# Lab 5 Waveform generators

In this lab you will build different types of waveform generators.

## Pre-lab

- 1. Understand why there is a pull-up resistor on the output of the LM 319.
- 2. Design the circuit in step 4.
- 3. Compute the oscillation frequency in step 9.
- 4. Compute the duty cycle in step 11.
- 5. Redesign the circuit in step 12.

#### Comparator

Build a comparator circuit and investigate how the switching voltage depends on the reference voltage.

1. Connect the comparator like this



- 2. Attach a 10 V pp triangular wave to  $V_{\rm in}$ .
- 3. Vary  $V_{\text{ref}}$  between 0 and 5 V (for example using a potentiometer) and describe how the switching voltage varies with reference voltage.

## Comparator with hysteresis (Schmitt trigger)

Add hysteresis to the comparator to create a Schmitt trigger by setting the reference voltage and the feedback resistances  $R_1$  and  $R_2$ . Although  $V_R$  is connected to ground in this figure you will need to select a different voltage.



- 4. Choose  $V_R$ ,  $R_1$ , and  $R_2$  to produce hysteresis levels of 0 V and 1.5 V.
- 5. With a triangular wave measure the hysteresis levels.
- 6. Plot the hysteresis curve ( $v_{out}$  as a function of  $v_{in}$ ).

## **Relaxation oscillator**

Use the Schmitt trigger to create a relaxation oscillator.



- 7. Build the circuit.
- 8. Plot the waveforms at the different outputs.
- 9. Measure the oscillation frequency and compare it with a theoretical calculation.
- 10. Explain why the inverter and connected -15 V offset are needed after the Schmitt trigger.
- 11. Measure the duty cycle and compare with a theoretical calculation.
- 12. Modify the circuit to create a 50% duty cycle.