What is EEPROM (electrically erasable programmable read-only memory)?

EEPROM (electrically erasable programmable read-only memory) is a user-modifiable ROM. It can be erased and reprogrammed (written to) repeatedly by applying an electrical voltage that is higher than normal.

EEPROM explained

EEPROM is a type of non-volatile ROM that enables individual bytes of data to be erased and reprogrammed. That is why EEPROM chips are known as *byte erasable* chips. EEPROM is usually used to store small amounts of data in computing and other electronic devices.

Prior to the use of EEPROM, EPROM technology was widely used. EPROM memory chips could be programmed and then erased if exposed to ultraviolet light. However, the chips could not be erased electrically. And the erasure process for EPROM took upward of an hour, which was acceptable for the development environments of the time but left little flexibility for potentially higher-speed environments of the future.

EEPROM technology evolved to address these challenges. Based on the existing EPROM structure, EEPROM can be erased and programmed electrically. Most EEPROM chips have a life span of 10,000 to 100,000 write cycles, which is considerably greater than the write cycles of EPROM chips.

EEPROM transistors

In EEPROM, floating gate or storage transistors hold a charge while a metal-oxide-silicon (MOS) transistor is used to erase the charge. The floating gate transistors (FGTs) are complementary MOS-based bit cells. When there is no charge on the floating gate, a pulse on the control gate causes current to flow. At this point, the transistor acts normally.

When the gate is charged, it blocks or impedes the action of the control gate, and current ceases to flow. In order to charge, the source and drain terminals must be

grounded, and sufficient voltage must be placed on the control gate tunnel through the oxide to the floating gate.

The charged/uncharged state is determined by the electrons that get trapped in the gate, which then determines whether the gate's content will be a 0 bit or a 1 bit. A reverse voltage channeled from another transistor causes the charge to dissipate into the substrate, consequently clearing it.

Types of EEPROM memory

Two types of EEPROM memory chips are available.

1. Serial EEPROM

Serial EEPROM chips can be contained within a small eight-pin package, making them denser than parallel EEPROM chips. Serial chips are also less expensive. The drawback is that data is transferred serially and, therefore, slowly. Additionally, their operations are more complex.

Many standard interface types are available for serial EEPROM:

- Serial Peripheral Interface
- Inter-Integrated Circuit
- Microwire
- UNI/O
- 1-Wire

Each of these interfaces requires one to four control signals for operation.

The EEPROM serial protocol consists of three phases:

1. operation code phase
2. address phase
3. data phase

2. Parallel EEPROM

The parallel EEPROM chip is compatible with both EPROM and flash memory devices. Its data transfer mechanism is faster and more reliable than the mechanism in serial EEPROM. However, it has a larger pin count, which increases its size, density and cost. For these reasons, parallel EEPROM is not as widely used as serial EEPROM or flash memory.

EEPROM failure modes

As with all computing and electronic devices, EEPROM chips are not failure-proof. There are two key modes in which EEPROM devices may fail.

1. Data endurance

During rewrite operations, the bit cells in EEPROM get stuck in the programmed state. This happens because the FGT accumulates trapped electrons. As more electrons get trapped, the threshold for the "zero state" cannot be detected, and the cells remain permanently in the programmed state, which may result in chip failure. This is why EEPROM manufacturers specify the minimum and maximum number of rewrite cycles.

2. Data retention time

The EEPROM architecture is set up to allow electrons injected into the floating gate to drift through the insulator, which is not a perfect insulator. This floating causes some charge to be lost, which results in some data getting erased and the memory cell reverting to its erased state.

For this reason, manufacturers guarantee a limited data retention time of a specific number of years -- e.g., 10 years. Environmental factors, such as temperature, can also reduce the data retention time in EEPROM.

Advantages and disadvantages of EEPROM

One of the biggest advantages of EEPROM is that it can be reprogrammed multiple times. The stored data is non-volatile and can be erased on a byte-by-byte basis. And, since the erasure happens electrically, it is almost instantaneous. Unlike

EPROM, EEPROM chips do not have to be removed from the computer to be modified.

Despite these advantages, EEPROM also has some disadvantages. It is more expensive than PROM and EPROM, and it has limited data retention time. Further, cost may be a drawback for systems using serial EEPROM chips.

Additionally, the read/write cycles on EEPROM are slower than the cycles on RAM. To accommodate for this, it's important to use the data stored in EEPROM in a way that doesn't slow down system operations.

Finally, different voltages are required to erase, read and write data from or onto EEPROM. However, newer EEPROM chips incorporate a high-voltage source on the chip itself, eliminating the need for a separate high-voltage source. Since these chips can run from a single supply, it simplifies the design and reduces the cost.

Despite the drawbacks, EEPROM memory is widely used, especially for applications where the number of read/write cycles is limited.

EEPROM and flash memory

Flash memory is a special form of EEPROM. Identical in structure to EEPROM, flash memory chips use normal PC voltages for erasure and reprogramming. Also, an entire block of bytes must first be erased.

Flash memory uses a single regular MOS transistor to erase an entire block of FGTs. Most EEPROMs have one MOS transistor for every eight FGTs. The FGT holds the charge, while the MOS transistor erases it.

Today, flash memory modules can hold large amounts of data to the scale of gigabytes and more for camera and computer storage. This data can be static or semistatic. In contrast, regular EEPROM memory chips are usually used on circuit boards to store only small amounts of data or computing instructions.