A power management circuit based on autonomous control

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Abstract. Based on the concept of external triggering and internal autonomous control, by using the semiconductor device with switching characteristics, using the function of capacitor voltage regulation and energy storage, and fully utilizing the charge and discharge function of the capacitor, the author introduces a new type of power management circuit. The circuit realizes the function of the device to independently control the power supply that is turned off when the storage, standby, etc. do not need to work. When the device needs to work, the power supply switch of the circuit is triggered by the external condition, and the power supply automatically supplies power to the device through the circuit. Therefore, the function of energy saving and energy saving of the device is realized, the battery life capability of the battery is improved, the loss of the power supply of the device is greatly reduced, and the technical problem that the battery of the current device is largely lost during idle and standby periods is solved, and the environmental protection and energy saving has Certain meaning.

1. Introduction
With the continuous improvement of global energy-saving demand and the continuous advancement of digital technology, the increasing power structure of split-type power supplies requires electronic devices to comply with the mandatory energy efficiency regulations. Power management refers to how to effectively distribute power to different components of the system. Power management is critical for mobile devices that rely on battery power. The development trend of miniaturization and multi-function of portable devices is the driving force behind the development of power management technology. By reducing the energy consumption when components are idle, an excellent power management system can extend battery life by two or three times, so the power management circuit is One of the most straightforward management methods.

In order to extend battery life and achieve environmental protection and energy saving, the current common method is to start with the power consumption circuit of the device and use more power-saving chips and circuits. However, the existing slave power consumption circuit solution cannot fundamentally solve the battery loss of the device during storage and during long standby. According to the current statistics, most of the battery of the device is lost during idle and standby. In response to this problem, the author introduces a power management circuit based on an externally triggered power switch, which internally controls the power supply. This circuit effectively solves the technical problem that the battery is heavily wasted during idle and standby.
2. Power management circuit

2.1. Power Management Circuit Introduction
The power supply circuit is based on the switching characteristics of the triode, and combines the principle of charge and discharge of the capacitor to realize the function of the device to independently control the power supply. The detailed power management circuit is shown in Figure 1[1-3].

![Circuit diagram of power management circuit](image)

Circuit related symbols and device descriptions[1]:
- \( \text{Vin} \) is the power supply for the device, usually connected to the battery.
- \( \text{Vout} \) is the working power of the device.
- \( \text{G1} \) is a trigger device with a switch function, which can be an external trigger switch such as a touch switch, a vibration switch, or a voice control switch[2].
- \( \text{MCU\_control} \) is the internal power-off control terminal of the device. The device sends a control signal through this port to implement the power switch control function[3].

Remark: When the current required by the device is large, that is, when the current of \( \text{Q1} \) is large, the MOS tube can be considered to replace the triode. This paper introduces the circuit principle based on the triode.

2.2. Power Management Circuit Principles:
MCU is the processor of the device[3].

2.2.1. Introduction to the process of power-on of the equipment and the process of autonomous power-off of the equipment
First, according to the conduction characteristics of the triode, when the voltage of the emitter (E pole) of the triode is higher than the voltage of the base (B pole), the triode is turned on, and the triode is turned on[1, 2]. When the electronic device is powered on, the battery is powered by \( \text{Vin} \), and the device is powered. MCU cannot operate normally because there is no power and voltage is too low, so there is no control signal at the control \( \text{MCU\_control} \) end of the device. The base (B pole) of the transistor \( \text{Q2} \) is pulled to the reference ground by the resistor \( \text{R4} \), and the emitter of the transistor \( \text{Q2} \) (E pole) and the collector (C pole) is disconnected, the current is charged to the capacitor \( \text{C2} \) through the resistor \( \text{R1} \) and the resistor \( \text{R3} \). In the charging process, the calculation formula of the charging time and charging voltage of the capacitor is as follows[2]:
V0 is the initial voltage value on the capacitor.
V1 is the voltage value at which the capacitor can eventually be charged or placed.
Vt is the voltage value at the time of time t.
R is the sum of the internal resistance of the resistor R1, the resistor R3 and the capacitor C2, but considering that the resistor R1 is much larger than the internal resistance of the resistor R3 and the capacitor C2, R can directly use the resistance of the resistor R1 when calculating.
C is the capacitance of the capacitor C2.

Then,
\[ V_t = V_0 + (V_1 - V_0) \times [1 - \exp(-t/RC)] \]

And so
\[ t = RC \times \ln[(V_1 - V_0)/(V_1 - V_t)] \]

When the capacitor C2 is charged, when the voltage across the capacitor C2 is less than (Vin-0.6V), the transistor Q1 is turned on, and the power supply is supplied to the MCU through the transistor Q1.

After the MCU has power, the MCU works normally. The MCU sends a high level signal through the Control_MCU control terminal, so that the emitter (E pole) and the collector (C pole) of the transistor Q2 are turned on. At this time, the capacitor C2 passes through the resistor R3 and Transistor Q2 discharge, the emitter (E-pole) voltage of the transistor Q1 is higher than the base (B-pole) voltage higher than the triode conduction voltage, the transistor Q1 continues to conduct, and the power supply continues to supply power to the MCU through the transistor Q1.

When the equipment storage, standby, etc. do not need to work, the MCU of the device sends a low level signal through the Control_MCU control terminal. At this time, the base (B pole) of the transistor Q2 is pulled to the reference ground by the control signal of the Control_MCU control terminal. The MCU does not output any signal, and the base (B pole) of the transistor Q2 is pulled to the ground by the resistor R4. According to the conduction characteristics of the transistor, the emitter (E pole) and the collector (C pole) of the transistor Q2 are disconnected, and the current is charged to the capacitor C2 through the resistor R1 and the resistor R3, and the voltage across the capacitor C2 rises. According to the capacitor charge and discharge formula, when the voltage across the capacitor C2 is greater than (Vin-0.6V), the emitter (E-pole) voltage and the base (B-pole) voltage of the transistor Q1 are smaller than the transistor turn-on voltage, and the transistor Q1 is from the saturation region. Turn to the zoom area. As the capacitor C2 is further charged, the voltage across the capacitor C2 is higher. When the emitter (E-pole) voltage and the base (B-pole) voltage of the transistor Q1 are less than 0.6V, the transistor Q1 emitter (E-pole) and the collector (C pole) is disconnected, that is, the transistor Q1 is turned off. The circuit cuts off the power supply of the device through the turn-off of the transistor Q1.

2.2.2. Description of the process that needs to be re-powered after the circuit is cut off
First, the capacitor C2 is charged before the MCU cuts off the power supply to the device.
Secondly, the device needs to be powered on again. The external touch control switch, voice control switch and other switching devices trigger the switch, that is, the switch G1 is closed, and the capacitor C2 is discharged through the switch G1 and the capacitor C1. It should be noted that, according to the calculation formula of the charge and discharge of the capacitor, in order to ensure that the capacitor C2 can be fully discharged, the charging time of the capacitor C1 needs to be greater than the discharge time of the capacitor C2, so the capacitance of the capacitor C1 can be 10 times or more of the capacitance of the capacitor C2. When the capacitor C2 is discharged, the emitter (E-pole) voltage and the base (B-pole) voltage difference of the transistor Q1 become larger and larger. According to the conduction characteristics of the transistor, the transistor Q1 goes from the off state to the amplified state, and finally to the saturation state. That is, the transistor Q1 is turned on, and the power supply supplies power to the controller (MCU) through the transistor Q1. After the MCU of the device has normal operation, the MCU sends a high level signal through the Control_MCU control terminal, so that the emitter (E pole) and the collector (C pole) of the transistor Q2 are turned on. At this time, the capacitor C2 passes through the resistor R3 and The transistor Q2 discharges, the emitter (E-pole) voltage of the transistor Q1 is higher than the base (B-pole) voltage, and the transistor Q1
continues to conduct. The power supply continues to supply power to the controller (MCU) through the transistor Q1 [1, 2].

Since the capacitor C1 does not store power from the power supply to the power supply process, the circuit needs to discharge the capacitor C1 before the next action of the G1 switch, that is, the resistor R6 provides a discharge function for the capacitor C1.

Note: Since the switch G1 in the circuit may continue to be turned on during the actual use, the capacitor C1 must be cut off after the power is fully charged, and the MCU cannot be turned off when the switch G1 is continuously turned on, and the power supply cannot be turned off.

When the equipment storage, standby, etc. do not need to work, the MCU of the device sends a low level signal through the Control_MCU control terminal. At this time, the base (B pole) of the transistor Q2 is pulled to the reference ground by the control signal of the Control_MCU control terminal. The MCU does not output any signal, and the base (B pole) of the transistor Q2 is pulled to the ground by the resistor R4. According to the conduction characteristics of the transistor, the emitter (E pole) and the collector (C pole) of the transistor Q2 are disconnected.

If the G1 switch has been turned off or the capacitor C1 has been charged, the circuit of switch G1 and capacitor C1 is cut off. And the current is charged to the capacitor C2 through the resistor R1 and the resistor R3, and the voltage across the capacitor C2 rises. According to the capacitor charge and discharge formula, when the voltage across the capacitor C2 is greater than (Vin-0.6V), the emitter (E-pole) voltage and the base (B-pole) voltage of the transistor Q1 are smaller than the transistor turn-on voltage, and the transistor Q1 is from the saturation region. Turn to the zoom area. As the capacitor C2 is further charged, the voltage across the capacitor C2 is higher. When the emitter (E-pole) voltage and the base (B-pole) voltage of the transistor Q1 are less than 0.6V, the transistor Q1 emitter (E-pole) and the collector (C pole) is disconnected, that is, the transistor Q1 is turned off. The circuit cuts off the power supply of the device through the turn-off of the transistor Q1.

If the G1 switch is still on and the capacitor C1 has not yet completed charging, it is necessary to wait for the capacitor C1 to complete charging to cut off the power of the MCU;

2.3. Circuit anti-abnormal self-recovery process description
When the controller (MCU) is working normally, the capacitor C2 is in a discharging state or the power has been discharged. Because the controller (MCU) is abnormal, the control signal of the Control_MCU control terminal is lost, the capacitor C2 is turned into charging, and the capacitor C2 is charged. Transistor Q1 continues to conduct, does not cut off the power to the controller (MCU), and the controller (MCU) can recover before the triode Q1 is powered off.

If an unrecoverable fault occurs in the MCU, the circuit can be restored to normal by cutting off the MCU power supply [1].

3. Conclusion:
The circuit is based on an externally triggered power supply and simultaneously cuts off the power supply according to the internal requirements of the circuit, and turns off the power supply when the device is not working, thereby achieving the purpose of power saving, and is very suitable for the battery power supply device and the circuit that needs energy saving. Moreover, the circuit is simple, has few components, high reliability, low failure rate, low cost, and strong practicability, and can be widely applied to consumer digital products such as toys, remote controls, mobile phones, and PDAs.

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