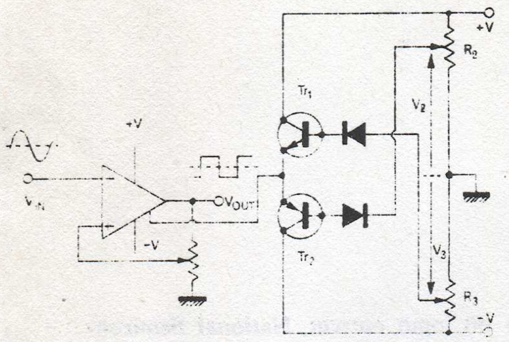
Wireless World Circard

Series 2: Comparators & Schmitts–1

Op-amp comparator/Schmitt (bipolar clamping)



For $0 < V_2 < 3V$
$V^+_{out} \approx V_2 + 3V_{be}$
$V^+_{clamp} = V^+_{out} - V_{be}$.
For $-3V < V_3 < 0$
$V^-_{out} \approx V_3 - 3V_{be}$
$V^-_{clamp} \approx V^-_{out} + V_{be}$.

Typical performance
Supplies: $\pm 5V$; IC: 748
Tr_1: BC125; Tr_2: BC126
Diodes: 1N914
R_1, R_2, R_3: 10kΩ
With $V_{in} = 1V$ pk-pk at 10kHz, $V\pm_{out}$ adjustable ± 1.6 to $\pm 4.4V$.
Rise and fall times ≈ 700ns.
Supply currents ± 2.5mA
Max $V_{in} = \pm V$.

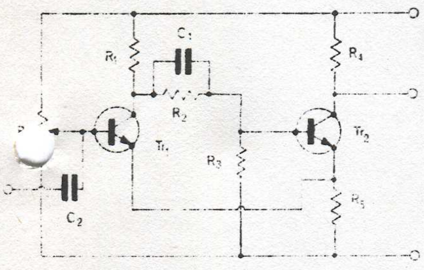
Circuit description
Operational amplifiers used as comparators (or as level-sensing circuits when positive feedback is used for hysteresis) have output swings which vary with temperature and from unit to unit. Some amplifiers have access to the drive point of the output stage and this point may be clamped at selected positive and negative potentials by zener diodes or suitably biased transistors as shown. Clipping is at much lower current levels than if attempted directly at the output. Variable resistors R_2 and R_3 set the positive and negative clamping levels, R_1 determines hysteresis at the clamping levels. Diodes provide base-emitter breakdown protection.

Component changes
Useful range of supplies: ± 5 to $\pm 18V$.
Transistors: general-purpose silicon types.
Useful range of R_1: 1 to 100kΩ.
Useful range of R_2, R_3: 1kΩ (increases supply current drawn) to 100kΩ (produces error in V_2 and V_3 unless base current loading is reduced by use of higher-gain transistors).
Useful frequency range: d.c. to approx. 160kHz. If a higher-speed operational amplifier is used, transistors may limit the frequency response unless high-speed versions are used.
Diodes may be omitted for low supply voltages and/or high reverse base-emitter breakdown transistors. Base-emitter junctions may receive supply voltage at extreme settings of R_2 and R_3.

Wireless World Circard

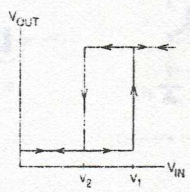
Series 2: Comparators & Schmitts–2

Basic Schmitt circuit



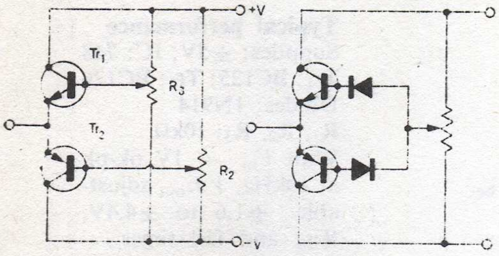
Component data
Transistors: BC125
Supply: +5V
R_1, R_4: 4.7kΩ
R_2, R_3: 2.2kΩ
R_5: 1kΩ $\pm 5\%$
R_6: 4.7kΩ pot.
C_1: 100pF (speed-up)
C_2: 2.2μF
Signal level from 500-Ω source: 2V pk-pk.
Output swing: 1.5 to 5V up to 100kHz.

Transfer characteristic



Circuit description
Emitter coupling between Tr_1 and Tr_2 introduces positive feedback causing a regenerative switching action into one of two states. When V_{in} is below threshold level V_1, Tr_1 is non-conducting and Tr_2 conducts, the base voltage being determined by R_1, R_2 and R_3. The emitter potential is then well-defined. As input voltage exceeds V_1, Tr_1 begins to conduct, reducing its collector potential, and hence that of the base and emitter of Tr_2. This drop in potential is fed back to the emitter of Tr_1, thus further increasing the conduction of Tr_1 until Tr_1 is on and Tr_2 is off. A similar regenerative action occurs when the input voltage is reduced below the threshold level V_2, returning the circuit to its original condition. A typical input-output voltage characteristic is shown above, where $V_1 - V_2$ is termed the hysteresis or backlash of the circuit.

Component changes
Resistor R_6 permits adjustment of threshold level V_1. Useful ratio R_2/R_3 is in the range 0.5 to 2.0, giving control of trip level and hysteresis range of 0.2 to 0.8V.
Useful C_1 range: 1nF to 100pF. Optimum 100pF at a source frequency of 1MHz.
Rise time: 150 to 100ns using oscilloscope probe.
For $R_4 = 1k\Omega$, $R_1 = 100\Omega$, $R_2/R_3 = 0.5$, output swing at 1MHz is 3 to 5V, for load capacitance up to 33pF.



Circuit modifications

- Diodes could be placed in series with the emitters of the transistors. This still provides base-emitter breakdown protection but the diodes then carry the larger emitter currents producing larger diode p.ds.
- R_2 and R_3 could be connected as shown on left allowing the base potentials of both Tr_1 and Tr_2 to be set positive or negative independently. It would then be possible for Tr_1 base to be positive and Tr_2 base to be negative, which would allow excessive conduction in Tr_1, Tr_2.
- Fig. on right shows a modification which allows the mean level of V_{out} to be set positive or negative by the potentiometer with its peak-to-peak value still determined by $\pm 3V_{be}$.

Further reading

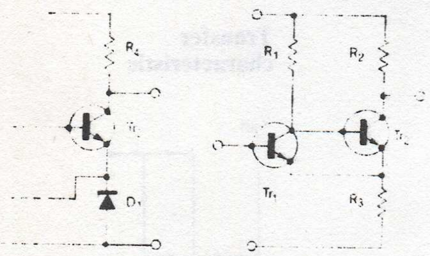
IC op.amp beats fets on input current, National Semiconductor application note AN-29, 1969, p.15.

Clayton, G. B., Operational Amplifiers, Butterworth 1971, pp.145-9.

Applications Manual for Operational Amplifiers Philbrick/Nexus Research, 1968, pp.59 & 101.

Cross references

Series 2, cards 4 & 6.



Circuit modifications

The emitter resistor may be replaced by a zener diode (left). This means the emitter potential variation is less dependent on current flow through each transistor. Typical performance:

V_{CC} 10V, D: 5.1V zener diode. R_1: 680Ω. R_2, R_4: 1.5kΩ, R_3: 3.3kΩ. Drive signal: 2V pk-pk: output swing: 5.2 to 10V. Hysteresis: 110mV.

On right,: useful range of R_3: 10 to 500Ω. Useful range of R_2 1 to 2kΩ. R_1: 1kΩ. Typical performance:

V_{CC} 5V, R_E = 10Ω, R_1 = R_2 = 1kΩ. Minimum sinusoidal drive signal at 100kHz: 2V pk-pk. Output swing: 0.8 to 5V.

Frequency may be increased to 300kHz if drive voltage is increased to 4V pk-pk.

Reference

1. Zero-hysteresis Schmitt trigger, in Electronic Circuit Design Handbook, 4th edition. 1971 p.108.

Further reading

Crump, A. E., Design of Schmitt trigger circuits, *Wireless World*, vol. 73, 1967, pp.122-7 and 175-7.

Circuit Consultant's Casebook, Hemingway, T. K., Business Books, 1970, pp.129-37.

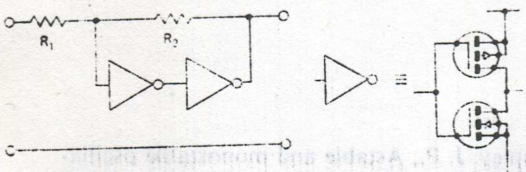
Cross references

Series 2, cards 3, 7 & 8.

Wireless World Circard

Series 2: Comparators & Schmitts–3

Complementary m.o.s. Schmitt



IC: CD4007AE (connected as triple inverter)
Supply: 10V
R_1: 1MΩ
R_2: 10MΩ
V_1: 5.9V
V_2: 5.1V
Output swing: 10V
Input current: $\pm 0.5\mu A$

Circuit description

Two c.m.o.s. inverters are cascaded with positive feedback defined by ratio R_2/R_1. Provided this ratio is less than the forward gain in the inverters' linear region, switching follows the appropriate input changes. Output swing approaches supply lines and current from source is small as very high input resistance of inverter allows R_1, R_2 to be large. With small hysteresis switching levels are near supply mid-point.

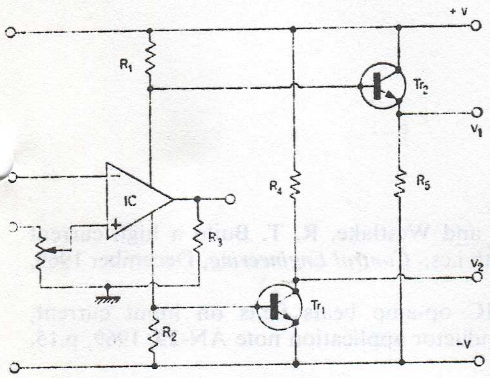
Component changes

- Any combination of inverters, gates or buffers giving voltage gain > + 1 may be used. Examples: RCA CD4001AE, Motorola MC14001 quad 2-input NOR gates; CD4009AE hex buffer inverters.
- Supply voltage + 3 to + 15V (special versions down to 1.5V).
- R_2/R_1 may be varied between 1 and 100. At upper end of range positive feedback may be too little to guarantee switching. At lower end hysteresis is comparable to supply voltage.
- To minimize capacitive effects/hum pickup reduce R_1, R_2 to ~ 10kΩ. Lower values reduce output swing and accuracy of hysteresis, while increasing current from source.

Wireless World Circard

Series 2: Comparators & Schmitts–4

High-power comparator/Schmitt



Performance data

IC: 741; Supplies ±5V
Tr_1: BFR41, Tr_2: BFR81
R_1, R_2: 220Ω, R_3: 270Ω
R_4, R_5: 68Ω, 3W
Minimum V_{in} = 800mV pk-pk.
Max. ±V = ±7V, limited by R_4 and R_5.

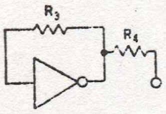
With maximum permissible sinusoidal input of 8V pk-pk, V_1 and V_2 are both square waves swinging between −5 and +4.8V, and −5 and +5V respectively. V_1 and V_2 are in-phase while the currents in R_4 and R_5 are in anti-phase. Max. frequency 1kHz—waveform squareness is lost at higher frequencies.

Circuit description

The output swing of standard op-amps is significantly less than the supply voltage, particularly when the latter is low. The current available is also low. With some op-amps the current in the positive supply lead is large when the output voltage is positive and the output current is large but is small when the output voltage is negative. The negative supply current behaves similarly. The change in supply current as the input signal varies can be used to drive following transistors which may supply currents of several hundred milliamperes at a voltage very close to the supply voltage.

Component changes

- To maximize output voltage swings Tr_1 and Tr_2 must be driven into saturation i.e. base currents of 5 to 10% of load current are required. Reducing R_3 will increase base current.
- Resistors R_1 and R_2 may need to be reduced for some op-amps having larger off-load currents (180Ω was found satisfactory for a 748).



Circuit modifications

- Buffer input with third inverter/gate increasing input resistance (typical input current ~ 10pA). Resistor R_1 may be dispensed with, the output resistance of buffer taking its place, with R_2 reduced to range 1 to 30kΩ. Resulting hysteresis in range 2.5 to 0.2V.
- Use spare inverter self-biased by large resistor (~10MΩ) (see Fig.) to bias input terminal of first inverter via second resistor (~ 10MΩ). This sets mean potential near to centre of linear region, assuming well-matched inverters. Signals may now be a.c. coupled and 200mV pk-pk typically triggers circuit over a range of supply voltage and temperature with no adjustment of bias level.

Further reading

Dean, J. A. & Rupley, J. P., Astable and monostable oscillators using RCA COSMOS digital integrated circuits, RCA application note ICAN-6267.

Schmidt, B., Schmitt trigger design uses CMOS logic, *Electronic Design*, Vol. 20, 27 April 1972, p.72.

Cross reference

Series 2, cards 1, 2 & 8.

Circuit modifications

The circuit can be altered to give a Schmitt characteristic with controllable hysteresis by connecting either V_1 or V_2 via the pot. shown to the non-inverting input of the op-amp. Using V_2 we obtain the characteristic shown right in which k is the pot tapping and V the supply voltage (5V). This hysteresis is not dependent on the saturation level of the amplifier as it would be if the amplifier output were fed back. Hysteresis width is controllable up to about 0.1V of the pk-pk value of the input provided the input is kept below about 5V pk-pk.

Further reading

Campbell, D. L. and Westlake, R. T. Build a high current servoamplifier with i.cs. *Control Engineering*, December 1969, p.91.

Widlar, R. J., IC op-amp beats f.e.ts on input current, National Semiconductor application note AN-29, 1969, p.15.

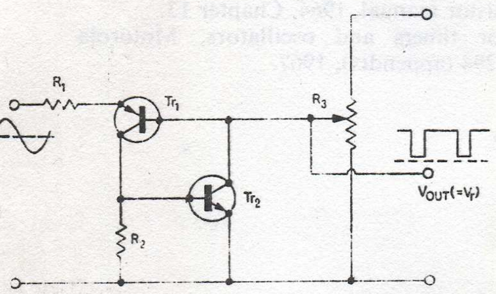
Cross references

Series 2, card 9.

Wireless World Circard

Series 2: Comparators & Schmitts–5

Unijunction-equivalent Schmitt



V_{in} (on) = $V_r + (n+1) V_{be}$ (on).
where $n = R_1/R_2$

Typical performance
Supply: +5V
Tr_1: BC126 Tr_2: BC125
R_1, R_2: 1kΩ R_3: 4.7kΩ
V_{out} (on) = 0.04V
V_{out} (off) = V_r = 2.5V
V_{in} (on) = 3.8V
V_{in} (off) 3.0V
Supply current: 8mA (on), 1mA (off)

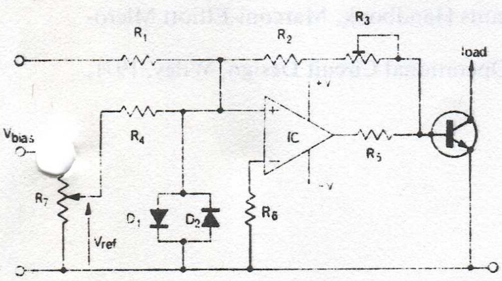
Circuit description
The transistors together have properties similar to those of a unijunction transistor. When V_{in} is low Tr_1 and Tr_2 do not conduct and V_r is defined by R_3. For $V_{in} \approx V_r + 1.3V$, Tr_1 and Tr_2 begin to conduct, regenerative switching via Tr_2 clamping V_{out} close to 0V. Reversal of switching occurs when V_{in} falls. Significant current is drawn from the source unless a limiting resistor (R_1) is included.

Component changes
Tr_1: any general purpose p-n-p silicon transistor.
Tr_2: any general purpose n-p-n silicon transistor.
Maximum useful frequency ≈ 100kHz.
Range of V_r source resistance (seen by Tr_1 base): about 2.2kΩ to 33kΩ.
R_1 (max) ≈ 3.3kΩ. For large R_1 values V_r source resistance must be increased for rapid switching action. The output can only be lightly loaded with large V_r source resistance.

Wireless World Circard

Series 2: Comparators & Schmitts–6

Variable hysteresis level detector



Component data
Supplies: ±15V
R_1, R_4: 2.2kΩ
R_2: 100kΩ
R_3: 100MΩ
R_5: 3.3kΩ
R_6: 1kΩ
R_7: 1kΩ
D_1, D_2: general-purpose diodes.
IC: 741
Tr: ME4103 (in general determined by driving circuit)
All resistors ±5%.

Circuit description
V_{ref} adjusts the level at which the output switches without affecting hysteresis. Positive feedback path R_2 and R_3 provides hysteresis controllable by R_3. Sensitivity can be modified by changing input resistance R_1. Positive output swing is determined by the base-emitter voltage of the transistor and the negative output by the particular operational amplifier used. Diodes on the input provide breakdown protection of the op-amp against excessive input voltages.

Component changes
IC: 748 or LM301A.
For V_{ref} of −1V to −14V, R_3 = 0, supplies: ±15V;
hysteresis: 180mV ±2%;
trip level: V_{ref} + 200mV.
For V_{ref} of −1V to −4V, R_3 = 0, supplies: ±5V;
hysteresis: 700mV ±5%;
trip level: V_{ref} + 100mV;
Hysteresis: 10mV, R_3 = 1MΩ, supplies: ±10→±15V; trip level: V_{ref} + 100mV.
In general, hysteresis may be further increased by reducing $R_2 + R_3$.

Circuit modifications

If the input voltage is fed directly to Tr_1 emitter the circuit may be used to clamp it to a low level (about 0.7V with a 5V supply) when it exceeds some maximum permissible level. For example, V_r could be the output from a voltage regulator and V_{in} its input voltage. If V_{in} (regulator input) rises excessively the circuit will rapidly clamp the regulator input to a low value protecting the regulator and the circuitry it supplies during the time taken for the supply fuse to blow. The transistors require a current rating greater than the supply peak current on s.c. loading. R_2 and R_3 may then need to be reduced.

Further reading

General Electric transistor manual, 1964, Chapter 13.
Unijunction transistor timers and oscillators, Motorola application note AN-294 (appendix), 1967.

Cross references

Series 2, cards 2 & 12.

Circuit modifications

- If output voltage swing required at lower currents, Tr may be omitted and R_5 reduced to zero. Hysteresis is then controlled by op-amp output swing.
- Alternative methods of defining output swing and hence hysteresis include series back-to-back zener diode or diode limiting circuits.
- For higher speed operation, IC may be any comparator.
- For higher output currents, Tr may be replaced by a Darlington pair. If only an indication of output state is required, most op-amps can deliver sufficient current to drive small light-emitting diodes.

Further reading

Linear Integrated Circuits Handbook, Marconi-Elliott Micro-electronics, pp.167/8.
Smith, J. I., Modern Operational Circuit Design, Wiley, 1971, pp.186/7.

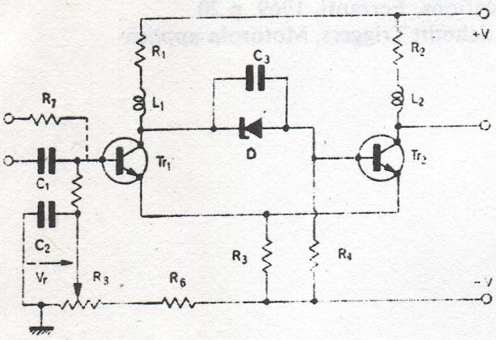
Cross references

Series 2, cards 9–11.

Wireless World Circard

Series 2: Comparators & Schmitts–7

High-speed Schmitt circuit



Typical performance
Supplies: ±5V
Tr_1, Tr_2: BSX20
D_1 = BZX55, C3V9
R_1, R_2, R_3, R_5, R_7: 100Ω
R_4 10kΩ.
R_6: 3.3kΩ: R_8: 1kΩ
C_1, C_2: 0.1μF: C_3: 27pF
L_1, L_2: 0

V_r = −1.0V; V_{in} (Tr_2on) = −2.02V; V_{in}(Tr_2off) = −0.31V
Hysteresis: 1.71V
V_{out}(on) = 0.2V
Supply current
+40mA, −50mA Tr_2off
+43mA, −51.5mA Tr_2on

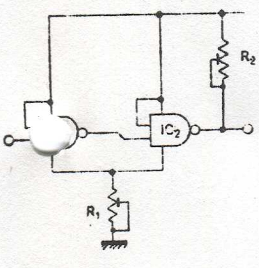
Component changes
Useful range of V_r: 0 to −1.47V
Corresponding hysteresis range: 2.9 to 1.64V.
L_1 and L_2 can be adjusted to produce a required rise time with a defined overshoot for given capacitive loading. The same principle applies to the complementary Schmitt. With $L_1 = L_2 = 0.11\mu H$, rise time < 8ns with 5% overshoot at low switching rates.
The circuit functions to at least 40MHz with defined output levels although the waveform is rounded at high frequencies. Careful printed circuit layout is necessary for good high-frequency operation.

Circuit description
For maximum speed, Schmitt trigger circuits should operate with the transistors out of saturation at all times. A zener diode in the bias network can assist this. In this circuit, current levels are higher than in the basic Schmitt to maximize gain-bandwith product. The inductors compensate for capacitive loading to optimize rise time. The upper and lower thresholds are negative and the hysteresis is variable but is not independent of the threshold levels.

Wireless World Circard

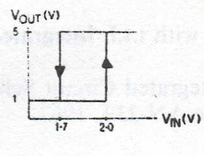
Series 2: Comparators & Schmitts–8

TTL Schmitt circuit



Performance data
Graph obtained with R_2: 250Ω, R_1: 30Ω
Supply: 5V
ICs: 7400
Frequency 0 to 1MHz.
Threshold values and hence hysteresis may be changed slightly by varying R_1 and R_2.

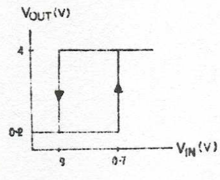
Lower limit (1V as shown) is affected by R_1 and R_2.
With R_1 = 0 there is no positive feedback and switching is not clean. With R_2 = ∞ upper limit is reduced from 5V.



Circuit description
Each NAND gate with one input gate disabled behaves as an inverter. The circuit with positive feedback via R_1 is very similar to the basic Schmitt trigger as each gate is essentially identical. This results in the potential across R_1 being constant and independent of which inverter is enabled. This results in an offset voltage compensated by R_2.

Component changes
Any t.t.l. inverter may be used.

Circuit modifications
An alternative t.t.l. Schmitt is SN7413, produced by Texas, and has two in a single package. Typical characteristics are shown below. Frequencies up to several MHz can be handled, but ringing may occur beyond 100kHz if the circuit layout is poor.



Circuit modifications
Precise adjustment of the negative rail voltage allows the output to be made truly t.t.l.-compatible with levels of 0V and +5V. The output from Tr_2 may be used to feed a high-speed t.t.l. gate or an e.c.l. gate to "square up" the waveform at high frequencies. Circuits of this type may be useful in conjunction with t.t.l. or e.c.l. circuitry as they provide alternative options of switching levels and hysteresis. To assist supply decoupling at high frequencies, ferrite beads can be added to the supply line wiring.

Further reading
E-Line Transistors Applications, Ferranti, 1969. p.20.
MECL Integrated Circuit Schmitt Triggers, Motorola application note AN-239.

Cross references
Series 2, card 2 & 8.

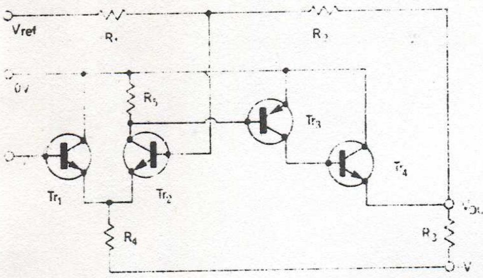
Further reading
Electronic Circuit Design Handbook, Tab Books, 4th edition, p.129.
Designing with t.t.l. Integrated Circuits, McGraw-Hill, 1971. pp.53-7.
MECL Integrated Circuit Schmitt Triggers, Motorola application note AN-239, 1967.

Cross references
Series 2, cards 2, 3 & 7.

Wireless World Circard

Series 2: Comparators & Schmitts–9

Low-voltage level sensor



Supply: –12V
V_{ref}: –1V
Tr_1, Tr_2, Tr_4: BC125
Tr_3: BC126
Switching levels
on: –1.35V
off: –1.03V

R_1: 3.3kΩ
R_2: 100kΩ
R_3: 470Ω
R_4: 82kΩ
R_5: 10kΩ

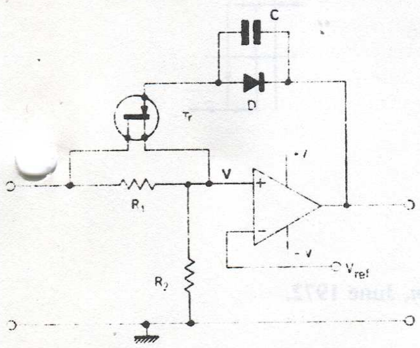
Circuit description
Operation from single-ended supplies makes level-sensing of low voltages difficult (lower limit usually set by transistor V_{be}). Taking signal and reference voltages with respect to opposite side of supply as shown allows much reduced triggering voltages. A long-tailed pair drives an inverting stage with positive feedback from the output to the non-inverting input. Input current is small, reducing to zero after switching. For positive-going signals, a complementary version using a positive supply voltage gives comparable results.

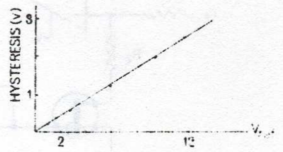
Component changes
- Supply voltage –5 to –25V, upper value depending on transistor breakdown. At lower voltages, switching levels become more supply sensitive. Reduce R_4 at lower supply voltages to keep current in it to ≃ 120μA.
- Reference voltage –200mV to –5V.
- Load currents up to 100mA possible with no change in circuit. Replacing Tr_4 by higher rating transistor, and scaling all resistors down by factor of 5 allows load currents of up to 0.5A (BFR41, BFY50 etc).
- Tr_1—Tr_4 replaced by any general-purpose silicon planar transistors results in comparable performance: matched pair at input reduces drift.

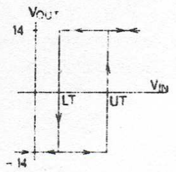
Wireless World Circard

Series 2: Comparators & Schmitts–10

Reference-controlled hysteresis circuit



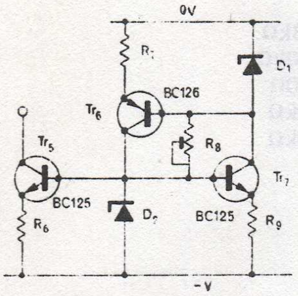




Performance data
Graphs obtained with
Supplies: ±15V
Tr: Motorola 2N4092
D: 1N914, IC: 741
R_1: 5.6kΩ ±5%
R_2: 27kΩ ±5%
C: 100pF
Lower threshold (l.t.): V_{ref}
Upper (u.t.): $V_{ref}\cdot(R_1+R_2)/R_2$
Hysteresis: V_{ref} R_1/R_2
Max. frequency: 300Hz
V_{ref} must remain positive.

Circuit description
With a low V_{in}, V_{out} is initially negative and the f.e.t. switch if off. V' is then given by $V_{in}.R_2/(R_1+R_2)$. Increasing V_{in} until V' is just greater than V_{ref} causes V_{out} to change sign, the f.e.t. then conducts and shorts out R_1 making V' equal to V_{in} and forcing V_{out} to become even more positive. V_{out} will only become negative again when V_{in} is reduced below V_{ref}. The positive feedback does not come into action immediately V_{out} starts to leave its saturated condition, so the output may lie between the saturated levels.

Component changes
Using a 748 op-amp the maximum frequency can be extended to 4kHz. National Semiconductor f.e.t. 2N3819/7127 may be used. R_1 is chosen such that the f.e.t. on-resistance is much lower than R_1 and the off-resistance is much higher than R_1. Varying R_1 and R_2 hysteresis of $0.1V_{ref}$ and $10V_{ref}$ can easily be obtained. Choice of diode and capacitor is not critical.



Circuit modifications

- Reference and signal inputs may be interchanged if minimum current drain from reference is required.
- Replacing R_4 by constant-current circuit minimizes shift of switching levels with varying supply voltage. Fig. shows a ring-of-two reference circuit biasing constant-current stage, and providing stable voltage across R_7 to act as switching-level reference. Replaced by potentiometer for variable reference.
- Tapping R_2 with a zener diode to 0-V line stabilizes hysteresis without limiting output voltage swing.
- For light loading Tr_4 may be omitted.

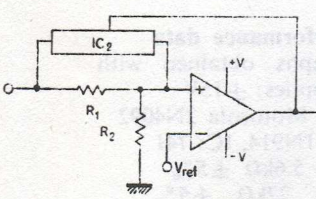
Further reading

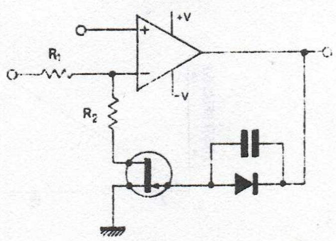
Williams, P., Low-voltage level-sensing circuit, *Electronic Engineering*, 1968, pp.517-9.

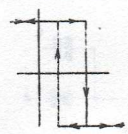
Callahan, M. J., Integrated level detector, *IEEE Journal of Solid-State Circuits*, vol. SC-7, 1972, pp.185-8.

Cross reference

Series 2, cards 6, 10 & 11.







Circuit modifications

- With a negative V_{ref}, V' should be connected to the inverting input and V_{ref} to the non-inverting input to obtain the positive feedback switching action.
- With a low reference voltage and low supply voltage (e.g. <1V with ±5V supply), f.e.t. pinch-off voltage causes unsatisfactory switching. The f.e.t. and its associated diode and capacitor may be replaced by a c.m.o.s. switch, left. The switch used was CD4016AE, the minimum R_1 in this case being about 10kΩ.
- For applications where V_0 is required to be positive, for positive V_{ref} and small V_{in}, one may use the circuit on right, the resulting characteristic being as shown on right. The formulae for the upper and lower thresholds and the hysteresis are the same as those for the original circuit.

Further reading

G. S. Oshiro, *Electronic Design*, June 1972.

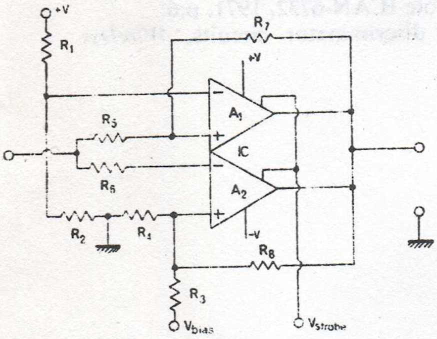
Cross reference

Series 2, cards 4 & 6.

Wireless World Circard

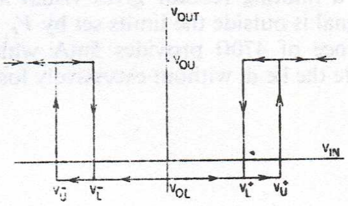
Series 2: Comparators & Schmitts–11

'Window' detector



Typical performance
IC: 711
Supplies +12V, -6V
V_{strobe} = +5V; V_{bias} -12V
R_1, R_3: 5.6kΩ
R_2, R_4, R_5, R_6: 470Ω
R_7, R_8: 22kΩ
V^+_U = 953mV; V^+_L = 886mV (i.e. V_{OU} hysteresis = 67mV)
V^-_U = -946mV; V^-_L = -879mV (i.e. V_{OL} hysteresis = 67mV)

V_{OU} = +4.4V; V_{OL} = -0.4V (inputs commoned)
Supply current: +11.5mA, -5mA
Strobe current: 76μA
Bias current: 2.2mA



Circuit description

A_1 is a non-inverting comparator having a positive reference level (V_{r_+}) set by R_1 and R_2. Amplifier A_2 is an inverting comparator having a negative reference (V_{r_-}) set by R_3 and R_4. V_{out} remains at a low level when $V_{r_-} < V_{in} < V_{r_+}$ and A_2 is capable of switching its output to $+V_{OU}$ when $V_{in} < V_{r_-}$. As the outputs of A_1 and A_2 are common, V_{out} = $+V_{OU}$ when $V_{in} < V_{r_-}$, or when $V_{in} > V_{r_+}$. Hysteresis is introduced by the positive feedback on A_1 (by R_7 and R_5) and A_2 (by R_8 and R_4). See transfer characteristic above. From an output level viewpoint the circuit is t.t.l. compatible.

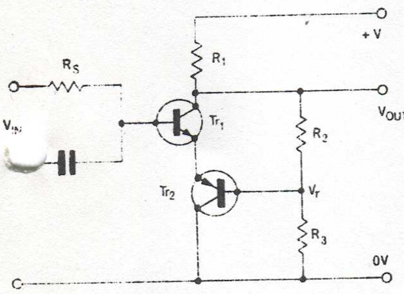
Component changes

Maximum useful frequency ≈ 1MHz.
V_{OU} may be varied over the range +0.4 to 4.4V by setting V_{strobe} in the range +1 to +5V. V_{OL} remains fixed at -0.4V. Variation of R_1 and/or R_3 provides independent control of the positive and negative threshold levels. Minimum useful value of R_1 and/or R_3 ≈ 700Ω.
Minimum load resistance (for 10% reduction of V_{OU}) ≈ 680Ω.

Wireless World Circard

Series 2: Comparators & Schmitts–12

Complementary Schmitt



Typical data
V_{in} (on) = V_r + $2V_{be}$
Supply: +12V
Tr_1: BC125; Tr_2: BC126
R_1, R_3: 1kΩ; R_2: 10kΩ
R_s: 100Ω; C_1: 0.1μF
V_{in}(on) = 2.16V
V_{in}(off) = 1.59V
hysteresis = 0.57V
V_O (on) = 1.0V
V_O(off) = 11V
Supply current:
10.5mA (on), 1mA (off)

Circuit description

This is a complementary form of circuit using emitter coupling, as in the classic Schmitt. Neither transistor conducts for low input voltages. When V_{in} exceeds $V_r + 2V_{be}$, both transistors conduct causing the output voltage to fall regeneratively. With suitable resistance values, the supply current in the off state can be made much less than in the on state.

Component changes

- Varying R_2 in the range 5 to 20kΩ allows the hysteresis to be adjusted within the range 1.16 to 0.21V, without significantly changing V_{in} (off).
V_n(on) correspondingly varies in the range 2.81 to 1.74V.
- If Tr_2 is a high-current-gain transistor V_{in} (off) ≈ $2V_{be}$; with a lower gain transistor V_{in} (off) will be increased due to the significant p.d. across R_3 produced by Tr_2 base current.
- A speed-up capacitor of about 27pF across R_2 improves the turn-on time from about 90ns to 30ns. Turn-off time is typically 90ns. Maximum useful frequency is typically 2MHz.

Circuit modifications

- Where hysteresis is not required the positive feedback resistors may be omitted.
- A visible-light-emitting diode connected to output terminal through a limiting resistor gives visual indication when the input signal is outside the limits set by V_{r_1} and V_{r_2}. Typically a resistance of 470Ω provides 5mA which is sufficient to illuminate the l.e.d. without excessively loading the IC.

Further reading

Application of linear microcircuits. SGS, 1969. pp.105-6.
Op-amp circuit collection, National Semiconductor application note AN-31, 1970, p.3.
Measurement of burst ("popcorn") noise in linear integrated circuits, RCA application note ICAN-6732, 1971. p.6.
Cole, H. A., Differential discriminator circuits, *Wireless World*, 1971, pp.603-4.

Cross references

Series 2, card 6.

Circuit modifications

A 47-Ω resistor included in series with the 'free collector' of Tr_2 provides a complementary pulse output. These pulses typically have an amplitude of 0.6V (with a 12-V supply) i.e. sufficient to drive a following transistor or thyristor. Tr_1 will still saturate and Tr_2 will remain unsaturated. The value of this resistor may be considerably increased if it is returned to a separate negative supply. With a value $\leqslant R_1$ a second output is then available without significantly changing the circuit action.

Further reading

Hemingway, T. K., Electronic Designer's Handbook, Business Books, 1970, 2nd edition, pp.177-181.
Feinberg, R., Handbook of Electronic Circuits, Chapman and Hall, 1966, p.52.

Cross references

Series 2, cards 2 & 5.