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Electronic comparator circuit with hysteresisThis article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources:"Schmitt trigger"news newspapers books scholar JSTOR (March 2021) (Learn how and when to remove this message)Transfer function of a Schmitt trigger. The horizontal and vertical axes are input voltage and output voltage, respectively. T and T are the switching thresholds, and M and M are the output voltage levels.In electronics, a Schmitt trigger is a comparator circuit with hysteresis implemented by applying positive feedback to the noninverting input of a comparator or differential amplifier. It is an active circuit which converts an analog input signal to a digital output signal. The circuit is named a trigger because the output retains its value until the input changes sufficiently to trigger a change. In the non-inverting configuration, when the input is higher than a chosen threshold, the output is high. When the input is below a different (lower) chosen threshold the output is low, and when the input is between the two levels the output retains its value. This dual threshold action is called hysteresis and implies that the Schmitt trigger possesses memory and can act as a bistable multivibrator (latch or flip-flop). There is a close relation between the two kinds of circuits: a Schmitt trigger can be converted into a latch and a latch can be converted into a Schmitt trigger.Schmitt trigger devices are typically used in signal conditioning applications to remove noise from signals used in digital circuits, particularly mechanical contact bounce in switches. They are also used in closed loop negative feedback configurations to implement relaxation oscillators, used in function generators and switching power supplies.Comparison of the action of an ordinary comparator (A) and a Schmitt trigger (B) on a noisy analog input signal (U). The green dotted lines are the circuit's switching thresholds. The Schmitt trigger tends to remove noise from the signal.In signal theory, a schmitt trigger is essentially a one-bit quantizer.The Schmitt trigger was invented by American scientist Otto H. Schmitt in 1934 while he was a graduate student,[1] later described in his doctoral dissertation (1937) as a thermionic trigger.[2] It was a direct result of Schmitt's study of the neural impulse propagation in squid nerves.[2]Block diagram of a Schmitt trigger circuit. It is a system with positive feedback in which the output signal fed back into the input causes the amplifier A to switch rapidly from one saturated state to the other when the input crosses a threshold. A > 1 is the amplifier gain B < 1 is the feedback transfer functionCircuits with hysteresis are based on positive feedback. Any active circuit can be made to behave as a Schmitt trigger by applying positive feedback so that the loop gain is more than one. The positive feedback is introduced by adding a part of the output voltage to the input voltage. These circuits contain an attenuator (the B box in the figure on the right) and an adder (the circle with "+" inside) in addition to an amplifier acting as a comparator. There are three specific techniques for implementing this general idea. The first two of them are dual versions (series and parallel) of the general positive feedback system. In these configurations, the output voltage increases the effective difference input voltage of the comparator by "decreasing the threshold" or by "increasing the circuit input voltage"; the threshold and memory properties are incorporated in one element. In the third technique, the threshold and memory properties are separated.Dynamic threshold (series feedback): when the input voltage crosses the threshold in either direction, the circuit itself changes its own threshold to the opposite direction. For this purpose, it subtracts a part of its output voltage from the threshold (it is equal to adding voltage to the input voltage). Thus the output affects the threshold and does not affect the input voltage. These circuits are implemented by a differential amplifier with "series positive feedback" where the input is connected to the inverting input and the inverted output to the non-inverting input. In this arrangement, attenuation and summation are separated: a voltage divider acts as an attenuator and the loop acts as a simple series voltage summer. Examples are the classic transistor emitter-coupled Schmitt trigger, the op-amp inverting Schmitt trigger, etc.Modified input voltage (parallel feedback): when the input voltage crosses the threshold in either direction the circuit changes its input voltage in the same direction (now it adds a part of its output voltage directly to the input voltage). Thus the output augments the input voltage and does not affect the threshold. These circuits can be implemented by a single-ended non-inverting amplifier with "parallel positive feedback" where the input and the output sources are connected through resistors to the input. The two resistors form a weighted parallel summer incorporating both the attenuation and summation. Examples are the less familiar collector-base coupled Schmitt trigger, the op-amp non-inverting Schmitt trigger, etc.Some circuits and elements exhibiting negative resistance can also act in a similar way: negative impedance converters (NIC), neon lamps, tunnel diodes (e.g., a diode with an N-shaped currentvoltage characteristic in the first quadrant), etc. In the last case, an oscillating input will cause the diode to move from one rising leg of the "N" to the other and back again as the input crosses the rising and falling switching thresholds.Two different unidirectional thresholds are assigned in this case to two separate open-loop comparators (without hysteresis) driving a bistable multivibrator (latch) or flip-flop. The trigger is toggled high when the input voltage crosses down to up the high threshold and low when the input voltage crosses up to down the low threshold. Again, there is a positive feedback, but now it is concentrated only in the memory cell. Examples are the 555 timer and the switch debouncing circuit.[3]The Schmitt trigger symbol shown with a non-inverting hysteresis curve embedded in a buffer. Schmitt triggers can also be shown with inverting hysteresis curves and may be followed by bubbles. The documentation for the particular Schmitt trigger being used must be consulted to determine whether the device is non-inverting (i.e., where positive output transitions are caused by positive-going inputs) or inverting (i.e., where positive output transitions are caused by negative-going inputs).The symbol for Schmitt triggers in circuit diagrams is a triangle with a symbol inside representing its ideal hysteresis curve.Schmitt trigger implemented by two emitter-coupled BJTs stages.The original Schmitt trigger is based on the dynamic threshold idea that is implemented by a voltage divider with a switchable upper leg (the collector resistors RC1 and RC2) and a steady lower leg (RE). Q1 acts as a comparator with a differential input (Q1 base-emitter junction) consisting of an inverting (Q1 base) and a non-inverting (Q1 emitter) inputs. The input voltage is applied to the inverting input; the output voltage of the voltage divider is applied to the non-inverting input thus determining its threshold. The comparator output drives the second common collector stage Q2 (an emitter follower) through the voltage divider R1-R2. The emitter-coupled transistors Q1 and Q2 actually compose an electronic double throw switch that switches over the upper legs of the voltage divider and changes the threshold in a different (to the input voltage) direction.This configuration can be considered as a differential amplifier with series positive feedback between its non-inverting input (Q2 base) and output (Q1 collector) that forces the transition process. There is also a smaller negative feedback introduced by the emitter resistor RE. To make the positive feedback dominate over the negative one and to obtain a hysteresis, the proportion between the two collector resistors is chosen so that RC1 > RC2. Thus less current flows through and there is less voltage drop across RE when Q1 is switched on than in the case when Q2 is switched on. As a result, the circuit has two different thresholds in regard to ground (V in the image).Initial state. For the NPN transistors shown on the right, imagine the input voltage is below the shared emitter voltage (high threshold for concreteness) so that the Q1 base-emitter junction is reverse-biased and Q1 does not conduct. The Q2 base voltage is determined by the divider described above so that Q2 is conducting and the trigger output is in the low state. The two resistors RC2 and RE form another voltage divider that determines the high threshold. Neglecting VBE, the high threshold value is approximately V H T = R E R E + R C 2 V + {\displaystyle V_{\mathrm {HT} }={\frac {R_{\mathrm {E} }}{R_{\mathrm {E} }+R_{\mathrm {C2} }}}}{V_{+}}} .The output voltage is low but well above ground. It is approximately equal to the high threshold and may not be low enough to be a logical zero for subsequent digital circuits. This may require an additional level shifting circuit following the trigger circuit.Crossing up the high threshold. When the input voltage (Q1 base voltage) rises slightly above the voltage across the emitter resistor RE (the high threshold), Q1 begins conducting. Its collector voltage goes down and Q2 starts toward cutoff, because the voltage divider now provides lower Q2 base voltage. The common emitter voltage follows this change and goes down, making Q1 conduct more. The current begins to steer from the right leg of the circuit to the left one. Although Q1 is conducting more, it passes less current through RE (since RC1 > RC2); the emitter voltage continues dropping and the effective Q1 base-emitter voltage continuously increases. This avalanche-like process continues until Q1 becomes completely turned on (saturated) and Q2 turned off. The trigger transitions to the high state and the output (Q2's collector) voltage is close to V+. Now the two resistors RC1 and RE form a voltage divider that determines the low threshold. Its value is approximately V L T = R E R E + R C 1 V + {\displaystyle V_{\mathrm {LT} }={\frac {R_{\mathrm {E} }}{R_{\mathrm {E} }+R_{\mathrm {C1} }}}}{V_{+}}} .Crossing down the low threshold. With the trigger now in the high state, if the input voltage drops enough (below the low threshold), Q1 begins cutting off. Its collector current reduces; as a result, the shared emitter voltage drops slightly and Q1's collector voltage rises significantly. The R1-R2 voltage divider conveys this change to the Q2 base voltage and it begins conducting. The voltage across RE rises, further reducing the Q1 base-emitter potential in the same avalanche-like manner, and Q1 ceases to conduct. Q2 becomes completely turned on (saturated) and the output voltage becomes low again.Symbol depicting an inverting Schmitt trigger by showing an inverted hysteresis curve inside a buffer. Other symbols show a hysteresis curve (which may be inverting or non-inverting) embedded in a buffer followed by a bubble, which is similar to the traditional symbol for a digital inverter that shows a buffer followed by a bubble. In general, the direction of the Schmitt trigger (inverting or non-inverting) is not necessarily clear from the symbol because multiple conventions are used, even with the same manufacturer. There are several factors leading to such ambiguity,[nb 1] These circumstances may warrant a closer investigation of the documentation for each particular Schmitt trigger.Non-inverting circuit. The classic non-inverting Schmitt trigger can be turned into an inverting trigger by taking Vout from the emitters instead of from a Q2 collector. In this configuration, the output voltage is equal to the dynamic threshold (the shared emitter voltage) and both the output levels stay away from the supply rails. Another disadvantage is that the load changes the thresholds so, it has to be high enough. The base resistor RB is obligatory to prevent the impact of the input voltage through Q1 base-emitter junction on the emitter voltage.Direct-coupled circuit. To simplify the circuit, the R1R2 voltage divider can be omitted connecting Q1 collector directly to Q2 base. The base resistor RB can be omitted as well so that the input voltage source drives directly Q1's base.[4] In this case, the common emitter voltage and Q1 collector voltage are not suitable for outputs. Only Q2 collector should be used as an output since, when the input voltage exceeds the high threshold and Q1 saturates, its base-emitter junction is forward biased and transfers the input voltage variations directly to the emitters. As a result, the common emitter voltage and Q1 collector voltage follow the input voltage. This situation is typical for over-driven transistor differential amplifiers and ECL gates.BJT bistable collector-base coupled circuit can be converted to a Schmitt trigger by connecting an additional base resistor to one of the basesLike every latch, the fundamental collector-base coupled bistable circuit operates with hysteresis. It can be converted to a Schmitt trigger by connecting an additional base resistor R to one of the inputs (Q1's base in the figure). The two resistors R and R4 form a parallel voltage summer (the circle in the block diagram above) that sums output (Q2's collector) voltage and the input voltage, and drives the single-ended transistor "comparator" Q1. When the base voltage crosses the threshold (VBE0 0.65 V) in either direction, a part of Q2's collector voltage is added in the same direction to the input voltage. Thus the output modifies the input voltage by means of parallel positive feedback and does not affect the threshold (the base-emitter voltage).The emitter-coupled version has the advantage that the input transistor is reverse biased when the input voltage is quite below the high threshold so the transistor is definitely cut off. This was important when germanium transistors were used for implementing the circuit, and this configuration has continued to be popular. The input base resistor can be omitted, since the emitter resistor limits the current when the input base-emitter junction is forward-biased.An emitter-coupled Schmitt trigger logical zero output level may not be low enough and might need an additional output level shifting circuit. The collector-coupled Schmitt trigger has extremely low (almost zero) output at logical zero.Schmitt triggers are commonly implemented using an operational amplifier or a dedicated comparator.[nb 2] An open-loop op-amp and comparator may be considered as an analog-digital device having analog inputs and a digital output that extracts the sign of the voltage difference between its two inputs.[nb 3] The positive feedback is applied by adding a part of the output voltage to the input voltage in series or parallel manner. Due to the extremely high op-amp gain, the loop gain is also high enough and provides the avalanche-like process.Schmitt trigger implemented by a non-inverting comparatorIn this circuit, the two resistors R1 and R2 form a parallel voltage summer. It adds a part of the output voltage to the input voltage thus augmenting it during and after switching that occurs when the resulting voltage is near ground. This parallel positive feedback creates the needed hysteresis that is controlled by the proportion between the resistances of R1 and R2. The output of the parallel voltage summer is single-ended (it produces voltage with respect to ground) so the circuit does not need an amplifier with a differential input. Since conventional op-amps have a differential input, the inverting input is grounded to make the reference point zero volts.The output voltage always has the same sign as the op-amp input voltage but it does not always have the same sign as the circuit input voltage (the signs of the two input voltages can differ). When the circuit input voltage is above the high threshold or below the low threshold, the output voltage has the same sign as the circuit input voltage (the circuit is non-inverting). It acts like a comparator that switches at a different point depending on whether the output of the comparator is high or low. When the circuit input voltage is between the thresholds, the output voltage is undefined and it depends on the last state (the circuit behaves as an elementary latch).Typical transfer function of a non-inverting Schmitt trigger like the circuit above. For instance, if the Schmitt trigger is currently in the high state, the output will be at the positive power supply rail (+VS). The output voltage V+ of the resistive summer can be found by applying the superposition theorem: V + = R 2 R 1 + R 2 V i n + R 1 R 1 + R 2 V s {\displaystyle V_{\mathrm {+} }={\frac {R_{2}}{R_{1}+R_{2}}}\cdot V_{\mathrm {in} }+{\frac {R_{1}}{R_{1}+R_{2}}}\cdot V_{\mathrm {s} }} The comparator will switch when V+=0. Then R 2 V i n = R 1 V s {\displaystyle {R_{2}}\cdot V_{\mathrm {in} }=-{R_{1}}\cdot V_{\mathrm {s} }} (the same result can be obtained by applying the current conservation principle). So V in {\displaystyle V_{\text{in}}} must drop below R 1 R 2 V s {\displaystyle -{\frac {R_{1}}{R_{2}}}{V_{s}}} to get the output to switch. Once the comparator output has switched to VS, the threshold becomes + R 1 R 2 V s {\displaystyle +{\frac {R_{1}}{R_{2}}}{V_{s}}} to switch back to high. So this circuit creates a switching band centered on zero, with trigger levels R 1 R 2 V s {\displaystyle \pm {\frac {R_{1}}{R_{2}}}{V_{s}}} (it can be shifted to the left or the right by applying a bias voltage to the inverting input). The input voltage must rise above the top of the band, and then below the bottom of the band, for the output to switch on (plus) and then back off (minus). If R1 is zero or R2 is infinity (i.e., an open circuit), the band collapses to zero width, and it behaves as a standard comparator. The transfer characteristic is shown in the picture on the left. The value of the threshold T is given by R 1 R 2 V s {\displaystyle {\frac {R_{1}}{R_{2}}}{V_{s}}} and the maximum value of the output M is the power supply rail.A practical Schmitt trigger configuration with precise thresholdsA unique property of circuits with parallel positive feedback is the impact on the input source.[citation needed] In circuits with negative parallel feedback (e.g., an inverting amplifier), the virtual ground at the inverting input separates the input source from the op-amp output. Here there is no virtual ground, and the steady op-amp output voltage is applied through R1-R2 network to the input source. The op-amp output passes an opposite current through the input source (it injects current into the source when the input voltage is positive and it draws current from the source when it is negative).A practical Schmitt trigger with precise thresholds is shown in the figure on the right. The transfer characteristic has exactly the same shape of the previous basic configuration, and the threshold values are the same as well. On the other hand, in the previous case, the output voltage was depending on the power supply, while now it is defined by the Zener diodes (which could also be replaced with a single double-anode Zener diode). In this configuration, the output levels can be modified by appropriate choice of Zener diode, and these levels are resistant to power supply fluctuations (i.e., they increase the PSRR of the comparator). The resistor R3 is there to limit the current through the diodes, and the resistor R4 minimizes the input voltage offset caused by the comparator's input leakage currents (see limitations of real op-amps).Schmitt trigger implemented by an inverting comparatorIn the inverting version, the attenuation and summation are separated. The two resistors R1 and R2 act only as a "pure" attenuator (voltage divider). The input loop acts as a series voltage summer that adds a part of the output voltage in series to the circuit input voltage. This series positive feedback creates the needed hysteresis that is controlled by the proportion between the resistances of R1 and the whole resistance (R1 and R2). The effective voltage applied to the op-amp input is floating so the op-amp must have a differential input.The circuit is named inverting since the output voltage always has an opposite sign to the input voltage when it is out of the hysteresis cycle (when the input voltage is above the high threshold or below the low threshold). However, if the input voltage is within the hysteresis cycle (between the high and low thresholds), the circuit can be inverting as well as non-inverting. The output voltage is undefined and it depends on the last state so the circuit behaves like an elementary latch.To compare the two versions, the circuit operation will be considered at the same conditions as above. If the Schmitt trigger is currently in the high state, the output will be at the positive power supply rail (+VS). The output voltage V+ of the voltage divider is: V + = R 1 R 1 + R 2 V s {\displaystyle V_{\mathrm {+} }={\frac {R_{1}}{R_{1}+R_{2}}}\cdot V_{\mathrm {s} }} The comparator will switch when Vin = V+. So V in {\displaystyle V_{\text{in}}} must exceed above this voltage to get the output to switch. Once the comparator output has switched to VS, the threshold becomes R 1 R 1 + R 2 V s {\displaystyle -{\frac {R_{1}}{R_{1}+R_{2}}}{V_{s}}} to switch back to high. So this circuit creates a switching band centered on zero, with trigger levels R 1 R 1 + R 2 V s {\displaystyle \pm {\frac {R_{1}}{R_{1}+R_{2}}}{V_{s}}} (it can be shifted to the left or the right by connecting R1 to a bias voltage). The input voltage must rise above the top of the band, and then below the bottom of the band, for the output to switch off (minus) and then back on (plus). If R1 is zero (i.e., a short circuit) or R2 is infinity, the band collapses to zero width, and it behaves as a standard comparator.In contrast with the parallel version, this circuit does not impact on the input source since the source is separated from the voltage divider output by the high op-amp input differential impedance.In the inverting amplifier voltage drop across resistor (R1) decides the reference voltages i.e., upper threshold voltage (V+) and lower threshold voltages (V) for the comparison with input signal applied. These voltages are fixed as the output voltage and resistor values are fixed.so by changing the drop across (R1) threshold voltages can be varied. By adding a bias voltage in series with resistor (R1) drop across it can be varied, which can change threshold voltages. Desired values of reference voltages can be obtained by varying bias voltage.The above equations can be modified as: V = V s R 1 R 1 + R 2 + V b R 2 R 1 + R 2 {\displaystyle V_{\pm }=\pm V_{s}{\frac {R_{1}}{R_{1}+R_{2}}}+V_{b}{\frac {R_{2}}{R_{1}+R_{2}}}} Schmitt triggers are typically used in open loop configurations for noise immunity and closed loop configurations to implement function generators.Analog-to-digital conversion: The Schmitt trigger is effectively a one bit analog to digital converter. When the signal reaches a given level it switches from its low to high state.Level detection: The Schmitt trigger circuit is able to provide level detection. When undertaking this application, it is necessary that the hysteresis voltage is taken into account so that the circuit switches on the required voltage.Line reception: When running a data line that may have picked up noise into a logic gate it is necessary to ensure that a logic output level is only changed as the data changed and not as a result of spurious noise that may have been picked up. Using a Schmitt trigger broadly enables the peak to peak noise to reach the level of the hysteresis before spurious triggering may occur.One application of a Schmitt trigger is to increase the noise immunity in a circuit with only a single input threshold. With only one input threshold, a noisy input signal [nb 4] near that threshold could cause the output to switch rapidly back and forth from noise alone. A noisy Schmitt Trigger input signal near one threshold can cause only one switch in output value, after which it would have to move beyond the other threshold in order to cause another switch.For example, an amplified infrared photodiode may generate an electric signal that switches frequently between its absolute lowest value and its absolute highest value. This signal is then low-pass filtered to form a smooth signal that rises and falls corresponding to the relative amount of time the switching signal is on and off. That filtered output passes to the input of a Schmitt trigger. The net effect is that the output of the Schmitt trigger only passes from low to high after a received infrared signal excites the photodiode for longer than some known period, and once the Schmitt trigger is high, it only moves low after the infrared signal ceases to excite the photodiode for longer than a similar known period. Whereas the photodiode is prone to spurious switching due to noise from the environment, the delay added by the filter and Schmitt trigger ensures that the output only switches when there is certainly an input stimulating the device.Schmitt triggers are common in many switching circuits for similar reasons (e.g., for switch debouncing).List of IC including input Schmitt triggersPhilips 74HCT14D, a hex inverting Schmitt triggerThe following 7400 series devices include a Schmitt trigger on their input(s): (see List of 7400-series integrated circuits)7413: Dual Schmitt trigger 4-input NAND Gate7414: Hex Schmitt trigger Inverter7418: Dual Schmitt trigger 4-input NAND Gate7419: Hex Schmitt trigger Inverter74121: Monostable Multivibrator with Schmitt Trigger Inputs74132: Quad 2-input NAND Schmitt Trigger74221: Dual Monostable Multivibrator with Schmitt Trigger Input74232: Quad NOR Schmitt Trigger74310: Octal Buffer with Schmitt Trigger Inputs74340: Octal Buffer with Schmitt Trigger Inputs and three-state inverted outputs74341: Octal Buffer with Schmitt Trigger Inputs and three-state noninverted outputs74344: Octal Buffer with Schmitt Trigger Inputs and three-state noninverted outputs74(HC/HCT)7541 Octal Buffer with Schmitt Trigger Inputs and Three-State Noninverted OutputsSN74LV8151 is a 10-bit universal Schmitt-trigger buffer with 3-state outputsA number of 4000 series devices include a Schmitt trigger on their inputs(s): (see List of 4000-series integrated circuits)4017: Decade Counter with Decoded Outputs4020: 14-Stage Binary Ripple Counter4022: Octal Counter with Decoded Outputs4024: 7-Stage Binary Ripple Counter4040: 12-Stage Binary Ripple Counter4093: Quad 2-Input NAND4538: Dual Monostable Multivibrator4584: Hex inverting Schmitt trigger40106: Hex InverterSchmitt input configurable single-gate chips: (see List of 7400-series integrated circuits#One gate chips)NC7SZ57 FairchildNC7SZ58 FairchildSN74LVC1G57 Texas InstrumentsSN74LVC1G58 Texas InstrumentsMain article: Relaxation oscillatorOutput and capacitor waveforms for comparator-based relaxation oscillatorA Schmitt Trigger-based implementation of a relaxation oscillatorA Schmitt trigger is a bistable multivibrator, and it can be used to implement another type of multivibrator, the relaxation oscillator. This is achieved by connecting a single RC integrating circuit between the output and the input of an inverting Schmitt trigger. The output will be a continuous square wave whose frequency depends on the values of R and C, and the threshold points of the Schmitt trigger. Since multiple Schmitt trigger circuits can be provided by a single integrated circuit (e.g. the 4000 series CMOS device type 40106 contains 6 of them), a spare section of the IC can be quickly pressed into service as a simple and reliable oscillator with only two external components.Here, a comparator-based Schmitt trigger is used in its inverting configuration. Additionally, slow negative feedback is added with an integrating RC network. The result, which is shown on the right, is that the output automatically oscillates from VSS to VDD as the capacitor charges from one Schmitt trigger threshold to the other.Operational amplifier applicationsThreshold detector with hysteresisList of 4000-series integrated circuits - includes logic chips with Schmitt trigger inputsList of 7400-series integrated circuits - includes logic chips with Schmitt trigger inputs^ One factor contributing to ambiguity is that one simple transistor-based realization of a Schmitt trigger is naturally inverting, with a non-inverting Schmitt trigger sometimes consisting of such an inverting implementation followed by an inverter. An additional inverter may be added for buffering a stand-alone inverting configuration. Consequently, inverting configurations within an integrated circuit may be naturally inverting, while non-inverting configurations are implemented with a single inverter, and stand-alone inverting configurations may be implemented with two inverters. As a result, symbols that combine inverting bubbles and hysteresis curves may be using the hysteresis curve to describe the entire device or the embedded Schmitt trigger only.^ Usually, negative feedback is used in op-amp circuits. Some operational amplifiers are designed to be used only in negative-feedback configurations that enforce a negligible difference between the inverting and non-inverting inputs. They incorporate input-protection circuitry that prevent the inverting and non-inverting inputs from operating far away from each other. For example, clipper circuits made up of two general purpose diodes with opposite bias in parallel [1] or two Zener diodes with opposite bias in series (i.e., a double-anode Zener diode) are sometimes used internally across the two inputs of the operational amplifier. In these cases, the operational amplifiers will fail to function well as comparators. Conversely, comparators are designed under the assumption that the input voltages can differ significantly.^ When the non-inverting (+) input is at a higher voltage than the inverting () input, the comparator output switches nearly to +VS, which is its high supply voltage. When the non-inverting (+) input is at a lower voltage than the inverting () input, the comparator output switches nearly to -VS, which is its low supply voltage.^ Where the noise amplitude is assumed to be small compared to the change in Schmitt trigger threshold.^ Schmitt, Otto H. (January 1938). "A Thermionic Trigger". Journal of Scientific Instruments. 15 (1): 2426. Bibcode:1938JScI...15...24S. doi:10.1088/0950-7671/15/1/305.^ a b August 2004 issue of the Pavek Museum of Broadcasting Newsletter Archived 2015-10-01 at the Wayback Machine^ Debouncing switches with an SR latch^ 7414 datasheetWikimedia Commons has media related to Schmitt triggers.Inverting Schmitt Trigger CalculatorNon-Inverting Schmitt Trigger CalculatorRetrieved from " The Schmitt trigger is actually a comparator circuit but there something extra added to the Schmitt trigger which makes it different from all the comparators. It is also known as regenerative comparator. In comparator we have some input signal and threshold value. The Schmitt trigger is also known as 1 bit quantizer because it converts the analogue signal in to digital signal. The input signal will be compare with the threshold value and the comparison will gives us either high or low value like we will get a square wave which is basic working of any comparator. The same thing is happening with the op amp circuits, in Schmitt trigger we do not have one threshold value. We have two threshold values in the Schmitt trigger and these two threshold values will help us in understanding when and how the high to low and low to high transition occurs specifically. There is specific upper and lower threshold and due to this upper and lower threshold values. The signal has to be exactly a dap level or greater to that a transition have to happen. So the main advantage of the Schmitt trigger is that it has two threshold values in which the input signal will not be compared with one threshold so the input signal will not just compared with one threshold to get the square wave and the square transition will depend upon whether the input is greater or less than input value. As in the Schmitt trigger we have two threshold values which are upper threshold value (VUT) and lower threshold value (VLT). So it will prevent the unnecessary transition created by the noises. We know that there will be not just input signal but there will be also noise or noise signal will come to the input signal. Due to which unnecessary transition will be created. The Schmitt trigger can function as latch or flip flop (bi-stable multivibrator). It is possible to interconvert a latch and schmitt trigger in to each other. Calculation of the values:Schmitt trigger has inverting amplifier actually in which we have inverting and non-inverting terminals. The input is connected at the inverted terminal and there is positive feedback connected to the non-inverting terminal and to there is reference signal. Generally this reference voltage should be kept to 5V or up to the VCC of the operational amplifier.But if we closely examine the threshold value or the voltage coming to the non-inverting terminal is not actually 5V but this is the voltage at the specific point which is taken as point A. The node voltage at the point A is given to the non-inverting terminal so that voltage is taken by the comparator or op amp for comparison. The voltage at point will be taken as the threshold voltage for the comparison and not the value given at reference. The value of this voltage will depend on as there is feedback connected from the output which is positive feedback. The voltage at the point A will depend on the output voltage and the values of the resistances. There is actually voltage division happening and the resulting and the resultant of this voltage division is the voltage coming at the node A and that voltage is taken by the Schmitt trigger for comparison. The output of the Schmitt trigger will be either 0V or 5V. The 5V represent high voltage while 0 V represents low voltage. The voltage coming to the node A will vary and hence we will get two values for voltage at A when the output voltage is 0V and from the output voltage to be 5V. So these two voltages are called upper threshold voltage and lower threshold voltage. The Schmitt trigger implements hysteresis. Hysteresis is basically the dependence on the state of the system on it history which means the history output. The past outputs which are connected through feedback to the input terminal. In simple words we can say that for Schmitt trigger the threshold voltage or the input is depending on the history or the past outputs and this dependence is implemented with the help of positive feedback.If we are giving analogue signal at the input side of the Schmitt trigger we will get square wave or a digital waveform. Suppose we have an analogue signal in which the dotted lines represent the upper threshold and the lower threshold. When the signal is passing through the upper threshold the output will be dropping suddenly to zero volt means the output will go from high to low. When the signal is crossing the lower threshold value then the output value will go from low to high. We will have two output values either at will be 5V or 0V.Now we will calculate the threshold value let us consider that we are giving 5V as a reference voltage at the input. Consider that the output voltage generated is zero volt. When the output voltage is 0V then the resistance R2 and R3 are connected to the ground and R1 is connected to the reference voltage. This is actually voltage division circuitry. Now by applying the voltage division rule when the Vout = 0 This will be the lower threshold value.VA = (R2 || R3 /R1 + R2 || R3) * VrefWhen the voltage will be 5V so for that case when the R2 will be connected to 5V and R1 will also be connected to 5V and R3 will be connected with the ground. This will give us the upper threshold voltage value.Depending upon the output voltage value we will get two different threshold values.Why we use Schmitt trigger?We have two inputs and one output in the comparator if we put a potentiometer at the negative terminal of the comparator we can change the threshold value for the signal as the output will pass too high or too low we can lower or increase this threshold with the help of potentiometer. Let suppose that we put a threshold of 3V using the potentiometer.Now at the positive input we have a signal that oscillates and we want to read that so we want each oscillation becomes a square wave. Each time the input is higher than 3 V. We will have high pulse at the output. When we have a noise at the input let us consider the same signal but have some noise. After the signal passes through the 3V we have a little bit of noise and a small ripple that goes below 3V that will result in the short low pulse at the output which would be an error since we do not want that so that is why we use the Schmitt trigger. Because it has two threshold values one for the rising edge and one for the falling edge. Let we will see the same signal but at the two threshold values. When the input gets over 3V the output will be high if want the signal to be high pulse just invert the signal two times. So then the input has the ripple and gets a little bit bellow 3V but since it did not pass below the second the second threshold the output will not change. Thus we will obtain a signal which we want this is the main function of the Schmitt trigger to convert a noisy signal in to a good square signal that could be than read by the microcontroller or other digital components .Schmitt trigger working:Now let us consider a Schmitt trigger in which we are using the positive have positive feedback. When it was open loop it was comparator in which the output will be whether positive Vsat or negative Vsat. In this circuit we have open loop gain is infinity and also Rin value in infinity.Vf Represents the feedback voltageVin= Input voltageVI= Inverting voltageVNI= Non Inverting voltageAOL= Open loop gainVout = AOL *(VNI VI)As the open loop gain is infinity so the equation will become:Vout = * (VNI VI)When the value it non inverting terminal is maximum then inverting terminal valueVNI > VIThen the output value will be positive Vsat.When the value it non inverting terminal is minimum then inverting terminal valueVNI > VIThen the output value will be negative Vsat.To find the feedback voltage we will apply the KCL law:Vf Vout / R1 + (Vf Vref /R2) + 0 = 0Vf/R1 Vout/R1 + Vf/R2 Vref /R2 = 0 Now by rearranging the equations we get:The feedback voltage is equal to the non-inverting voltage .The resistance values are constant which will not be changing; also the reference voltage which is dc voltage will also be constant. So there will be only change in the output voltage which is:This is called lower threshold voltage.VLT = ((-Vsat R2)+(R1Vref))/((R1+ R2))There will be two types of voltage at the non-inverting terminal which are upper threshold voltage and lower threshold voltage.Condition for Schmitt trigger:There is condition for Schmitt which should be satisfied for designing the Schmitt trigger.|R1Vref| > |R2 Vsat|This means that the upper threshold voltage and lower threshold voltage both number will be positive.The second condition is that the saturation voltage will be greater than the reference voltage.|Vsat| > |Vref|Case 1:When the reference voltage is positive the feedback voltage be:Suppose that the input voltage is VIN= 5sint so the VM=5V and we consider the upper threshold voltage is 3V and the lower threshold voltage is 1V. If V(out)=+VSat then Vf= VUTV(out)=-VSat then Vf= VLT = 1VSchmitt trigger using 555 timer:In this circuit we will connect some external components with the 555 timer so that it will work like Schmitt in which we will generate square wave from sinusoidal wave.The first pin of the 555 timer is connected to the ground. Connect the 2 and 6 pin together. The second pin is called trigger pin and the 6 pin is called threshold pin and are connected with R2with the ground. Pin number will be used for reset. If we want to reset we will give negative pulse and if does not want the timer to reset connect the 4 pin with the Vcc. Pin number 5 is control pin and it control the output pulse width and is grounded through capacitor in order to reduce noise. The pin number 7 is discharge pin and nothing is connected with it. pin number 8 is supply pin which is connected with the Vcc. The pin number 6 and 7 is connected with the capacitor and sinusoidal signal is applied through this capacitor which will allow ac and block dc. The R1 and R2 value should be kept equal.The capacitor is coupling capacitor so for AC analysis capacitor will be short circuit. So voltage and current will be connected directly. For dc analysis it will be open circuit. So when the capacitor is open circuit so the voltage at pin 2 and 6 will be equal to:V2= V6= Vcc/2Whenever we apply sinusoidal signal the capacitor behave short circuit which will couple the sinusoidal signal or AC signal across the 2 and 6 terminals. So the voltage will become:V2= V6= Vcc/2 + ViWhen the V2 and V6 are greater then 2/3 Vcc. When the V2 is greater then 2/3 V_cc then it will be +Vsat and it will become logic 1. When the V6 is greater then 2/3 Vcc then it will be -Vsat and it will become logic 0. In this way we will obtain a square wave. Application of Schmitt trigger:Schmitt Trigger devices find applications in:Signal conditioning means it will convert the noisy signal in to square wave without any noise.Schmitt trigger are used in oscillator as closed loop negative feedback configurationsThe Schmitt trigger can be used to Switching power supplies and function generators. The Schmitt Trigger circuit design using Op Amp is an incredibly versatile and efficient tool in the tech world. It's a cornerstone of modern engineering, and is used to ensure precision and accuracy in a variety of applications.The Schmitt trigger circuit is composed of an op amp and two resistors. Its designed to provide hysteresis, or the ability to distinguish between different signals within an electronic system. By using the op amp, it can detect when a signal has crossed a certain threshold before responding appropriately. This gives the circuit the precision it needs to operate efficiently.The Schmitt circuit also has some advantages over other circuits. It requires less power than most standard amplifiers, which makes it ideal for low-power applications such as sensors and medical devices. In addition, it can differentiate between signals that are very close in amplitude, which can be critical for precision work. One of the key components of the Schmitt design is the ability to adjust the triggering level of the circuit. With two resistors, the user can adjust the voltage at which the circuit will switch from one state to the other, allowing for even greater control. This is especially useful in applications where accuracy is vital.The Schmitt Trigger circuit design using Op Amp is a necessary tool in the modern engineering landscape. Its versatility and precision make it a highly desirable choice for a wide range of applications. From low-power sensors to medical devices, the Schmitt Trigger can provide the precision and accuracy needed to get the job done right. If you're looking to maximize efficiency and accuracy in your next project, consider adding a Schmitt Trigger circuit design to your toolkit. Op-amp Circuits Include: Introduction Circuits summary Circuit design hints & tips Inverting amplifier Summing amplifier Non-inverting amplifier Inverting vs non-inverting circuits Variable gain amplifier High pass active filter Low pass active filter Bandpass filter Notch filter Comparator Schmitt trigger Multivibrator Bistable Integrator Differentiator Wien bridge oscillator Phase shift oscillator A Schmitt trigger is form of comparator circuit that has hysteresis or different input switching levels to change the output between the two states.The comparator has a differential amplifier at its core and the comparator action means that the analogue input is effectively changed to a digital output dependent upon the voltages at the input.By using the hysteresis, the effect of noise at the input which might cause several switches at the output as the input voltage nears the switching voltage is significantly reduced.The essence of the Schmitt trigger is a differential amplifier: operational amplifiers are often used in this role, but it is far better to use a specific comparator chip in this role. What is hysteresisHysteresis occurs in many instances throughout science, but in the case of the Schmitt trigger hysteresis means that the circuit triggers at different voltages to switch the output from one state to the other.To explain this in more detail, take the example where the reference voltage is, say 5 volts. As the voltage rises, dependent upon the circuit is for example 5.5 volts. Then to switch in the other direction, the input voltage must fall to, for example 4.5 volts.In this way, there is a 1 volt difference between the switching in either direction, and this provides some significant noise immunity. Concept of hysteresis used in Schmitt trigger circuit The problem of not using hysteresis with a comparator is that if the input signal rises slowly, then noise on the waveform will cause multiple switches of state of the output of the comparator. By using hysteresis, this issue is overcome, unless the noise levels are very high. The Schmitt trigger circuit is ideal for many applications in overcoming this issue. Fortunately a straight comparator can be converted into a Schmitt trigger by the addition of a single electronic component in most casesMultiple switches of the output due to noise can give rise to many issues with the following digital circuits, and in very many instances, electronic circuit design engineers have spent many hours debugging circuits with this type of issue as they can be difficult to track down sometimes. Schmitt trigger basicsThe Schmitt trigger circuit has been widely used for many years. It was invented by an American scientist named Otto Schmitt. The Schmitt trigger switches at different voltages depending upon whether it is moving from low to high or high to low, employing what is termed hysteresis.In terms of the fact that the Schmitt trigger has hysteresis, the circuit symbol for one of these circuits incorporates the hysteresis symbol into it. Accordingly all Schmitt triggers use this symbol. Schmitt Trigger Circuit Symbol Schmitt trigger circuitA standard comparator circuit can normally converted into a Schmitt trigger at the electronic design stage by introducing positive feedback by the addition of an additional electronic component. In the circuit below this is provided by the addition of a resistor R3. Operational amplifier Schmitt trigger circuit The effect of the new resistor, R3 is to give the circuit different switching thresholds dependent upon the output state of the comparator or operational amplifier. When the output of the comparator is high, this voltage is fed back to the non-inverting input of the operational amplifier of comparator. As a result the switching threshold becomes higher. When the output is switched in the opposite sense, the switching threshold is lowered. This g