meter
• Adjust F_o (via RV1) to each of the other frequencies in Table 2-1, and at each frequency disconnect the frequency meter and observe the V_o reading	At each new frequency: • Allow a few seconds for V_o to settle • Record V_o in Table 2-1 • Re-connect the frequency meter
• Plot the frequency/voltage combinations from Table 2-1 onto Figure 2-1. Use absolute voltage values $\lvert V_o \rvert$ to emphasise the direct proportionality between frequency and voltage • Draw a straight line of best fit through these points, continuing the ends of the straight line to intersect the vertical side axes of the graph	• Note where the ends of the straight line intersect the vertical axes of Figure 2-1 • Record the coordinates of these intersections in Table 2-2 • Calculate the slope of the straight line as indicated below Table 2-2 • Use the calculated conversion factor in future MS-1 applications instead of the -36 Hz/V figure quoted in the specification

Table 2-1

MS-1 Calibration measurements

F_o (Hz)	V_o (V)
20	
40	
60	
80	
100	

Table 2-2

MS-1 Calibration co-ordinates

	F_o (Hz)	$\lvert V_o \rvert$ (V)
[1]	0	
[2]	100	

Conversion factor calculation:

$$\left(\frac{\Delta F_o}{\Delta V_o}\right) = -\left(\frac{F_o[2]-F_o[1]}{|V_o|[2]-|V_o|[1]}\right)$$

$$= -\left(\frac{100Hz}{\text{.............}\ V}\right)$$

$$= \quad \text{......................}\ Hz/V$$

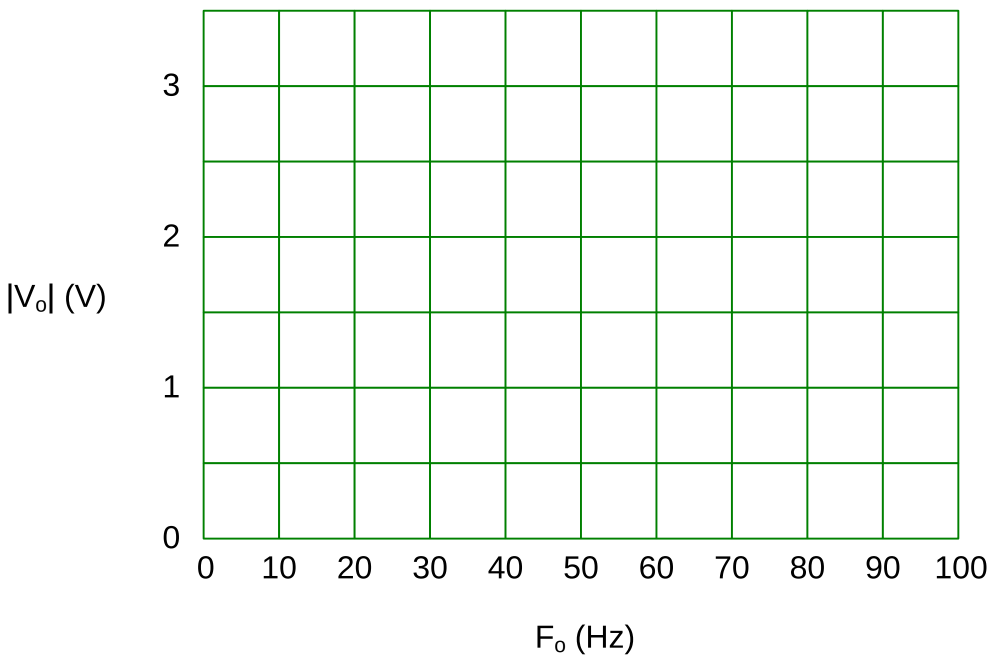


Figure 2-1 MS-1 Calibration transfer function

Part 3 Specifications

MS-1 produces constant-width, white light **Strobe** pulses. When these light pulses illuminate a rotating or vibrating object, and the pulse frequency is **Adjust**ed until the object appears to 'freeze' in position, the pulse frequency will be harmonically related to the frequency of motion of the object. The MS-1 produces two output signals that can be measured to obtain this frequency information:

1. **Fout** is a continuous pulse train at the **Strobe** frequency (F_o), and can be connected to a frequency meter for direct frequency measurement.
2. **Vout** is a 'smoothed' (low-pass filtered) version of the **Fout** pulse train. The resulting DC voltage (V_o) can be measured with a voltmeter and multiplied by a conversion factor to obtain the approximate **Strobe** frequency (F_o).

In the following table:

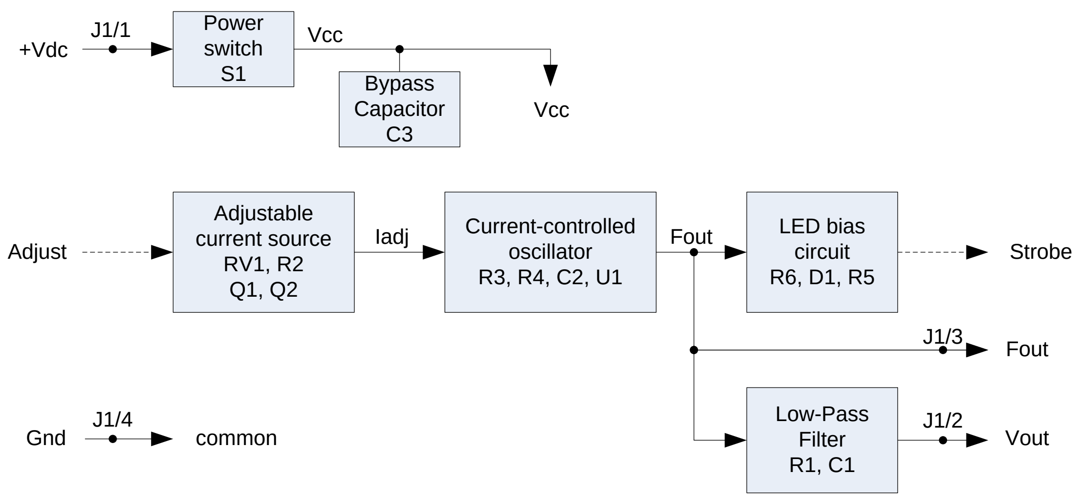
- Voltages are quoted relative to **Gnd** unless otherwise stated.
- Quoted figures apply to an MS-1 with a DC power supply of 9.0 V

Parameter	Typical range or value
DC power supply +Vdc	
Operating voltage	5 V to 12 V
Specification voltage	9.0 V
Current drain	6 mA at 1 Hz **Strobe** frequency 25 mA at 100 Hz **Strobe** frequency
Light pulses Strobe	
Luminous intensity	10 cd (30° beamwidth)
Pulse duration (t_{LOW})	3.3 ms
Pulse frequency (F_o)	1.0 Hz to 120 Hz
Voltage pulses Fout	
Amplitude	8.5 V(pp) LOW-going pulses
Pulse LOW duration (t_{LOW})	3.3 ms (same as **Strobe** pulse duration)
Pulse frequency (F_o)	1.0 Hz to 120 Hz (same as **Strobe** frequency)
Filtered voltage pulses Vout	
Waveform	Low-pass filtered average of **Fout** pulses
Filter settling time	3.5 s
DC voltage (V_o)	0 V to -3.3 V across the frequency adjustment range (voltmeter: reference **+Vdc**, impedance ≥ 1MΩ)
AC ripple voltage	40 mV(pp)
Voltage to frequency conversion factor	-36 Hz/V [$F_o = (V_o).(-36\text{ Hz/V})$]

Part 4 Circuit operation

- Refer to circuit diagram provided with the kit
- In all calculations, circuit components are assumed to be ideal. Manufacturing tolerances and temperature effects are ignored unless they contribute significantly to performance
- The DC power supply voltage **+Vdc** is assumed to be 9.0 V
- Unless otherwise stated, voltages are quoted relative to **Gnd.**

MS-1 block diagram



Power switch S1 and bypass capacitor C3

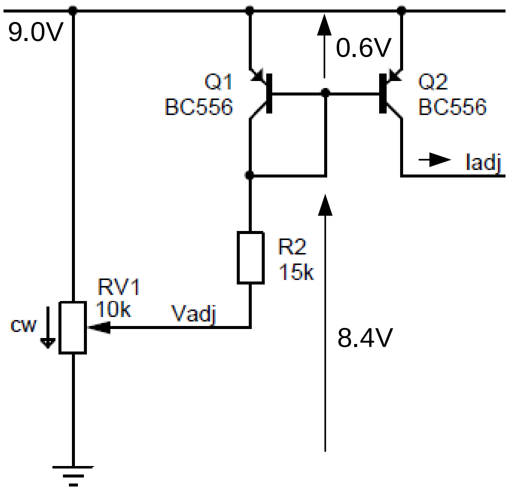
- Slide switch S1 connects **+Vdc** to **Vcc** to power-up the MS-1
- Bypass capacitor C3 reduces the effects of electrical noise on the circuit. C3 presents a high frequency low impedance between **Vcc** and **Gnd**, with two desirable effects:

    1. Together with any resistance and inductance in external power supply wiring, C3 completes a low-pass filter, reducing effects of conducted external noise on the circuit

    2. High frequency switching current drawn by the NE555 timer U1 and white LED D1, together with noise current from transistors Q1 and Q2, flows through C3 - bypassing the external power supply wiring. This reduces circuit-induced noise voltage on **Vcc**, improving circuit stability. C3 is physically placed as close as possible to U1 and D1.

Adjustable current source: RV1, R2, Q1, Q2

- This delivers current to the timing capacitor C2 in the NE555 astable multivibrator (oscillator), under the control of potentiometer RV1. The resulting oscillator frequency is linearly related to the angular position of the potentiometer wiper
- Transistors Q1 and Q2 form a current mirror, where the Q2 collector current 'mirrors' or follows the Q1 collector current. Closely matched transistor pairs are supplied in the kits
- Q1 collector current is approximately equal to the current through R2 (I_{R2}), which is controlled by the wiper voltage (**V_{adj}**) from potentiometer RV1:



Allowing 600 mV for the BC556 base-emitter junctions, and applying Ohm's law to R2:

$$I_{R2} = \frac{(8.4V - V_{adj})}{15k\Omega} \Rightarrow I_{adj}$$

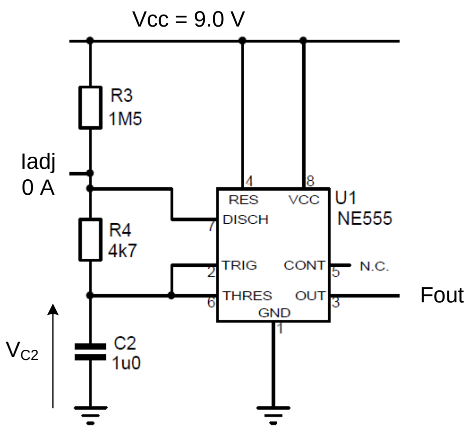
As **V_{adj}** varies from 0 V to 8.4 V, I_{R2} and **I_{adj}** vary from 560 µA to 0 A (minimum **V_{adj}** producing maximum current).

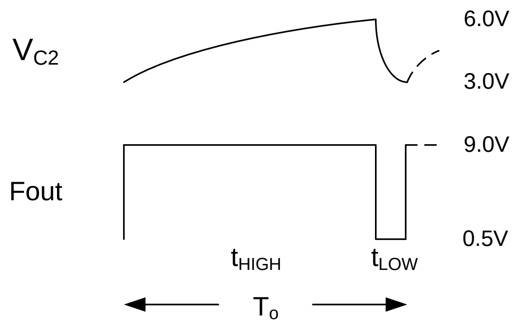
As **V_{adj}** rises above 8.4 V, the base-emitter junctions of Q1 and Q2 cease to conduct, so I_{R2} and **I_{adj}**, approach zero.

- Q2 acts as a constant current source, where **I_{adj}** is controlled only by **V_{adj}**, and is not affected by voltage variations on the Q2 collector (due to U1 oscillator action).

Current-controlled oscillator U1

- This is an astable multivibrator circuit, producing a pulsed output waveform at a frequency controlled by **I_{adj}** , R3, R4 and C2
- When **I_{adj}** is zero, the frequency of oscillation is determined only by R3, R4 and C2:





$$t_{HIGH} = 0.693(R3 + R4)C2 = 1.04\,s$$

$$t_{LOW} = 0.693(R4)C2 = 3.26\,ms$$

$$T_o = t_{HIGH} + t_{LOW} = 1.04\,s + 3.26\,ms = 1.04\,s\ (\approx 1.0\,s)$$

$$F_o = \frac{1}{T_o} = 0.96\,Hz\ (\approx 1.0\,Hz)$$

- When Q2 injects current $\mathbf{I_{adj}}$ into the oscillator circuit, C2 charges more rapidly than before and the frequency of oscillation increases
- At the maximum $\mathbf{I_{adj}}$ of 560 µA, the current into C2 is also approximately 560 µA (R3 and U1 contribute only a few microamps). The resulting frequency approaches 120 Hz:

From capacitor theory, $\mathbf{V_{C2}}$ rises at a rate of:

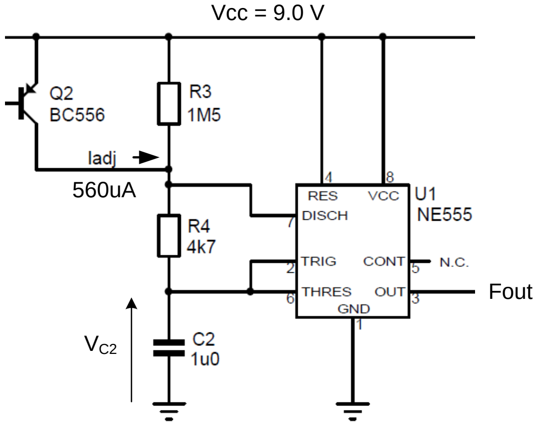
$$\frac{\Delta V_{C2}}{\Delta t} = \frac{I_{C2}}{C2} = \frac{560\,\mu A}{1.0\,\mu F} = 560\ V/s$$

The time it takes for $\mathbf{V_{C2}}$ to charge from 3.0V to 6.0V is:

$$\Delta t = \frac{\Delta V_{C2}}{560\ V/s} = \frac{(6.0V - 3.0V)}{560\ V/s} = 5.4\,ms = t_{HIGH}$$

C2 still discharges through R4 only, so t_{LOW} remains as before:

$$t_{LOW} = 0.693(R4)C2 = 3.26\,ms$$



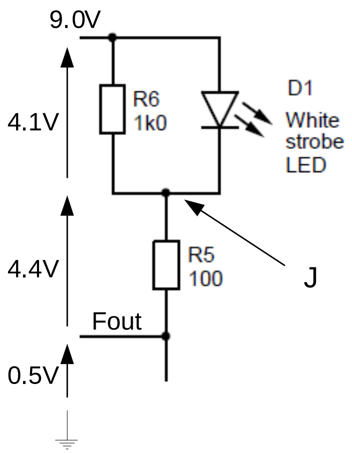
Combining these t_{HIGH} and t_{LOW} values:

$$T_o = t_{HIGH} + t_{LOW} = 5.4\,ms + 3.26\,ms = 8.66\,ms\ (\approx 8.7\,ms)$$

$$F_o = \frac{1}{T_o} = 115\,Hz\ (\approx 120\,Hz)$$

LED bias circuit

- This bias circuit limits the LED forward current to about 40 mA to produce the desired white light intensity
- This current occurs when **Fout** is LOW (typically 0.5V from NE555 data)



Applying KCL to junction J:

$$I_{R6} + I_{D1} = I_{R5}$$

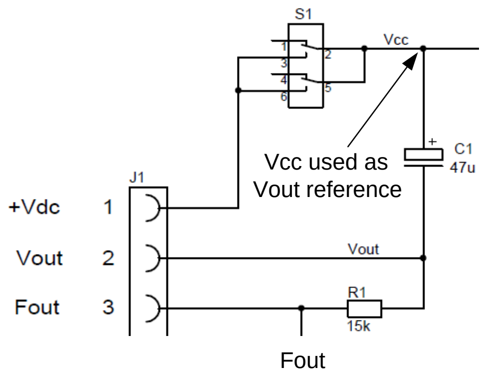
$$\therefore I_{D1} = I_{R5} - I_{R6} = \frac{4.4V}{100\Omega} - \frac{4.1V}{1.0\,k\Omega} \approx 40\,mA$$

Assumption: V_{D1} = 4.1 V (LED data)

- When **Fout** is HIGH, LED D1 is reverse biased, and does not conduct or illuminate
- During this time, pull-up resistor R6 ensures that **Fout** approaches 9.0V, improving the performance of the low-pass filter that follows.

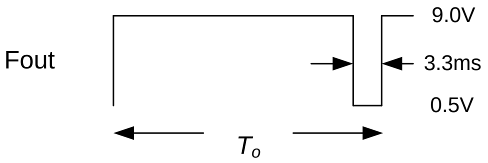
Low pass filter

- The low-pass filter smooths the **Fout** pulses to produce at **Vout** a DC voltage (V_o) that is proportional to the **Fout** frequency (F_o) and can be measured with a voltmeter
- The **Fout** pulses have fixed LOW durations (t_{LOW}) and variable HIGH durations (t_{HIGH}), so as the pulse frequency decreases, the average value increases – an inverse relationship
- To measure a voltage that is directly proportional to frequency, and therefore more intuitive to use, **Vcc** (9.0V) is used as the measurement reference instead of **Gnd**.



- The DC voltmeter is connected:
  Red lead to **Vout**, Black lead to **+Vdc**
- The measured voltage V_o is negative, but a negative voltage-to-frequency conversion factor restores a positive sign to the calculated frequency:

$$F_o = (V_o) \cdot (-36\,Hz/V)$$

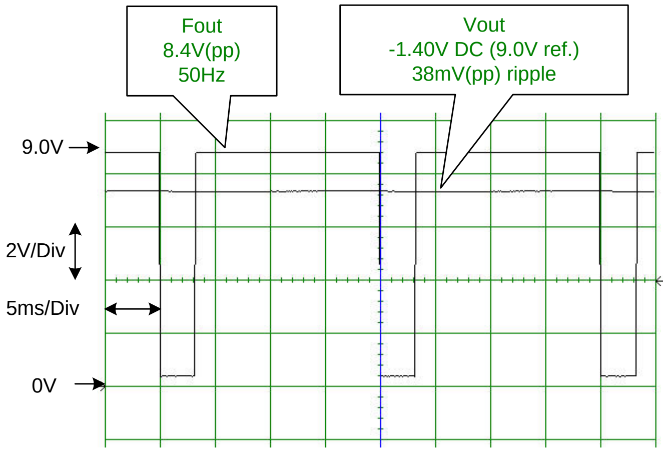


Note: $T_o = \left(\frac{1}{F_o}\right)$

Deriving the conversion factor:

$$V_o = average\ value\ of\ \text{Fout}\ waveform$$
$$= (duty\ cycle) \cdot (pulse\ amplitude)$$
$$= \left(\frac{3.3\,ms}{T_o}\right) \cdot (-8.5\,V)$$
$$= (-28\,ms.V) \cdot (F_o)$$
$$\therefore \left(\frac{F_o}{V_o}\right) = (-36\,Hz/V)$$

- R1 and C1 are chosen to have a time constant (R1.C1 product) of about 700 ms, which is a compromise between effective 'smoothing' of the narrow 8.5 V(pp) **Fout** pulses and the time taken for the filter output voltage V_o to settle before a measurement can be made
- The residual ripple voltage from this filter is about 40mV(pp), which is insignificant
- Oscilloscope images of typical **Fout** and **Vout** waveforms appear below:



DS1M12 'StingRay' Multi-Function Instrument