Time to Voltage Converter & Window Comparator

Group 19:
Aayushi Singla (Panjab University, Chandigarh)
Arnab Sarker (Tezpur University, Assam)
Katie Walkingshaw Pass (University of Bristol, UK)

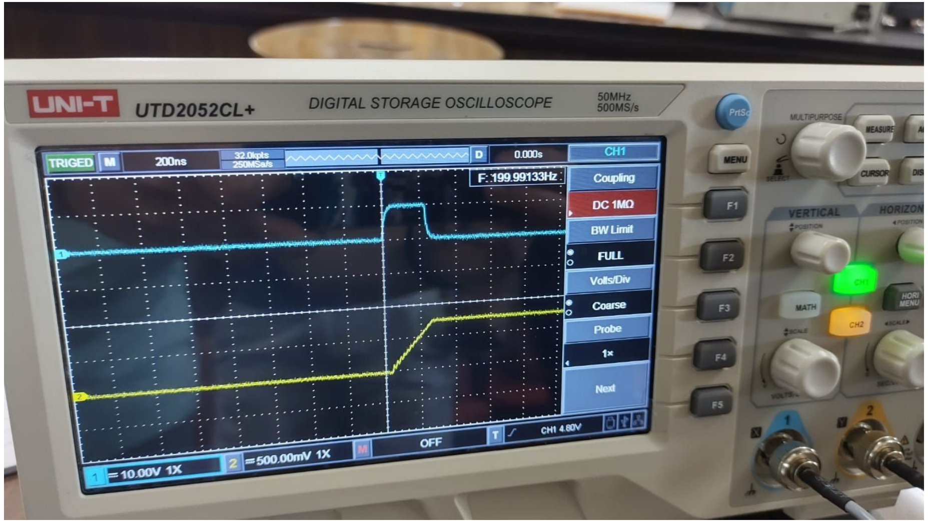
- Time to Voltage Conversion: Discharging the Capacitor
- Comparator: Measuring Hysteresis
- Window Comparator

What is Time to Voltage Conversion?

- Uses the measurement of the time interval between two events (two electronic signals)
- It is the first stage in the time to digital converter (TDC)
- Useful for:
    - Determining the angle of incidence of an air shower generated by High Energy Cosmic Rays
    - In accelerator-based experiments

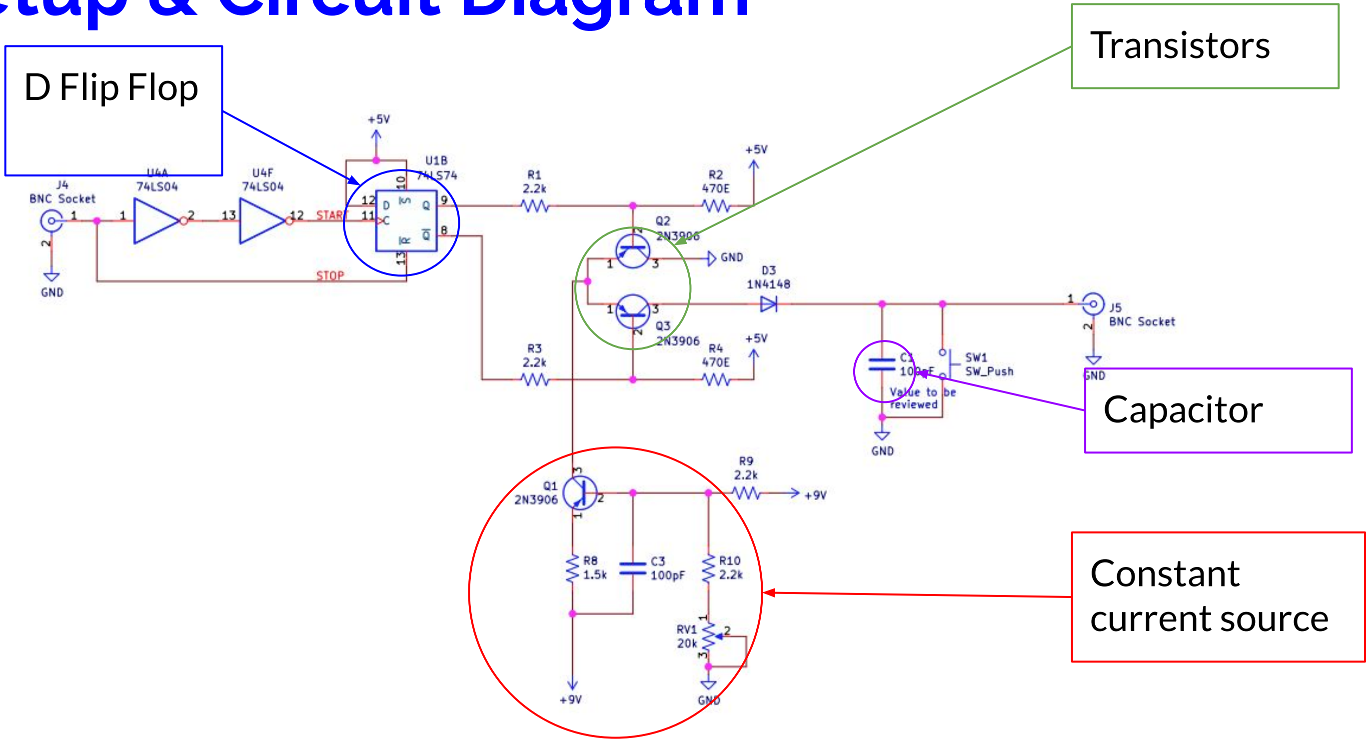
How is TVC Measured?

- A capacitor is charged up by a constant current source
- The total charge delivered to the capacitor is then an analog representation of the time interval
- An analog-to-digital conversion is performed on the voltage held by the capacitor. Where the charge is removed at a constant rate



Experiment Setup & Circuit Diagram

- When no pulse: when Q is low -> Q2 is on -> Q1 charge is drained by Q2 to ground
- When pulse is applied: when Qbar is low -> Q3 is on -> Q1 charges the capacitor C1
- Q output of the FF goes again low when the input pulse ends
- Capacitor is essentially charged by a constant current supplied by Q1 for the duration of the input pulse



Calculating the current

- The current is kept constant in order to measure the circuit output voltage
- Voltage over the capacitor is proportional to the time that it is charged

Supply voltage to emitter

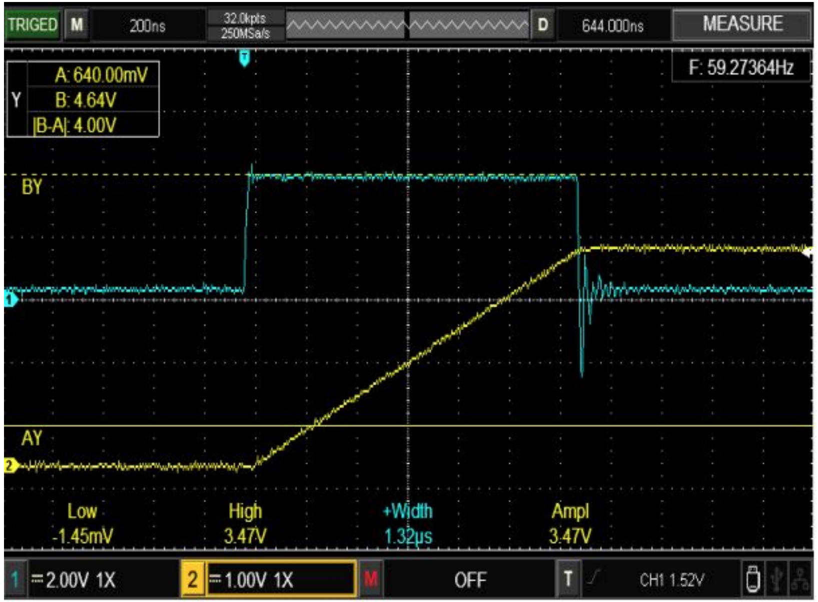
Emitter to base forward bias drop (0.7V for the transistor used)

Set to 8V

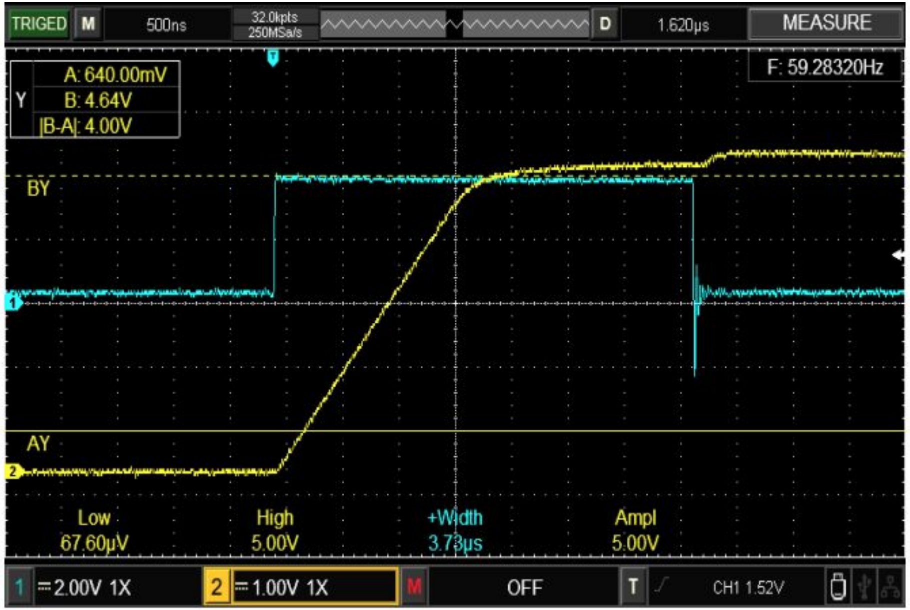
$$i = \frac{VCC_e - V_f - REFERENCE}{R_e}$$

Emitter resistance

Scope Output

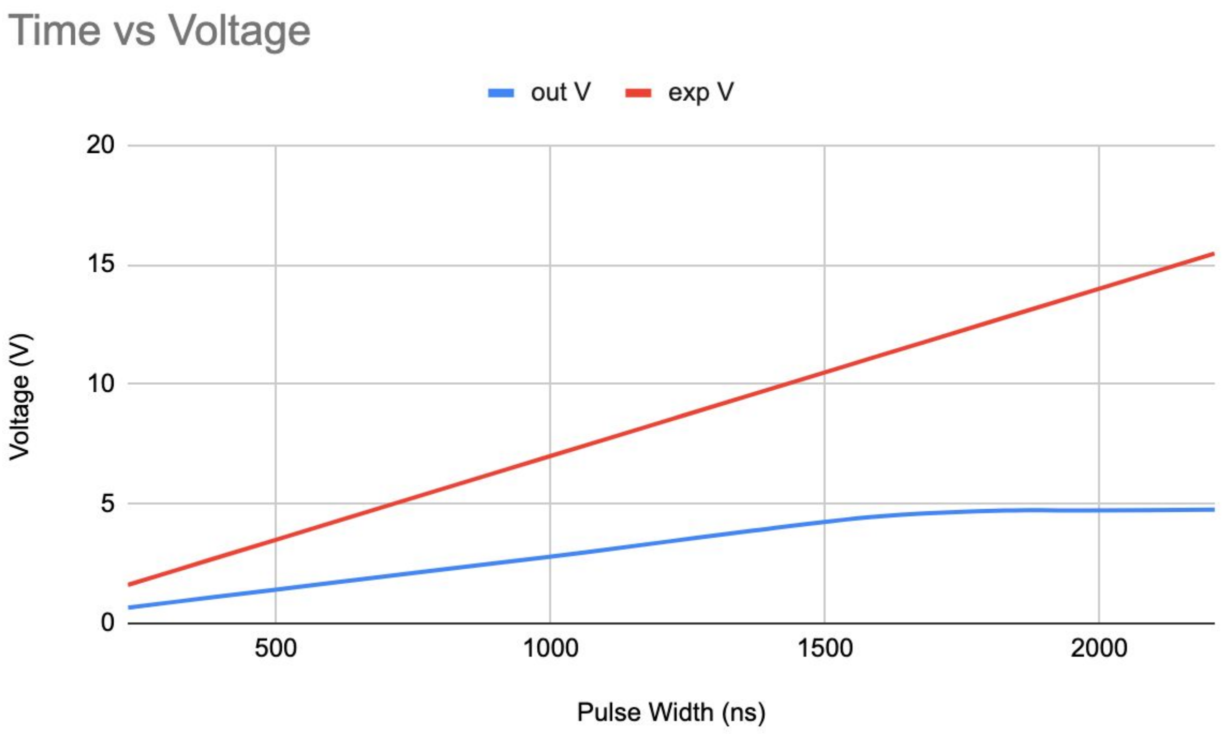


Without saturation



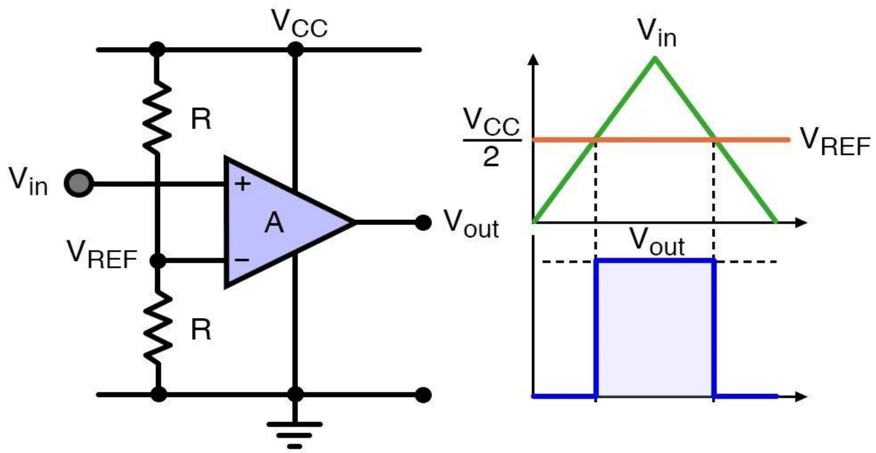
With saturation

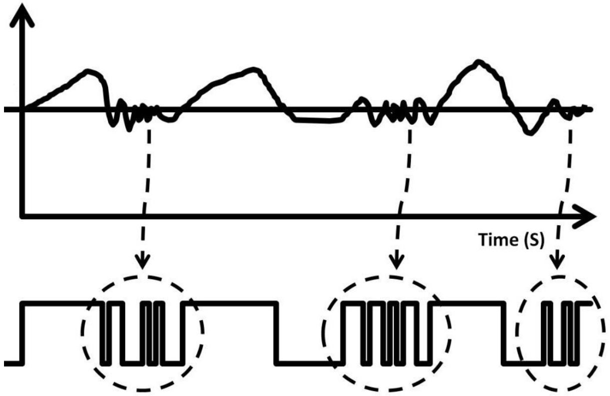
Results


Time vs Voltage
out V
exp V
20
15
10
5
0
Voltage (V)
500
1000
1500
2000
Pulse Width (ns)

Comparator Circuit

- Circuit used for comparing between two analog signals or a reference signal.

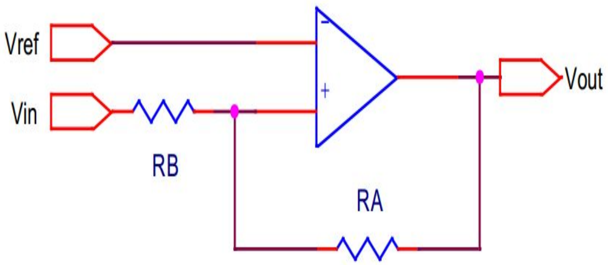


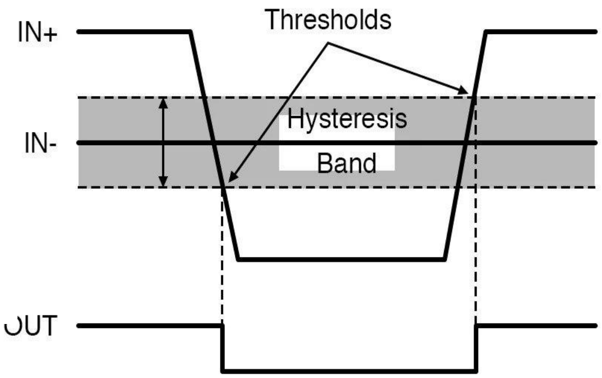


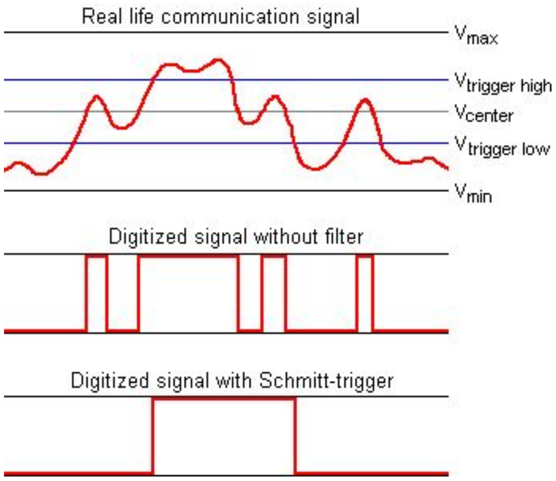
- When $V_{in} > V_{ref}$: V_{out} reaches positive saturation level.
- When $V_{in} < V_{ref}$: V_{out} reaches negative saturation level.
- Comparator circuit - Unstable & Sensitive to noise in signal.

Comparator Circuit with hysteresis

- Working of Comparator circuit can be improved.
- Implementing a Hysteresis voltage range to reduce its sensitivity to noise.
- Positive feedback to Non-Inverting comparator.
- Sets a Upper and Lower limit on voltage to eliminate unwanted transitions by noise.
- Hysteresis band - Output is immune to input noise.





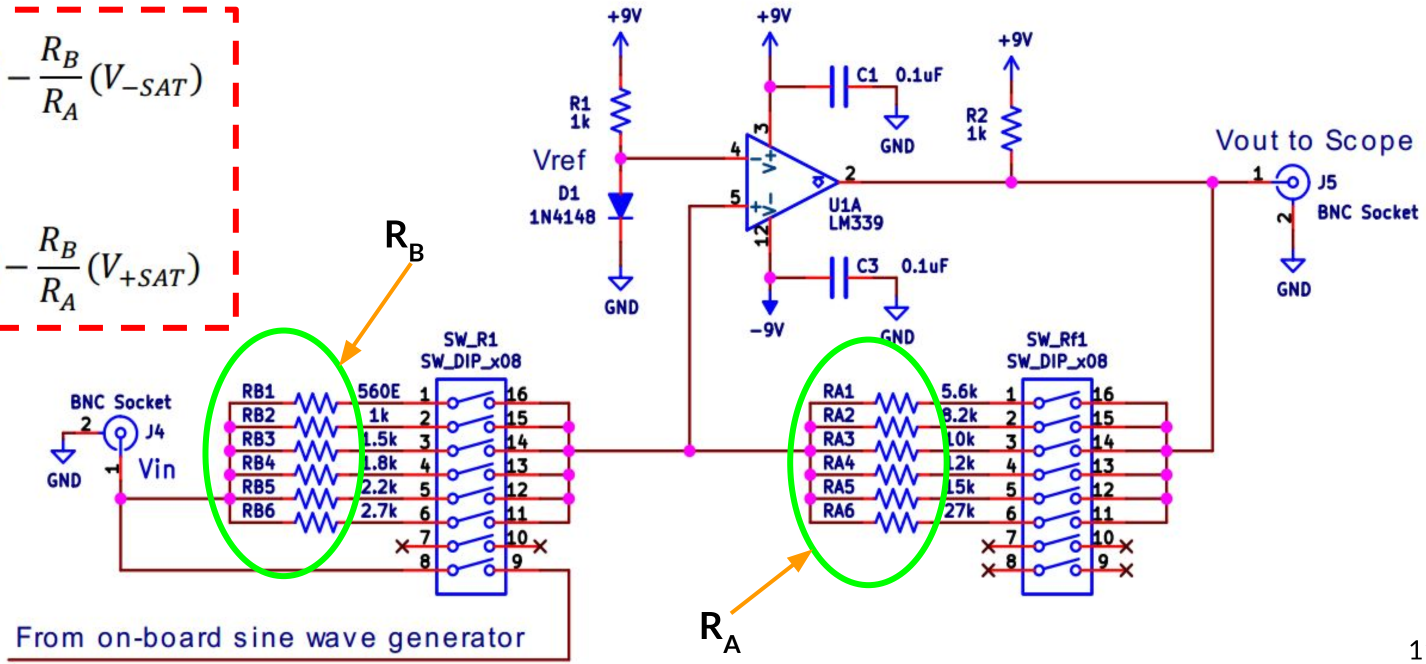


Circuit Diagram

- The Hysteresis band depends on chosen values of R_A and R_B
- Vin > V_{UT} , Vout is High (V+sat)
- Vin < V_{LT} , Vout is Low (V-sat)
- Hysteresis band, $V_{HYST} = V_{UT} - V_{LT}$

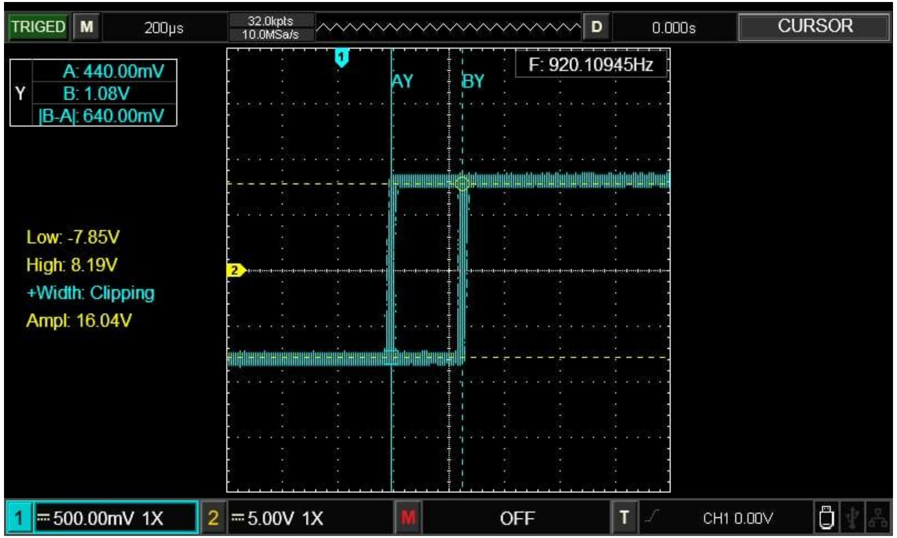
$$V_{UT} = \frac{R_A + R_B}{R_A}(V_{ref}) - \frac{R_B}{R_A}(V_{-SAT})$$

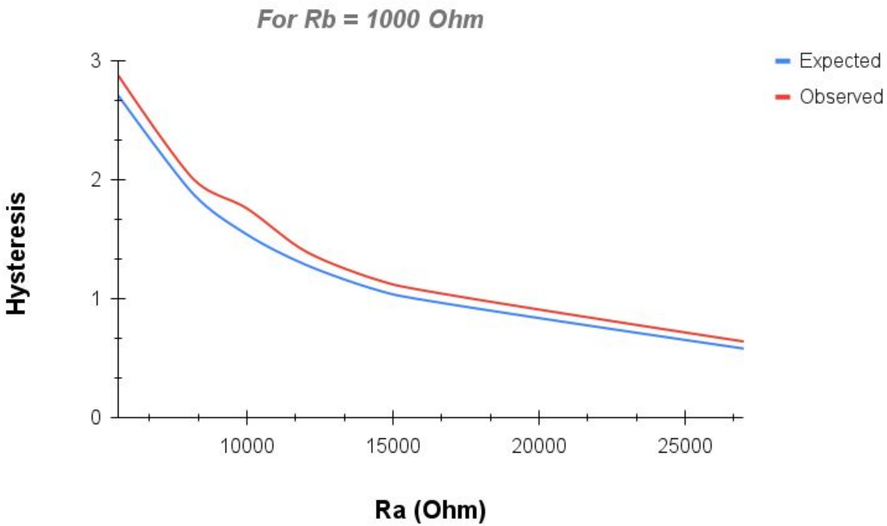
$$V_{LT} = \frac{R_A + R_B}{R_A}(V_{ref}) - \frac{R_B}{R_A}(V_{+SAT})$$



Observation

- Hysteresis band depends on the configuration of resistances R_A and R_B
- Varied R_A for a fixed value of R_B and studied the change in Hysteresis band.



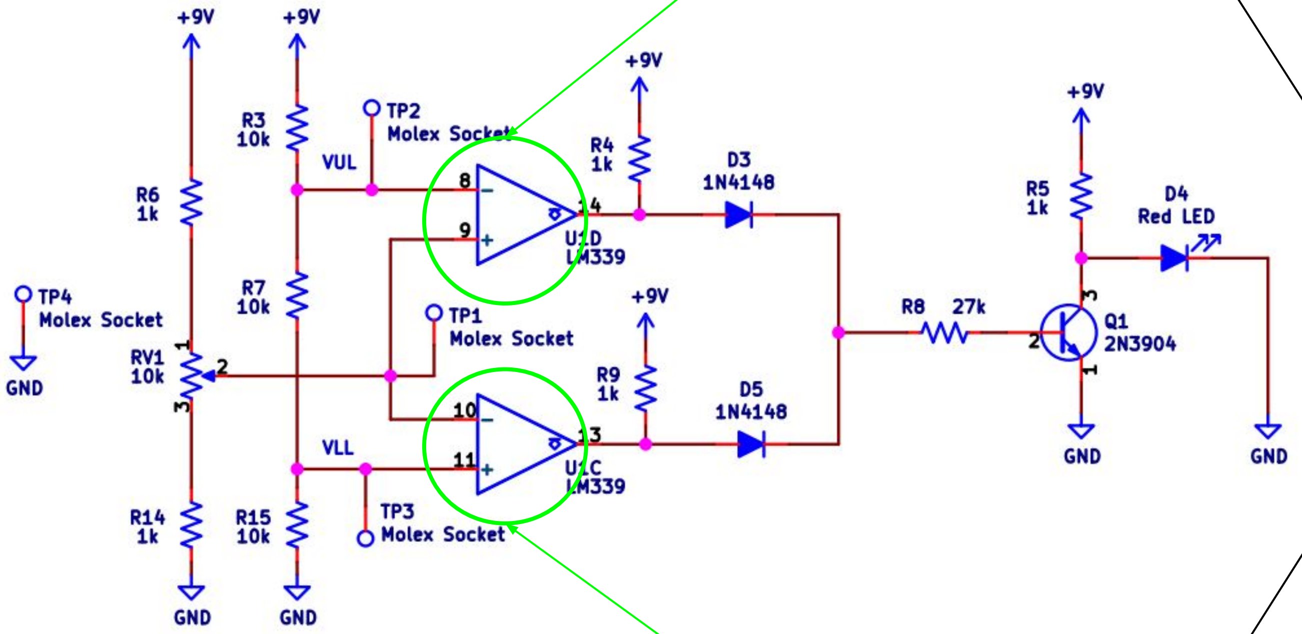


Window Comparator

- Used for selecting signals only within a specified range or ‘window’ of voltage.
- Logically combining the outputs from an inverting comparator and a non-inverting comparator.
- It employs two comparators to detect over-voltage or under-voltage condition.

Circuit Diagram

Non-inverting Op-Amp
VUL > Vin, Vout is low



VLL < Vin < VUL, both Vout low

Inverting Op-Amp
VLL < Vin, Vout is low

Observations

The calculated value of:

The upper threshold is $VUL = \dfrac{10k + 10k}{(10k + 10k + 10k)} \times 9V = 6V$

The lower threshold is $VLL = \dfrac{10k}{(10k + 10k + 10k)} \times 9V = 3V$

	VUL (in V)	VLL (in V)
Expected	5.562	2.77
Observed	5.584	2.78

Conclusions

- TVC and Comparator circuits are very useful for analysing analog signals e.g. in a HEP DAQ system

- These three circuits are the building blocks for Analog to Digital Converters.

- Voltage comparator is essentially a 1-bit analogue to digital converter, as the input signal is analogue but the output behaves digitally.

Thank You

BackUp Slides

Backup Equations

$$q = C \times V$$

$$q = i \times t$$

$$V = \frac{i \times t}{C}$$

$$V \propto t$$

$$i = \frac{VCC_e - V_f - REFERENCE}{R_e}$$

Data recorded: TVC

Pulse width (ns)	Vout (V)	ExpV (V)
230	0.66	1.61
380	1.08	2.66
610	1.72	4.27
760	2.14	5.32
990	2.76	6.93
1220	3.44	8.54
1370	3.88	9.59
1600	4.48	11.2
1830	4.72	12.81
1980	4.72	13.86
2210	4.76	15.47

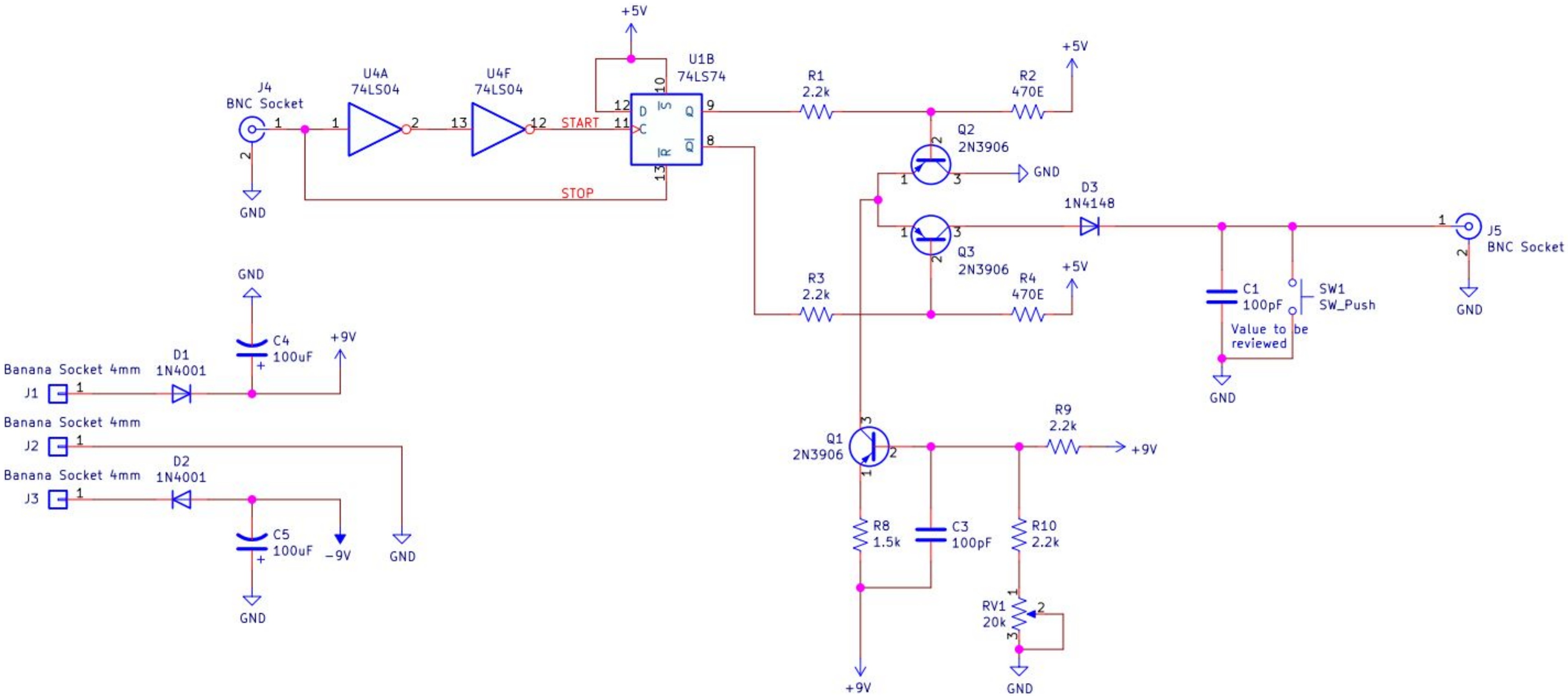
Data recorded: Comparator

Rb (ohm)	Ra (ohm)	Vut (V)	Vlt (V)	Hysteresis	V+sat (V)	V-sat (V)	Observed hysteresis
560	5600	1.5426	0.0516	1.491	7.36	-7.55	1.8
560	8200	1.281873171	0.2322146341	1.049658537	7.8	-7.57	1.24
560	10000	1.180016	0.317616	0.8624	7.83	-7.57	1.1
560	12000	1.103613333	0.3821466667	0.7214666667	7.87	-7.59	0.88
560	15000	1.026090667	0.445184	0.5809066667	7.97	-7.59	0.72
560	27000	0.8886874074	0.5638874074	0.3248	8.05	-7.61	0.42
1000	5600	2.190285714	-0.5204285714	2.710714286	7.64	-7.54	2.88
1000	8200	1.726487805	-0.1466829268	1.873170732	7.79	-7.57	2
1000	10000	1.5456	0.0046	1.541	7.83	-7.58	1.76
1000	12000	1.407333333	0.1198333333	1.2875	7.87	-7.58	1.4
1000	15000	1.269733333	0.2330666667	1.036666667	7.96	-7.59	1.12
1000	27000	1.02437037	0.444	0.5803703704	8.06	-7.61	0.64

Data recorded: Window Comparator

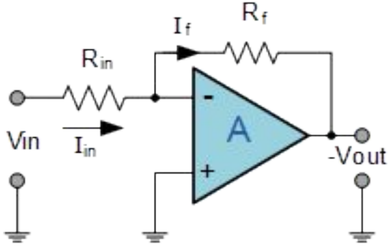
	VUL	VLL
expected	5.562	2.77
observed	5.584	2.78

Full TVC Circuit



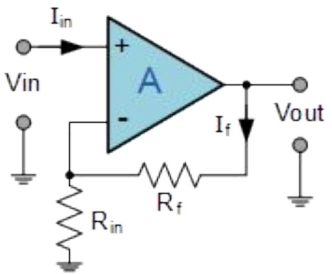
Extras

Inverting Op-amp



$$A = \frac{Vout}{Vin} = -\frac{Rf}{Rin}$$

Non-inverting Op-amp



$$A = \frac{Vout}{Vin} = 1 + \frac{Rf}{Rin}$$