Chapter 17:
Analog Switches and Sample-and-Hold Circuits

An analog switch is designed to switch a continuous input signal on and off. When the switch is in the on-state, the output voltage must be as close to the input voltage as possible; when the switch is off, it must be zero. The principal characteristics of an analog switch are defined by the following parameters:

- the forward attenuation (the on-state resistance),
- the reverse attenuation (the off-state current),
- the analog voltage range,
- the switching times.

17.1 Principle

There are several switch arrangements that fulfill the above requirements. They are represented in Fig. 17.1 as mechanical switches.

A single-throw series switch is shown in Fig. 17.1a. As long as its contact is closed, \( V_o = V_i \). On opening the switch, the output voltage becomes zero, although this only applies to no-load conditions. For capacitive loads, the output voltage will only fall to zero slowly because of the finite output resistance \( r_o = R \).

The single-throw short-circuiting switch shown in Fig. 17.1b overcomes this difficulty. However, in the on-state – that is, when the contact is open – the circuit possesses a finite output resistance \( r_o = R \).

The double-throw series/short-circuiting switch in Fig. 17.1c combines both advantages, and has a low output resistance in both states. The forward attenuation is low and the reverse attenuation is high. However, the fact that the output is short-circuited in the off-state may also cause problems – for example, if the output voltage is to be stored in a capacitor, as in the sample-and-hold circuits of Sect. 17.4. In this case, switch S3 can be added, as shown in Fig. 17.2. When the switch is open, the input signal that is capacitively coupled via S3 is short-circuited by S2; however, the output remains at high impedance due to S3. This arrangement therefore behaves like the series switch in Fig. 17.1a, but has a much better reverse attenuation for high frequencies.

Extending this principle to several inputs, we obtain the arrangement shown in Fig. 17.3. One of the four switches is closed at any one time, which means that the output voltage is

![Fig. 17.1. Switch configurations](image-url)
equal to the particular input voltage selected. This arrangement is therefore also known as an analog multiplexer.

By inverting the arrangement, an input voltage can be distributed to several outputs, thus providing an analog demultiplexer function. The corresponding circuits for digital signals have already been described in Sect. 8.2 on page 643.

### 17.2 Electronic Switches

Field effect transistors, diodes, or bipolar transistors are used to implement the switches. They possess quite different characteristics, and specific advantages and disadvantages. They do, however, have the same basic arrangement, which is shown in Fig. 17.4. In most cases, TTL-compatible control signals are required. These are amplified by a power gate followed by a level converter, which generates the voltages that are required for opening or closing the switch.

#### 17.2.1 FET Switch

As we saw in Sect. 3.1.3, a FET behaves like an ohmic resistor whose value can be varied by several orders of magnitude using the gate–source voltage $U_{GS}$. This behavior makes it extremely useful as a series switch (see Fig. 17.5). The FET is turned off if we apply a control voltage that is negative with respect to the input voltage by at least the threshold $V_{C\text{off}} \leq V_i + V_{th}$.

To make the junction-FET conduct, the voltage $V_{GS}$ must be zero. This condition is not so easy to fulfill, as the source potential is not constant. A solution to this problem is shown in Fig. 17.6, where diode D becomes reverse biased if $V_C$ is made larger than the most positive input voltage, and therefore $V_{GS} = 0$, as required.

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**Fig. 17.2. Series switch with improved reverse attenuation**

**Fig. 17.3. Analog multiplexer–demultiplexer**

**Fig. 17.4. Drive arrangement for a switch**