

PhotoMOS output characteristics

Modern relays remain the first choice for switching loads in myriad applications - in automation, home appliance, home automation, the automotive industry, telecommunications and measurement technology. Their reliability, compact size and optimised coil power consumption are simply hard to beat.

Such kinds of voltage controlled mechanical switches had long been the only choice for switching an electrical output circuit. However, during the last two decades, relay manufacturers have capitalised on the advantages semiconductor technology offers to overcome the wear and lifetime problems of electromechanical relays. Two paths were pursued during the evolution of semiconductor relays: MOSFET-based PhotoMOS relays and TRIAC-based solid state relays (SSRs).

The input side of a PhotoMOS relay consists of an LED. An input current causes the LED to emit light that passes through an epoxy resin, directing it to an array of solar cells. From the consequent voltage drop, two source-coupled MOSFETs are controlled, thereby switching the output from the on- to off-state and vice versa (figure 1). It is apparent that the electrical characteristics of the PhotoMOS relay are influenced by its output MOSFET.

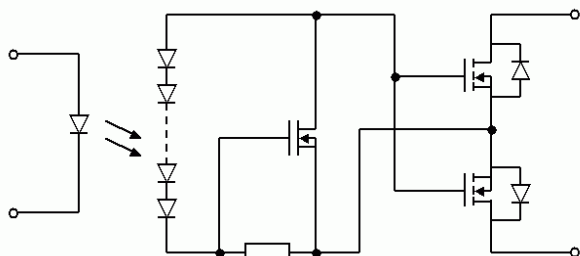


Figure 1: Electrical circuit of PhotoMOS relay

Due to the semiconductor's structure, temperature limits and package utilized, there is a trade-off between load voltage and load current, plus the load current's derating when the ambient temperature increases. Moreover, the vertical structure of power MOSFETs and their intrinsic elements influence the output behaviour of the PhotoMOS. In addition to the ohmic resistance of the region between drain and source, the MOSFET'S structure (see figure 2) causes a reverse biased drain-source diode and capacitances that are responsible for the output behaviour.

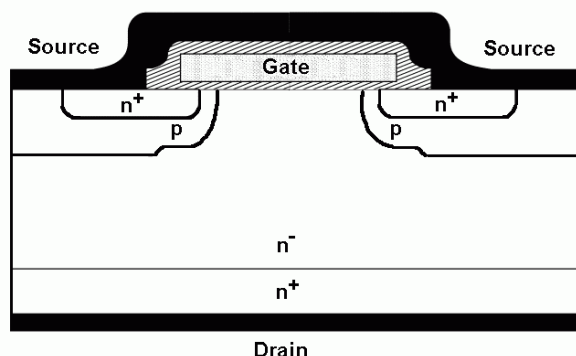


Figure 2: Cross section of power MOSFET

Not only do the capacitances' charging/discharging influence the MOSFET's switching times, they also influence the output's isolation characteristics for higher frequency load signals. The MOSFET's capacitances act as a reactance whose value is related to frequency: for lower frequencies, the reactance is high and decreases as the frequency rises. Therefore, higher frequency load signals will leak through the off-state output due to its capacitance. The behaviour can be calculated by assuming a high-pass filter with the component's off-resistance (load voltage divided by leakage current), internal resistance of the signal source and the output's capacitance value. The reduction in isolation is 20 dB per decade as for any other high-pass filter of the first order.

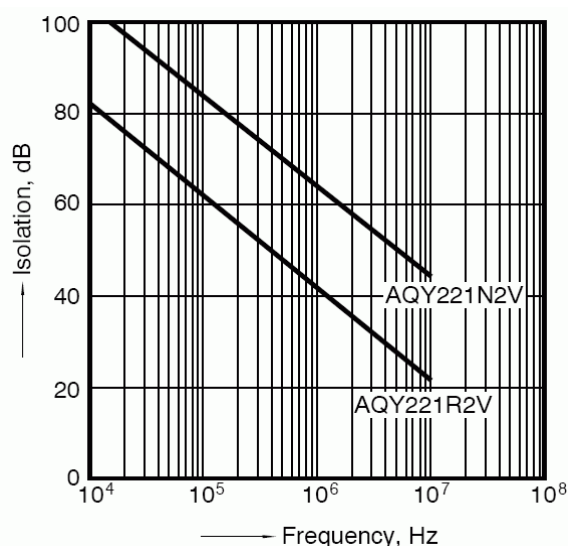


Figure 3: Isolation vs. load frequency for AQY221_2V

Figure 3 illustrates how the output capacitance of the AQY221R2V (12.5 pF) and AQY221N2V (1.0 pF) yield a high-pass filter, leading to decreasing isolation with rising frequency. As the output capacitance of the AQY221R2V is more than ten

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times higher than that of AQY221N2V, an isolation difference of approx. 20 dB at the same frequency is the result. Due to the relationship between capacitance and on-resistance for the MOSFET, the AQY221R2V ($0.75\ \Omega$) consequently has a lower on-resistance than the AQY221N2V ($9.5\ \Omega$).

Off-state leakage current, i.e. the reverse current through the drain-source-diode of the blocking MOSFET, is another very important characteristic behaviour of PhotoMOS relays. It depends on the applied load voltage in the off-state and on the electrons' mobility, which varies according to the ambient temperature and ranges from a few pA to several nA (see figure 4).

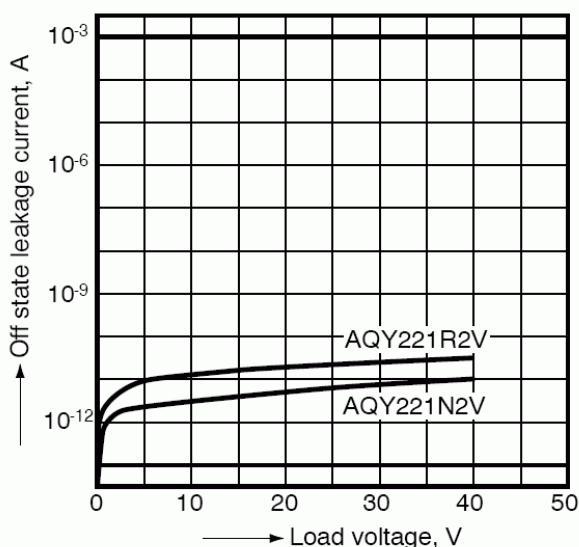


Figure 4: Leakage current vs. load voltage for AQY221_2V

The electrons' mobility decreases with rising temperature; hence the MOSFET's on-resistance depends on temperature effects. This is illustrated in the data sheet: on-resistance versus ambient temperature characteristics. In addition, there is a second output behaviour in the on-state which originates from the drain-source diodes of the two power MOSFETs. During AC operation, one of these two diodes is reverse-biased, whereby the other diode is forward-biased (see figure 1). The forward-biased diode is connected in parallel with the MOSFET's ohmic on-resistance.

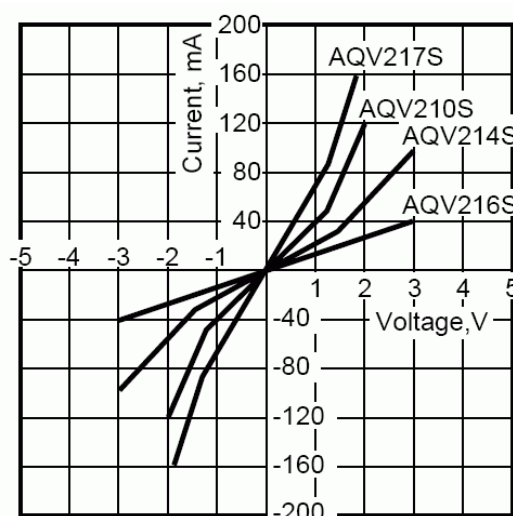


Figure 5: Current vs. voltage for AQV21_S

This yields a nonlinear behaviour between load current and load voltage for certain types of power MOSFETs with higher on-resistance (figure 5).

PhotoMOS relays utilize a power MOSFET--a semiconductor perfectly suited for switching elements as it acts like a pure ohmic resistor without any offset or saturation voltage. Other advantages of PhotoMOS relays include:

- Low control current
- Control wide range of analogue signals
- Low leakage current
- Stable on-resistance over lifetime
- Extremely long lifetime
- Small size
- No preferred mounting position
- High vibration and shock resistance
- No bouncing
- No switching noise

Nevertheless, the load signal may be distorted by the effects explained previously. Therefore, to capitalise on the significant benefits PhotoMOS relays profess over electromechanical relays, be sure to check the data sheet and, if necessary, contact our application engineering department.