Simple toggle circuits illustrate low power-MOSFET leakage

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The novelty circuit in **Figure 1** illustrates the extremely low gate-leakage current typical of modern power MOSFETs. You can find parts that, in a moderately dry environment, will hold their state for days at a time. In operation, if MOSFET Q_1 is off, the load—perhaps a lamp or a buzzer—pulls Q_1's drain to nearly the 12V-dc power-supply voltage. R_2 charges C_1 to practically the same voltage. If you tap momentary-contact switch S_1, C_2 and the gate of Q_1 charge to about 99% of C_1's initial voltage, assuming that the tap is short enough that C_1 doesn't discharge significantly back through R_2 to the drain of Q_1, which is now at a low voltage. During the next couple of seconds, C_1 discharges through R_2 toward the new drain voltage of Q_1, which now conducts current through load resistor R_1.

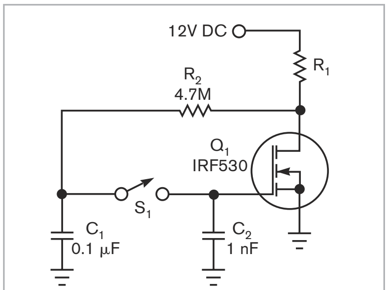


Figure 1 This "toggle" circuit demonstrates the low gate leakage of modern power MOSFETs.

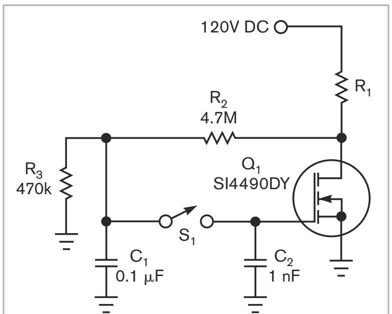
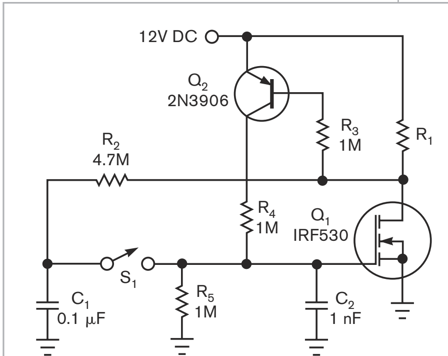


Figure 2 This circuit can control higher voltages because it supplements R_2 with a resistor to ground to form a voltage divider, ensuring that C_1 doesn't charge to a voltage that would destroy the gate of Q_1.

In the construction of the circuit, you must ensure extremely low leakage from the MOSFET's gate node. You can omit C_2 if you use a switch with essentially no leakage, and you may find that the gate capacitance of Q_1 is enough and that the leakage is low enough that days pass before the output changes significantly. If you'd like to ensure a longer hold time, you can increase the value of C_2. A modern polypropylene capacitor should have a self-discharge time constant measured in years if you keep it clean, dry, and not too far above room temperature. If you increase C_2, proportionately increase C_1 and decrease R_2 to maintain an R_2C_1 time constant of about half a second.



NOTE: LOADS AS LARGE AS A FEW AMPS ARE POSSIBLE WITH THE RIGHT POWER MOSFET.

Figure 3 This version of the toggle circuit indefinitely holds a state.

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Another curious behavior of this novelty circuit occurs if you hold down S_1 for a few seconds. The gate of Q_1 then goes to a voltage slightly higher than the gate's threshold voltage for Q_1. If, for example, the power supply is 6V and the load is a 6V incandescent lamp and Q_1's gate threshold is approximately 3V, the lamp will light dimly. When you release the switch, because a typical power MOSFET has a high rate of drain-current change with gate-voltage change—that is, transconductance—you can observe the slow change in gate voltage as a change in lamp brightness. Any leakage is inside and external to Q_1. You may be able to detect a change in lamp brightness within a few seconds. But, even if you don't notice it, some change of voltage will occur. If you tap S_1 several times at intervals of a few seconds, the lamp will soon toggle between full brightness and fully off.

To use the circuit to control higher voltages, you can supplement R_2 with a resistor to ground to form a voltage divider to ensure that C_1 doesn't charge to a voltage that would destroy the gate of Q_1 (**Figure 2**). For a more practical toggle circuit that will indefinitely hold a state, you can add a transistor and some resistors (**Figure 3**).

If Q_1 is on and powers the load, then Q_2 is also on, holding Q_1's gate on at about half the power-supply voltage because of the voltage-divider action of R_4 and R_5. Tapping S_1 toggles the output as before, and, with Q_1 off, Q_2 is also off, allowing R_5 to hold Q_1's gate near ground potential. EDN