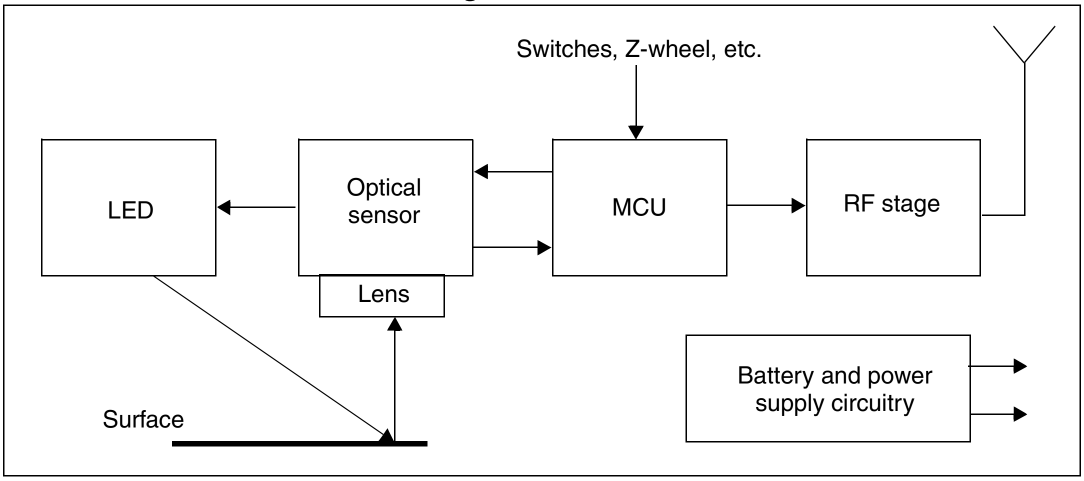
Optical wireless mouse design using VT5366

Overview

This application note describes the typical architectures used in wireless optical mice and describes how the STMicroelectronics VT5366 can be used to realize such a mouse. This applications note should be read in conjunction with the VT5366 datasheet.

A typical optical 27MHz wireless mice consists of 5 major blocks as shown below.

27MHz Wireless mouse block diagram



These blocks are described in more detail in the following sections.

Optical sensor

The optical sensor is the heart of the system. Images of the surface underneath the mouse are focussed onto the sensor using a suitable lens. The differences between subsequent images are analyzed in order to determine what, if any, movement has occurred.

LED

An LED is generally used to illuminate the surface underneath the optical sensor. The LED is controlled by the optical sensor. The light from the LED is directed onto the surface using a light-guide which is often contained within the same assembly as the lens.

MCU

A microprocessor (MCU) is used to control the complete mouse system. The MCU is used to configure the optical sensor and to read data from it. The data is encoded and then sent to the RF transmitter stage. Additional switch inputs (i.e. buttons and scroll wheel) are handled by the MCU. The firmware running inside the MCU is responsible for the power management of the whole system.

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RF output stage

The RF output stage is usually realized using discrete components and a crystal oscillator. Data output from the MCU is transmitted to the receiver usually using a Frequency Shift Keying (FSK) method.

Batteries and power supply

Wireless mice are generally powered from batteries, usually 1 or 2 AA or AAA cells. The cells can be used in either series or parallel. In order to generate the voltage rails which are required by various parts of the design DC to DC converters are often employed.

1 Operating modes

In order to obtain good battery life the firmware running in the MCU must implement a power-management strategy which will result in the mouse having a number of different operating modes. Typically 3 or 4 operating modes are employed as described in the following sections.

1.1 Run

In this mode the mouse is moving and transmitting RF data. The sensor is in its active state. Once motion has stopped RF transmission will also stop but the mouse can remain in this mode checking for motion for a while longer. This is the highest power consumption mode.

1.2 Idle1

Having decided that there is no motion the mouse will enter an idle mode; IDLE1. In this mode there is no RF transmission. The sensor will be activated periodically in order to check for any motion. The higher the frequency of activation of the sensor the lower the latency (i.e. responsiveness) of the mouse.

1.3 Idle2

Having detected no motion in the IDLE1 state for some time some mice may enter a second idle state, IDLE2 where the sensor is activated periodically as in IDLE 1 but less frequently. The less frequent activation results in lower power consumption but higher latency.

1.4 Sleep

Some mice may have a SLEEP state where the motion is either not checked at all or checked periodically as in IDLE mode, but much less frequently (some latency is usually tolerated in SLEEP mode). The first option could result in extremely low power consumption but as the mouse cannot be woken up by moving it another method (usually a button press) will have to be employed.

The time spent in each mode before moving to another mode and the exact behavior in each mode is up to the individual designer. For best battery life the aim must be to reduce overall power consumption by both reducing the consumption of each mode as much as possible and by remaining in the higher current modes for as little time as possible. Of course this must be done while maintaining acceptable mouse performance.

2 Battery life

The battery life of a wireless mouse depends on three key factors:

1. Current consumption in various operating modes
2. Battery capacity
3. Usage model

2.1 Current consumption

The current consumption in various modes is a function of the components used and the exact behavior in each mode. These figures can vary greatly but current consumption can be accurately determined (and measured) for any given design.

2.2 Battery capacity

The larger the battery capacity the longer a given battery will last. Practical considerations such as size and weight and the requirement to use standard readily-available batteries usually result in mice operating from either 1 or 2 standard AA or AAA cells.

2.3 Usage model

To accurately determine battery life it is necessary to know how long a given mouse will be in any of its operating modes. It is also useful to know the type of surfaces that the mouse will be used on, as brighter more reflective surfaces may require less illumination and result in lower power consumption.

This information is what we refer to as a usage model. This is very difficult to measure and will of course vary significantly between different mouse users. The model used by ST is based on data collected from a number of different office users and is described in *Table 1*.

Table 1. ST Usage model

Mode	% of the total time	Latency	Notes
RUN	2	None	Mouse actually moving
IDLE1 / IDLE2	16	To be invisible to user	As soon as mouse stops moving
SLEEP	82	some accepted	After X minutes of no motion

These figures assume that the mouse is actually moving only 2% of the time i.e. for only around 3.5 hours per week.

3 Designing mice with the VT5366

The VT5366 has been optimized for low power operation and requires only a 1.8 V power supply. This compares favorably with other devices on the market which require 3.3 V.

However, a higher voltage is usually still required to drive the navigation LED and can also be required for other parts of the complete system.

3.1 VT5366 power supply

The VT5366 requires an analogue supply of 1.8 V and a separate digital supply of 1.8 V. In practice these may be generated from the same source.

3.2 LED power supply

The navigation LED is driven by the VT5366 but depending on the type of LED used can require a higher power supply than 1.8 V The minimum required depends on the maximum forward voltage (Vf) of the LED which for a RED LED is likely to be around 2.5 V. A typical implementation for this would probably use a 3.0 V or 3.3 V supply with a series resistor used to limit the LED current. IR LEDs have a Vf of 1.5V so can use the same supply voltage as the sensor.

3.3 VT5366 current consumption

The VT5366 has two operating states: POWERDOWN and RUN. The current consumption in these two states is shown in *Table 2*.

Note: This is the VT5366 only and excludes the LED current.

Table 2. Current consumption

State	Frame rate	VT5366 current (AVDD + DVDD)	Notes
POWERDOWN		10µA	POWERDOWN=1
RUN (6MHz clock)	9375	9mA	POWERDOWN=0, Current at 1.8 V

The default external clock rate of the VT5366 is 6 MHz resulting in a frame rate of 9375 fps. Slower external resonators can be used resulting in lower frame rates and lower power consumption in the RUN state.

In practice a wireless optical mouse will have various operating modes in which the VT5366 will switch between the RUN and POWERDOWN states with varying duty cycles.

Table 3. Duty cycles

Mode	Duty cycle (typ) controlled externally	VT5366 Current (AVDD + DVDD)	Notes
RUN	100 %	9 mA	When mouse is moving
IDLE1	1 %	130 µA	
IDLE2	0.1 %	30 µA	

3.4 Led current

The navigation LED is controlled by the VT5366 and is used in a non-continuous mode. The instantaneous current is determined by the power supply used and the series resistor fitted. For good navigation on the widest range of surfaces an instantaneous current of around 11 mA (red LED) should be used (this is reduced for IR LED).

The duty cycle of the LED is varied by the exposure controller inside the VT5366 and has a maximum value of 40 %. Thus the maximum average LED current is 4.5mA (assuming the instantaneous current is 11 mA). Reducing the frame rate will reduce the LED duty cycle even further. Typical LED duty cycle for navigating on white paper is shown in *Table 4*.

Table 4. LED duty cycle on white paper

Mode	Frame rate	LED duty cycle	Average LED current
RUN (6MHz)	9375	20%	2.5mA

Note: The maximum duty cycle of 40 % is independent of sensor frame rate but this will only happen on extremely dark surfaces.

4 General power supply design

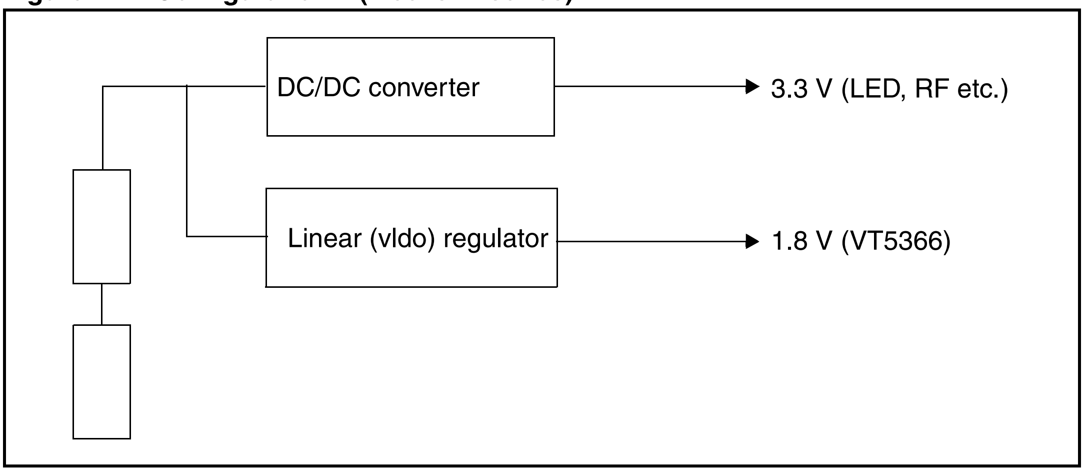
Wireless mice are generally powered from either 1 or 2 AAA or AA cells either in series or parallel. Usually a switch-mode DC/DC converter is employed to produce a higher voltage than is available from the batteries directly. This higher voltage may be used to power the LED as well as other elements of the design such as the MCU and RF stage.

4.1 VT5366 power supply

The STMicroelectronics VT5366 device requires only a 1.8 V supply for operation (a larger voltage may still be required for the LED). In order to gain the maximum benefit from this lower voltage operation it is important to choose the best power supply configuration. If the 1.8 V supply which is required by the VT5366 is generated from a higher voltage supply using a linear regulator then any potential power savings are lost as heat dissipated in the regulator. To derive maximum benefit from the 1.8 V design of the VT5366 it is necessary to choose an optimum power supply configuration.

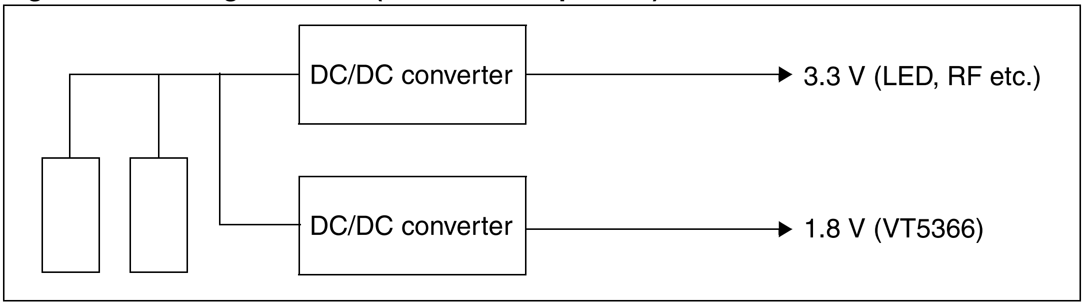
Assuming that the other components of the mouse system (MCU, RF stage etc.) require a 3.3 V supply then there are three basic configurations

Figure 1. Configuration 1 (2 cells in series)



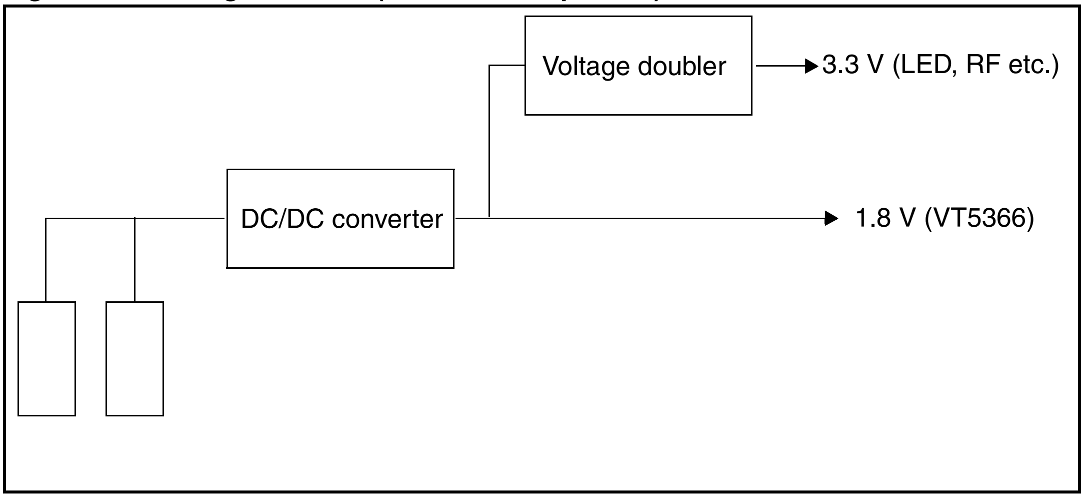
This configuration uses 2 cells in series driving a DC/DC step-up converter to produce 3.3 V. A linear low drop out regulator is used to provide 1.8 V directly from the cells. This configuration is reasonably efficient but power is wasted in the linear regulator especially when the cells are new and have a higher output voltage.

Figure 2. **Configuration 2a (1 or 2 cells in parallel)**



This configuration uses 1 cell or 2 cells in parallel. A DC/DC step-up converter is used to produce 1.8 V for the VT5366 and a second converter is used to produce 3.3 V for the rest of the system. This configuration is the most efficient but is also the most costly in terms of components.

Figure 3. **Configuration 2b (1 or 2 cells in parallel)**



This is a slightly modified version of configuration 2a. Here only one DC/DC converter is employed in order to produce 1.8 V from the batteries. A voltage doubler is used to produce the higher voltages required by the rest of the system. This configuration may be cheaper to realize than 2a but a voltage doubler may not be suitable for all applications, particularly those where there is a high current demand on the 'doubled' supply.

4.2 Predicting battery life

Predicting the battery life for a given wireless mouse design is extremely difficult because it depends on such a large range of parameters many of which are outside the control of the sensor designer (user model for example). For this reason manufacturers almost never state the expected battery life.

What is certainly true is that the less power that the system consumes the longer the batteries will last. The VT5366 consumes significantly less power than many competitive devices on the market and therefore existing mouse manufacturers should be able to benefit from increased battery life from changing to the VT5366 even if other parts of their systems (the MCU, RF stage etc.) remain unchanged.

5 Revision history

Table 5. Document revision history

Date	Revision	Changes
08-Dec-2006	1	Initial release.