



Single chip optical/laser mouse sensor for wireless applications

Features

- One chip solution with internal microprocessor and minimal external circuitry
- 1.8 V (single battery) or 2.0 V to 3.2 V (serial batteries) supply operation
- Very low power operation, enabling long battery life
- 800 / 1600 CPI resolution (switchable by simultaneous button press)
- Up to 10,000 frames per second
- Tracking at up to 40 ips
- Internal 27.045 MHz modulator available
- Single 12 MHz crystal design
- ST 4.8 kbps protocol
- 254 ID codes
- Mechanical Z-wheel + 5 buttons
- Low battery detect and indicator
- ID update & E2 store at every CONNECT press
- Firmware customization available on request
- Proven, high volume package technology, smallest package currently available on market
- Suitable for use with LED and laser light sources
- Reference designs available

Applications

- Wireless optical mouse for Laptop/Desktop PC

Description

The VT5365 is the first generally available complete system on-chip for use in wireless optical mice. The device has been designed to provide long battery life while enabling excellent navigation control and precision on a wide range of surfaces. Housed in the smallest currently available package (7 mm x 7 mm), the chip is suitable for use in small form-factor mice demanded by laptop users. Minimal external circuitry is required, thereby reducing BOM and assembly costs.

Table 1. Technical specifications

Resolution	800 (default) / 1600 CPI
Pixel size	30.4 μ m
Array size	20*20 pixels
Frame rate	Up to 10,000 frames/second
High speed motion detector ⁽¹⁾	400 CPI - 32 ips 800 CPI - 16 ips 1600 CPI - 8 ips 3200 CPI - 4 ips
Clock	12 MHz
Supply voltage	1.8 V
Supply current ⁽²⁾	Fast RUN (10 Kfps) - 28 mA Slow RUN (2.5 Kfps) - 16 mA IDLE 1 - 500 μ A IDLE 2 - 120 μ A SLEEP - 60 μ A
Operating temperature	[0 - 60] ° C
Package type	7*7 mm 32 lead LOQFP (Low profile Optical Quad Flat Pack)

1. Speed limitation is due to RF protocol, which is also in line with the USB Low Speed Device. The VT5365 motion detector can handle up to 40 ips.

2. All currents were measured on an ST Reference Design Mouse supplied with 1.8 V at maximum exposure and include an IR LED and RF stage.

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1 Introduction

The VT5365 sensor is a single-chip solid state optical tracking engine with no moving parts. It allows the creation of a high performance, fully featured wireless mouse with the minimum of external components. The device, which provides excellent navigation control and precision, works on a wide range of surfaces.

The VT5365 incorporates features that simplify product design and reduce time to market. By minimizing the number of external components, the mouse manufacturer has flexibility for layout and product design.

ST has worked with optical component suppliers to produce a single piece light guide with integrated lens, and makes recommendations for a compatible LED. Details of the optics and LED are included in this document.

Figure 1. VT5365 reference design mouse



1.1 Detailed overview

The VT5365 has been optimized for low power operation, enabling long battery life, which is achieved by either a single 1.8 V or 2.0 V to 3.2 V supply.

The on-chip regulators allow for a wide range of power supplies taken from 2 batteries in series, enabling a low cost BOM. However, for the most efficient power consumption, the regulators can be bypassed so that the chip is driven at the minimal supply of 1.8 V by an external power source (typically a DC/DC convertor from a single cell voltage). In both cases, an on-chip DCDC regulator controls the LED, so that only a single 1.8 V supply is required for the overall application. The supply scheme is selected by connecting an IO to GND or VDD.

Care has been taken to implement ultra-low power idle/sleep modes with wakeups at programmable periods and/or via external events, enabling very long battery life. It is estimated that with a typical user and two AA Alkaline batteries configured in parallel, a useful battery lifetime of 9 months can be achieved.

STMicroelectronics default firmware supports 5 buttons, mechanical Z-wheel, low battery level detect/indicate output and internal DC/DC controller to supply the navigation LED.

The firmware generates baseband 4.8 kbps, Manchester coded data with RF on signal for standby.

The output can be selected as either baseband RF serial data, or 27.045 MHz FSK digitally modulated signal. In this case, minimal external circuitry is required for filtering and amplification, and the overall system can be achieved using a single 12 MHz Xtal.

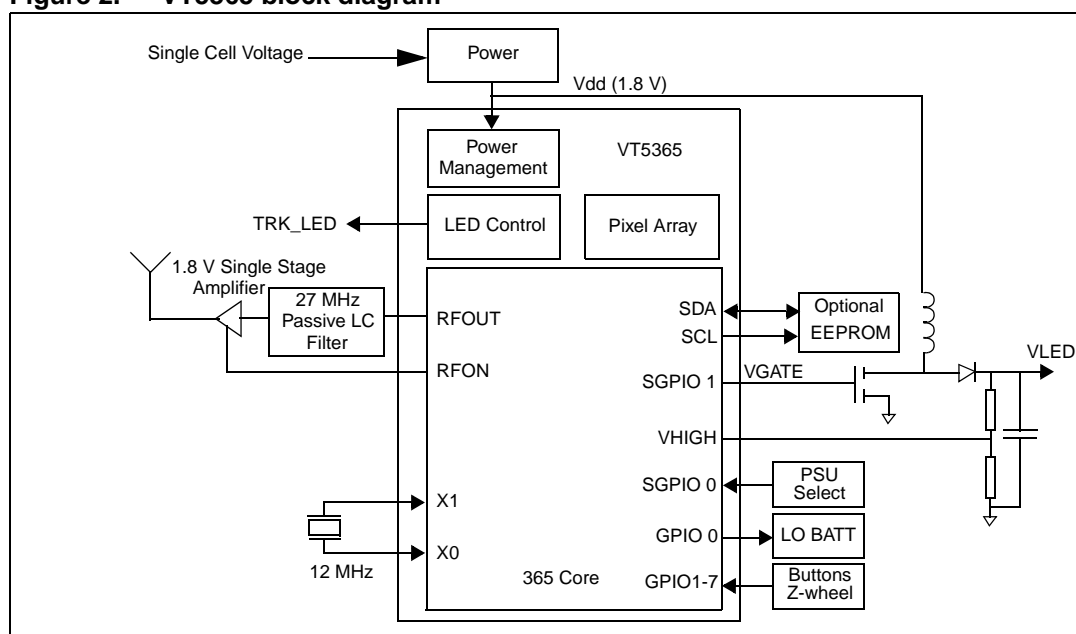
This firmware may be replaced allowing customers to build in their own features for their particular mouse (including 2 extra GPIO). For more details please refer to [Section 4: Customizable firmware on page 16](#).

The VT5365 sensor will operate over a wide range of illuminant wavelengths and is suitable for use with visible, IR and laser light sources.

A specifically designed optical system with integrated light guide and lens is available along with an aperture piece which clips the package in place aligning the optics. This has been optimized for low cost, space saving and ease of assembly in high volume mouse manufacture.

The main functional blocks of the VT5365 are shown in [Figure 2](#).

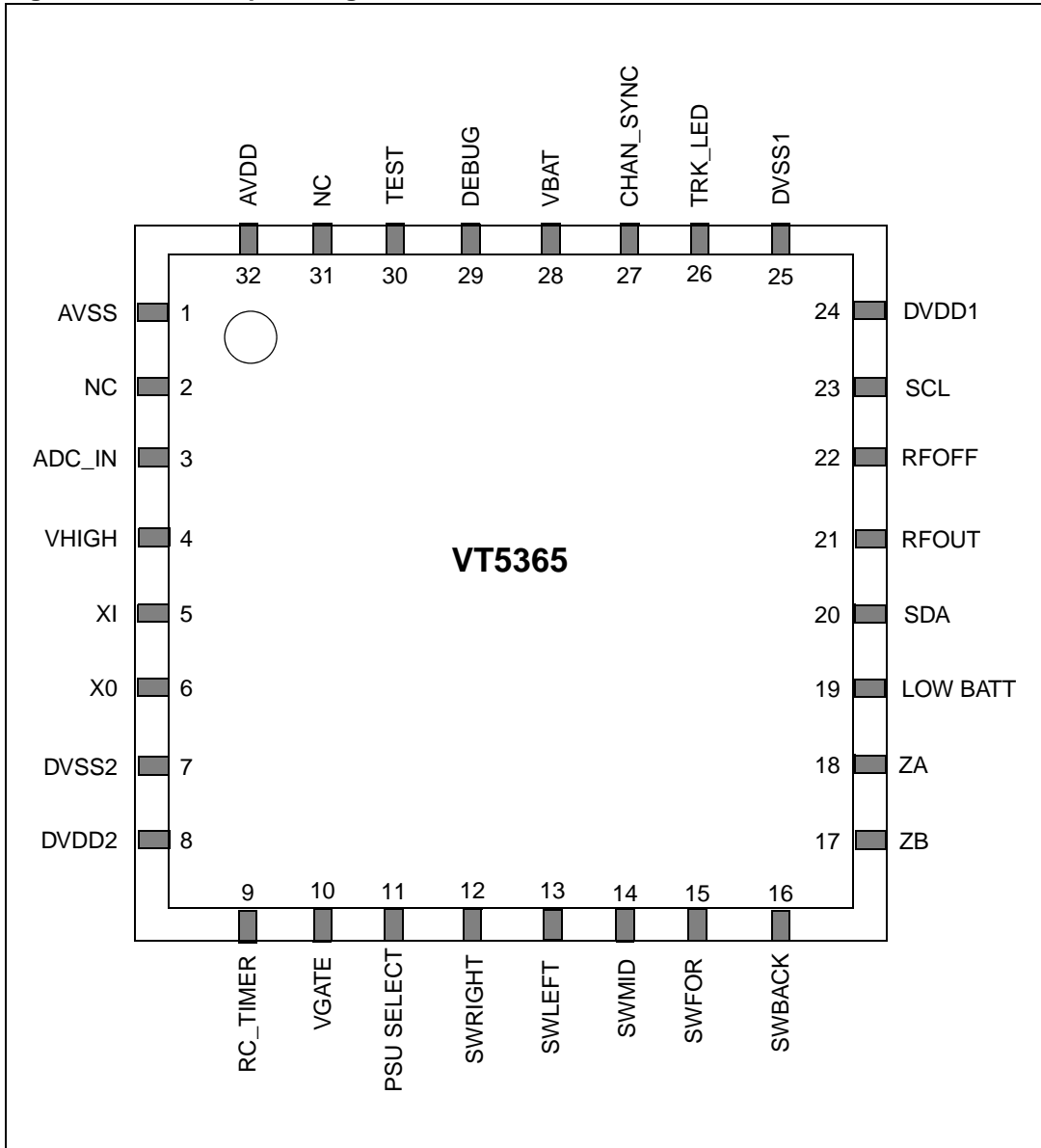
Figure 2. VT5365 block diagram



2 Design notes

2.1 Pin assignment

Figure 3. VT5365 pin assignment



2.2 Pin description

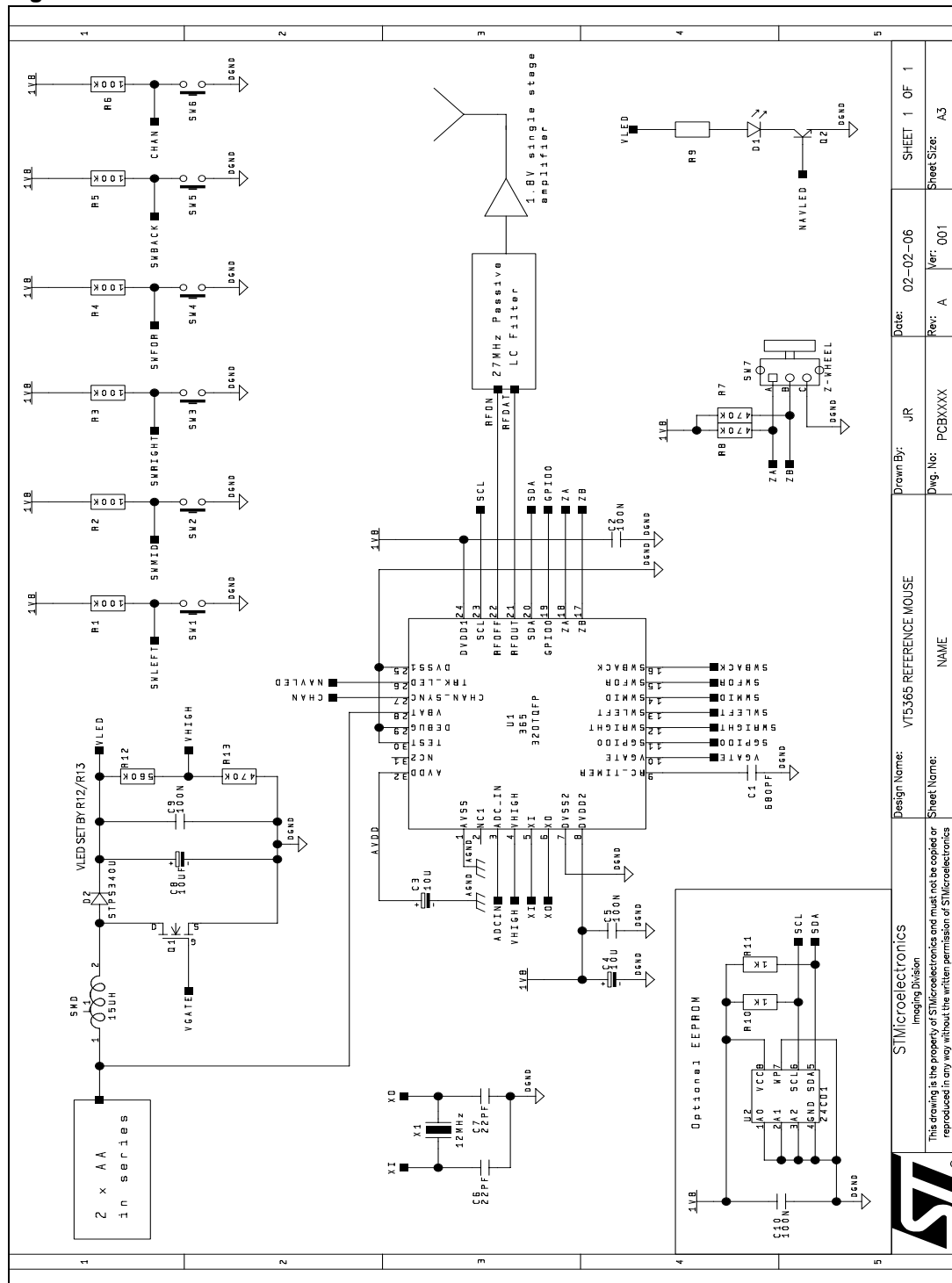
Table 2. VT5365 pin description

Pin No.	Pin Name	Type	Description
1	AVSS	PWR	Analog Ground
3	ADC_IN	I/O	Analog input
4	VHIGH	I/O	Analog Input Feedback
5	XI	OSC	12 MHz Xtal
6	XO	OSC	12 MHz Xtal
7	DVSS2	PWR	Digital Ground
8	DVDD2	PWR	1.8 V Digital Supply
9	RC_TIMER	I/O	
10	SGPIO1	I/O	VGATE
11	SGPIO0	I/O	PSU Select
12	GPIO7	IO	SWRIGHT - 'Right' switch input (active low)
13	GPIO6	I/O	SWLEFT - 'Left' switch input (active low)
14	GPIO5	I/O	SWMID - 'Middle' switch input (active low)
15	GPIO4	I/O	SWFOR - 'Forward' switch input (active low)
16	GPIO3	I/O	SWBACK - 'Back' switch input (active low)
17	GPIO2	I/O	ZB
18	GPIO1	I/O	ZA
19	GPIO0	I/O	LBAT_OUT - Low Battery Indicator
20	SDA	I/O	I2C SDA Line
21	RFOUT	I/O	RF Data
22	RFOFF	I/O	RF On
23	SCL	I/O	I2C SCL Line
24	DVDD1	PWR	1.8 V Digital Supply
25	DVSS1	PWR	Digital Ground
26	TRK_LED	I/O	Navigation LED Output
27	CHAN_SYNC	I/O	ID Button
28	VBAT	PWR	2.0 V to 3.2 V Power Supply Pin
29	DEBUG	I/O	Connect to GROUND
30	TEST	I	Connect to GROUND
32	AVDD	PWR	1.8 V analog supply

Note: All other pins are not connected.

2.3 Reference design schematic

Figure 4. VT5365 reference schematic - batteries in series



Design Name: VT5365 REFERENCE MOUSE	Drawn By: JR	Date: 02-02-06	SHEET 1 OF 1
Design No: PCBXXXX	Rev: A	Ver: 001	Sheet Size: A3
Sheet Name: NAME			



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2.4 Reference design - bill of materials

Table 3. Bill of materials: main components

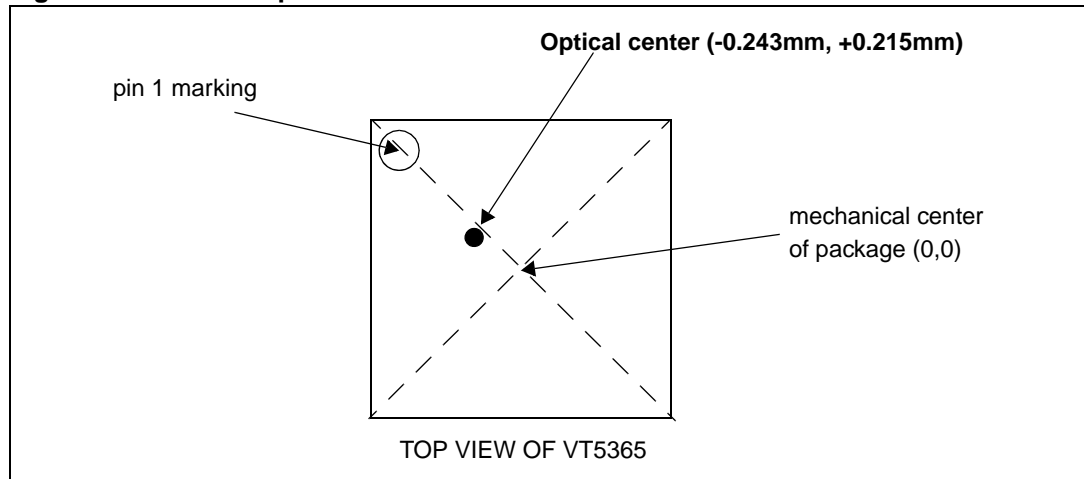
Ref.	Description	Manufacturer	Part Number
U1	Optical mouse sensor	STMicroelectronics	VT5365V032
Q1	BSS138 N-channel MOSFET, SOT23	Farnell	518-621
Q2	NPN transistor to drive D1	Standard component - many supplier	
D2	SMD power Schottky diode, STPS340U SMB	Farnell	935-207
L1	15 μ H surface mount inductor DO1608 series	CoilCraft	
D1	Navigation LED	See Section 6: LED selection on page 21	
X1	12 MHz low profile HS49 Xtal	TXC	
SW1 - SW6	Sealed keyswitch (SMD) B3S1000, ID button	Standard component - many supplier	
SW7	Z-wheel	Dicgu HK Electronics	EN028D-11PS1-30-R
R1- R6	100K resistor	Standard component - many suppliers	
R9	Controls max current through LED	Standard component - many suppliers	
R12	560K resistor	Standard component - many suppliers	
R7,R8,R13	470K resistor	Standard component - many suppliers	
C6,C7	22 pF capacitor	Standard component - many suppliers	
C1	680 pF capacitor	Standard component - many suppliers	
C2,C5,C9	100 nF capacitor	Standard component - many suppliers	
C3,C4,C8	10 μ F tantalum capacitor	Standard component - many suppliers	
Only required if EEPROM is fitted			
U2	256 or 4 KByte EEPROM	STMicroelectronics	
R10,R11	1K2 resistor	Standard component - many suppliers	
Additional items not mounted on the PCB			
	Optics assembly	See Section 5: Optics assembly on page 18	
	Aperture stop	See Section 5: Optics assembly on page 18	

For complete reference design schematics for both single battery and batteries in series designs, please refer to the STV-365-R0X user manuals.

2.5 Optical center

The optical center of the VT5365 is NOT in the centre of the package, it is offset by -0.243 mm in the X-axis and 0.215 mm in the Y axis with respect to the centre of the package as shown in *Figure 5*. The PCB designer must take this into account when laying out the PCB.

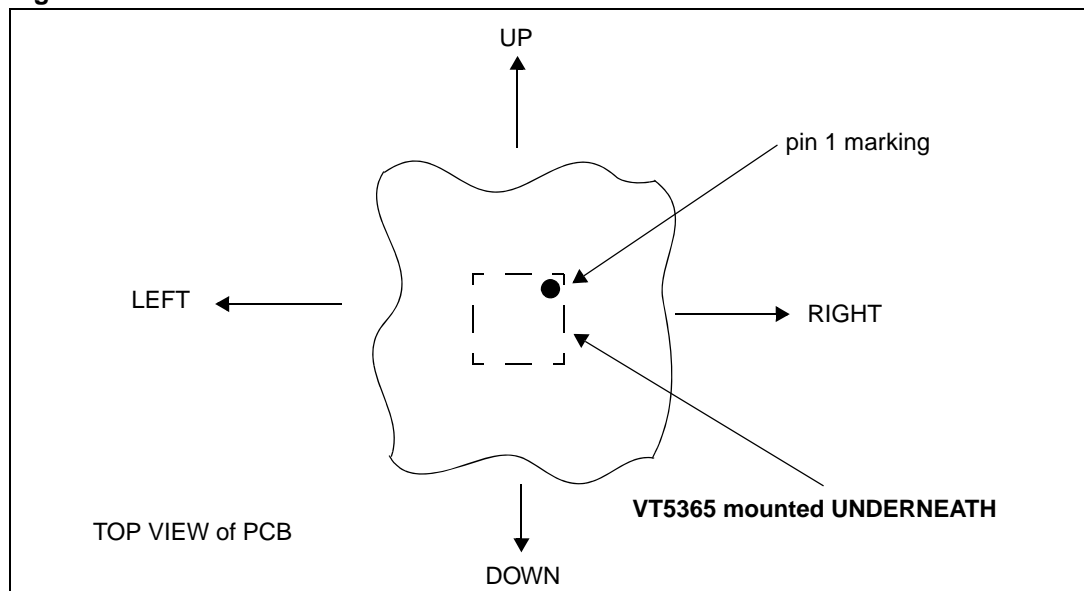
Figure 5. VT5365 optical center



2.6 Sensor orientation on PCB

The VT5365 must be orientated correctly on the PCB in order to move the cursor in the correct directions when the mouse is moved. This is shown in *Figure 6*.

Figure 6. VT5365 sensor orientation



2.7 Driving the navigation LED

The VT5365 provides an output (NAV_LED) to drive the LED that is used to illuminate the mousing surface. This output is active HIGH but cannot be used to drive the navigation LED directly. An external NPN bipolar transistor is recommended as shown in the reference schematic ([Figure 4 on page 8](#)). The maximum current through the LED is controlled by a resistor (R9 on the reference schematic).

Note: The navigation LED is used in a non-continuous mode. The duty cycle of the LED is varied by the exposure controller inside the VT5365 and has a maximum value of 40% (on very dark surfaces).

3 ST default firmware

3.1 Switches (GPIO 3 - 7)

The VT5365 supports up to 5 switch inputs with the default firmware. These switches provide the standard mouse functions of LEFT, RIGHT and MIDDLE as well as the advanced functions of BACK and FORWARD. The switch inputs are all active LOW. An external pull-up resistor is required between the switch input and the VBAT (1.8 V) supply.

3.2 Scroll wheel (GPIO 1 & 2)

The VT5365 supports the use of an external mechanical shaft encoder with quadrature outputs to act as a scroll wheel. Pull-up resistors are required between the ZA and ZB outputs of the shaft encoder and the VBAT supply. Note that the two quadrature outputs ZA and ZB are not interchangeable and must be connected correctly.

3.3 GPIO 0 - internal/external RF selection + low battery output

3.3.1 Internal/external RF selection

The state of GPIO 0 is detected at power-up:

- If GPIO 0 is LOW, the RF output will be baseband serial data and an external RF modulator will be required.
- However, if GPIO 0 is HIGH at power-up, the internal RF modulator will be enabled and the output will be digitally modulated 27.045 MHz FSK. In this case, very minimal external circuitry is required for filtering and amplification, and the overall system can be achieved using a single 12MHz crystal.

For more details and schematics, please refer to the STV-365-R0X user manuals.

3.3.2 Low battery output

After power-up, if a low battery condition is detected, GPIO 0 becomes an output that can drive a low current LED.

If the battery goes below 0.8 V, GPIO 0 will be pulled low during RUNNING mode only (that is, when the mouse is moving or during ZWheel/button presses), and goes to highZ in IDLE or SLEEP modes. If the battery voltage goes above 1 V, GPIO 0 will stay highZ in all modes.

3.4 SGPIO 0 - power supply select

The VT5365 can be powered by either a single 1.8 V supply (single/parallel batteries) or a 2.0 V to 3.2 V supply (batteries in series).

Connecting SGPIO 0 to 0 V enables the direct drive, turning off the internal 1.8 V regulator. While connecting SGPIO 0 to 1V8 allows the VT5365 to be driven at the minimal supply of 1.8 V, all internal regulators are used.

3.5 SGPIO 1 - VGate

If required, (that is, if $V_{LED} > 1.8\text{ V}$) SGPIO 1 can be used as a DCDC Controller output to supply VLED. For more details please refer to STV-365-R0X user manuals.

3.6 CPI swap

The default CPI 'Counts Per Inch' of the VT5365 is 800 CPI. This can easily be toggled between 800/1600 CPI by the user, by simply holding down the left and right buttons for 2 seconds. Once the CPI has changed, GPIO 0 will go low and turn on the Low Battery LED. The LED turns off again as soon as one of the buttons is released.

If the batteries are removed from the mouse it will return to the default (800 CPI).

3.7 ST protocol

ST has designed their own 27 MHz RF protocol for wireless mouse applications. The coded scheme used is the Manchester method, baud rate = 4.8 kbps.

There is support for 5 buttons, Z-wheel, 254 channel IDs + checksum.

3.8 RF ID - external EEPROM

The RF identification is stored in and read from an external EEPROM. If there is no EEPROM fitted, then every time the mouse is powered off the user will have to reconnect the mouse/receiver on power up.

3.9 Power management

The VT5365 is self contained, controlling everything on chip, including power management and automatic sleep or wake-up.

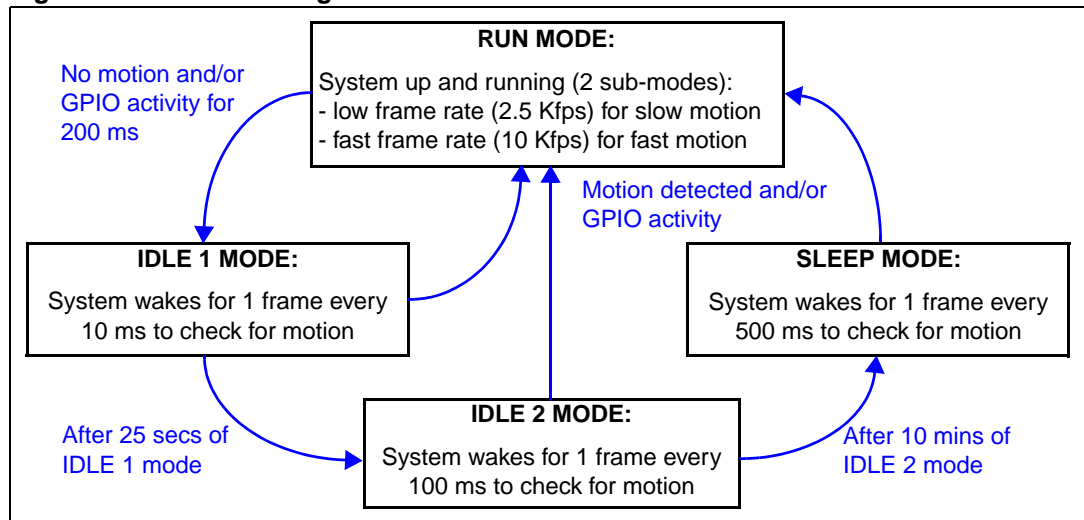
The VT5365 includes several features that enable the user to choose the implementation to maximize battery life. Typically, the MCU has the power to shut the complete chip down (with the exception of the digital regulator, the POR and the on-chip low frequency timer). In this mode all the clocks are OFF and the chip can wake up in two ways:

1. Upon completion of a timer cycle (period is programmable and is set prior to going to sleep).
2. Upon reception of an external event, such as a state change on one of the eight main GPIOs.

Note: The user can program which GPIO has the ability to wake up, or not to wake up, the system.

3.9.1 Power management scheme

Figure 7. Power management modes



The VT5365 has a four state power scheme - RUN, IDLE1, IDLE2, and SLEEP.

RUN mode is the mode where the whole system is up and running. This mode has three submodes, dependant on the mouse velocity: 2.5 Kfps (for motion slower than 3 ips), 5 Kfps (for motion between 3 and 6 ips) and 10 Kfps (for motion faster than 6 ips).

As long as there is some motion or any GPIO activity (e.g. Z-wheel, buttons) the mouse will remain in this state.

After 50 ms of mouse inactivity, the mouse goes into the IDLE1 mode. In this mode the system wakes up for 1 frame every 10 ms and checks for motion: if the mouse has not moved, the system automatically goes back to its low power state, otherwise the system will go into RUN mode.

Note: As described in [Figure 7](#) above, the system will wake up if any GPIO activity occurs during the low power states. GPIO means - in this case - the CHANNEL_SYNC and the standard GPIOs (e.g. buttons, Z-wheel).

After 25 seconds of IDLE1 mode, the system then goes into IDLE2 mode, where it wakes up for 1 frame every 100 ms.

After 10 minutes of no activity, the system then falls into SLEEP mode, which is exactly the same as the IDLE modes except that the system wakes up only every 500 ms to check motion activity. As per the IDLE modes, any GPIO activity will send the system back to RUN mode.

3.10 Overall system performance

The overall performance of a wireless mouse system depends on many different factors including:

- Battery choice
- Power supply design
- Design of external RF transmission circuitry
- User model (that is, how much time the mouse is actually being used)

4 Customizable firmware

The VT5365 features 4 kBytes of code space that is held in RAM. The RAM can be uploaded at power-up from an external EEPROM (via the on-chip I2C master module) which can be programmed with customer specific firmware. Please contact ST for more details.

The EEPROM must be connected to the SDA and SCL pins of the VT5365. The EEPROM cannot be programmed by the VT5365 itself and must be pre-programmed before being fitted to the final PCB. This sequence is only performed once at power-up, (for example, when the batteries are replaced).

4.1 GPIO management

There are up to 9 GPIOs available for customization: GPIO 0 - 7 and SGPIO 1 (SGPIO 1 - output only, if not being used as a DCDC controller output to supply VLED, see [Section 3.5: SGPIO 1 - VGate](#)).

SGPIO 0 is not available for customization as it is used as the Power Supply Select (see [Section 3.4: SGPIO 0 - power supply select](#)).

4.2 Battery level monitoring

In the default firmware, the low battery level is set at 0.8 V with 200 mV hysteresis. This level can be customized to be set from 0.6 V to 1.6 V in steps of 3.9 mV (1 V / 256).

4.3 Power mode time constants

The following power management time constants are also available for customization:

1. The time before the mouse goes from one mode to the next i.e. from RUN to IDLE1 or from IDLE 1 to IDLE 2. Minimum time between modes is 50 ms.
2. RUN mode frame rate, up to a maximum of 10 Kfps.
3. Speed at which the frame rate changes occur: low / medium / high frame rate.
4. IDLE and SLEEP times, for example increase or decrease IDLE 2 off time from 100 ms. Minimum 'off time' = 10 ms.

4.4 RF protocol

If required, the ST 27 MHz RF protocol can be replaced by the customer's own protocol. Please contact ST for more details.

4.5 RF channels

The chip features a digital programmable frequency synthesizer using a 108 MHz clock as an input, creating fractionally divided signals with frequencies around 27 MHz.

The different frequencies available are listed below:

- F = 26.995 MHz,
- **F = 27.045 MHz, (default)**
- F = 27.095 MHz,
- F = 27.145 MHz,
- F = 27.195 MHz,
- F = 27.245 MHz

The ST firmware enables all the frequencies, with the default (at power up) being 27.045 MHz. Depending on particular requirements, the customer can choose to have up to all six frequencies available, selecting their own default channel.

Note: As the output is digital, it will feature some unwanted frequency components, that will require additional filtering circuitry to remove.

4.6 CPI

The customer can choose their own default CPI, although increasing the CPI will decrease the maximum speed (due to the RF protocol). For example:

- 400 CPI : max. speed = 32 ips
- 800 CPI : max. speed = 16 ips
- 1600 CPI : max. speed = 8 ips
- 3200 CPI : max. speed = 4 ips

4.7 Motion sensitivity tuning

The motion engine has the ability to force no motion detection, if the features reported to it are less than the minimum feature threshold. As at this point the mouse is either on a very low contrast surface or is raised, the motion detection is stopped as noise could create false wake-ups.

Depending on the typical surfaces to be used, the customer can decide on the threshold value to enable the best balance between the mouse working on low contrast surfaces and being able to go into its non-run (idle/sleep) modes.

5 Optics assembly

5.1 Drawings

The optics assembly is shown in *Figure 8* and *Figure 9*.

Figure 8. MaxEmil optics

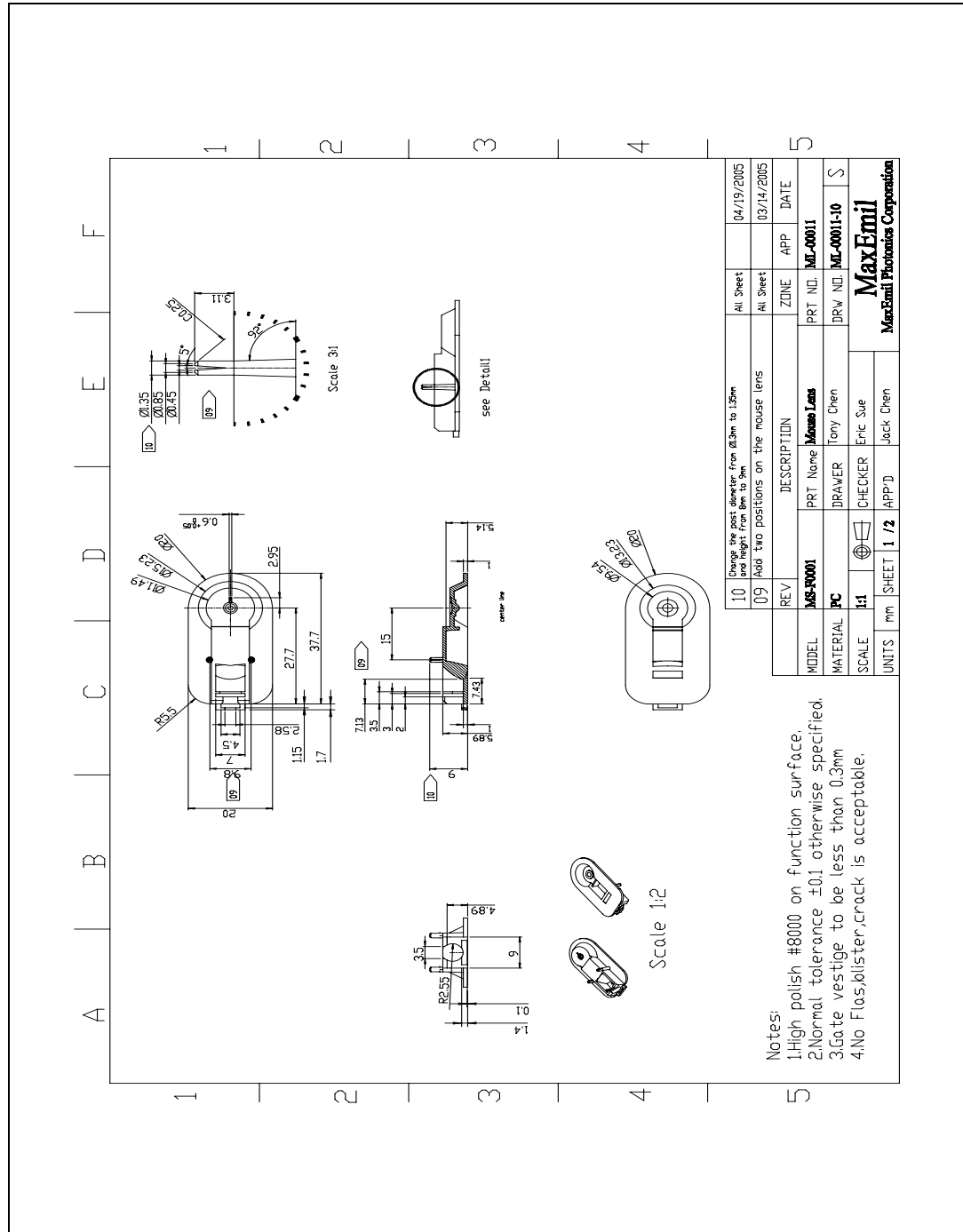
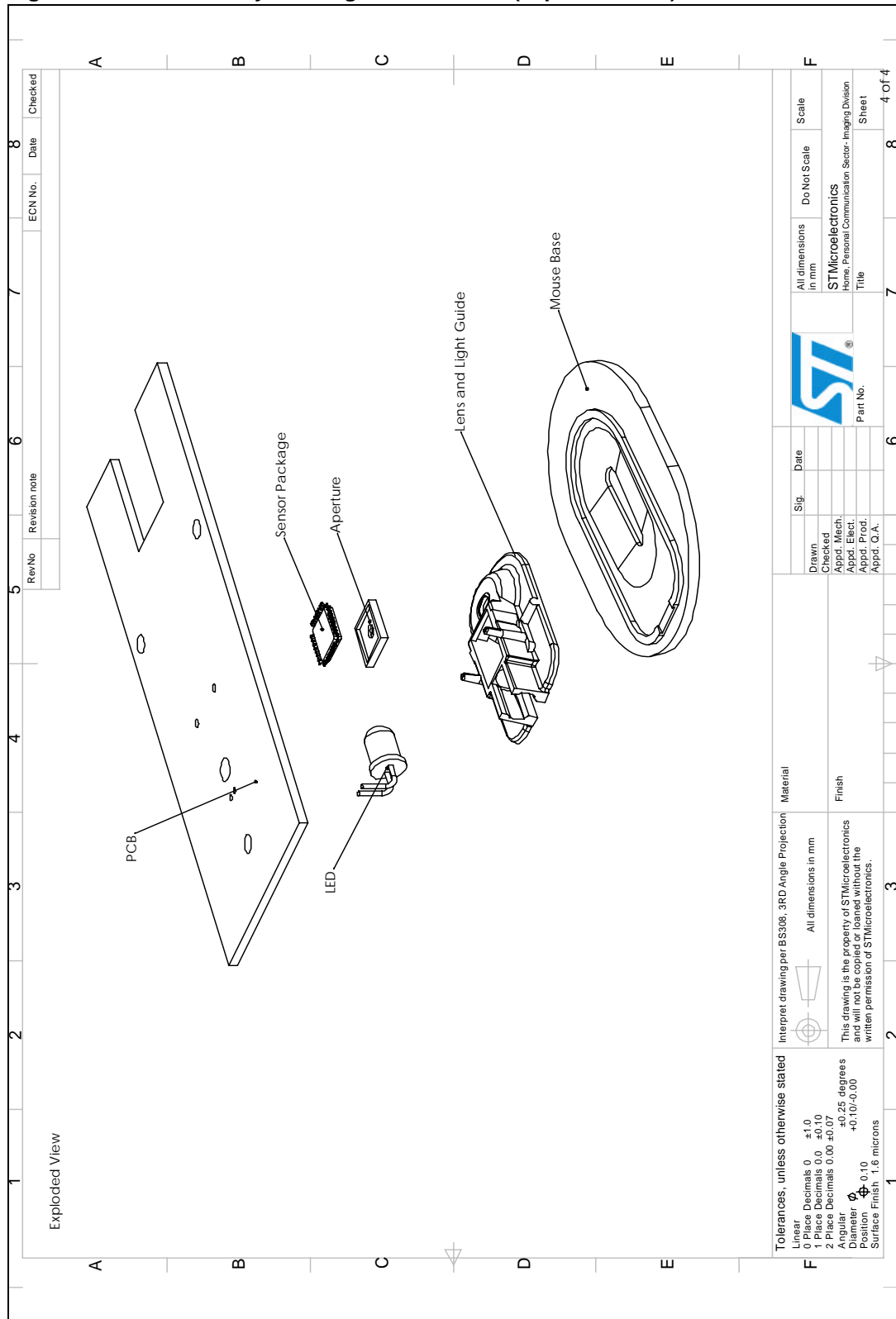


Figure 9. 2D assembly drawing of the VT5365 (exploded view)



5.2 Mouse assembly guidelines

1. Attach the sensor and all other electrical components onto the PCB, with the exception of the navigation LED.
2. Form the LED leads and insert the LED into the optical assembly.
3. Fit the optics with aperture to the PCB using the guideposts, and feed the navigation LED leads through their openings. Take care to avoid contamination of the sensor surface. The aperture should self-align to the sensor package.
4. Assemble the completed PCB onto the base plate.
5. Solder the navigation LED leads and trim.
6. Add the mouse top case, feet etc.

Note: For more details on the optics (including manufacturers) please refer to the STV-365-R0X user manuals.

6 LED selection

6.1 Overview

There are a number of LEDs from a range of suppliers which will work well with the VT5365. It is the responsibility of the customer to ensure that the chosen LED works in their specific implementation. There are various price/performance trade-offs that can be made.

6.2 Key LED parameters

For optimal performance, the VT5365 system requires a bright visible RED LED in a standard 5 mm (T1 3/4) package. The ideal viewing angle is 20° and the intensity should be at least 900 mcd at a forward current of 20 mA. The key LED parameters are listed in [Table 4](#):

Table 4. Key LED parameters

Parameter	Recommended value	Notes
Diameter	5 mm	important for fit with lens
Length	8.6 mm	Important for fit with lens
Material	AllnGaP	For long-term reliability
Luminous intensity (@20 mA)	900 mcd	Minimum value
Viewing angle	20°	Half intensity
Mechanical accuracy	+/- 2°	Accuracy of the die positioning within the LED body
Colour	Red	
Wavelength	640 nm +/- 50 nm	
Relative Illumination at sensor plane for a circle of 1.1 mm diameter	80%	Illumination value required for Red/IR LED and VCSEL

6.3 VCSEL & IR illumination

The VT5365 sensor will operate over a wide range of illuminant wavelengths. For devices operating at approx 850 nm (IR LED or VCSEL), the on-die automatic exposure controller (AEC) will compensate for the change in sensitivity compared to 640 nm (red LED). Navigation performance may be improved by increasing the illuminated device drive.

7 Electrical characteristics

7.1 Typical operating conditions

Table 5. Operating conditions

Symbol	Parameter	Min.	Typ.	Max.	Unit
V _{in}	Supply voltage	1.7	1.8	2.0	V
V _{top}	Supply Voltage	2.0		3.2	v
	Supply current (Fast RUN mode - 10 Kfps)		28		mA
	Supply current (Slow RUN mode - 2.5 Kfps)		16		mA
	Supply current (IDLE 1 mode)		500		μA
	Supply current (IDLE 2 mode)		120		μA
	Supply current (SLEEP mode)		60		μA

Note: 1 Supply currents above are for VT5365 sensor, IR LED and RF stage, measured at 1.8 V (direct drive).

2 V_{top} - VT5365 in regulated mode. In direct drive V_{top} should be connected to V_{in}.

7.2 Logic IO

Table 6. Digital IO electrical characteristics

Symbol	Parameter description	Min.	Typ.	Max.	Unit
CMOS digital inputs					
V _{IL}	Low level input voltage	0V		0.3 VDD	V
V _{IH}	High level input voltage	0.7 VDD		5.5 V	V
I _{IL}	Low level input current			-1	μA
I _{IH}	High level input current			1	μA
CMOS digital outputs					
V _{OL}	Low level output voltage (4 mA load)			0.3 VDD	V
V _{OH}	High level output voltage (4 mA load)	0.7 VDD			V

Note: All digital inputs/outputs are 1.8 V capable, 5 V tolerant.

8 Package mechanical data

Figure 10. LQFP32 clear resin body 7.0 x 7.0 x 1.40 foot print 1.0

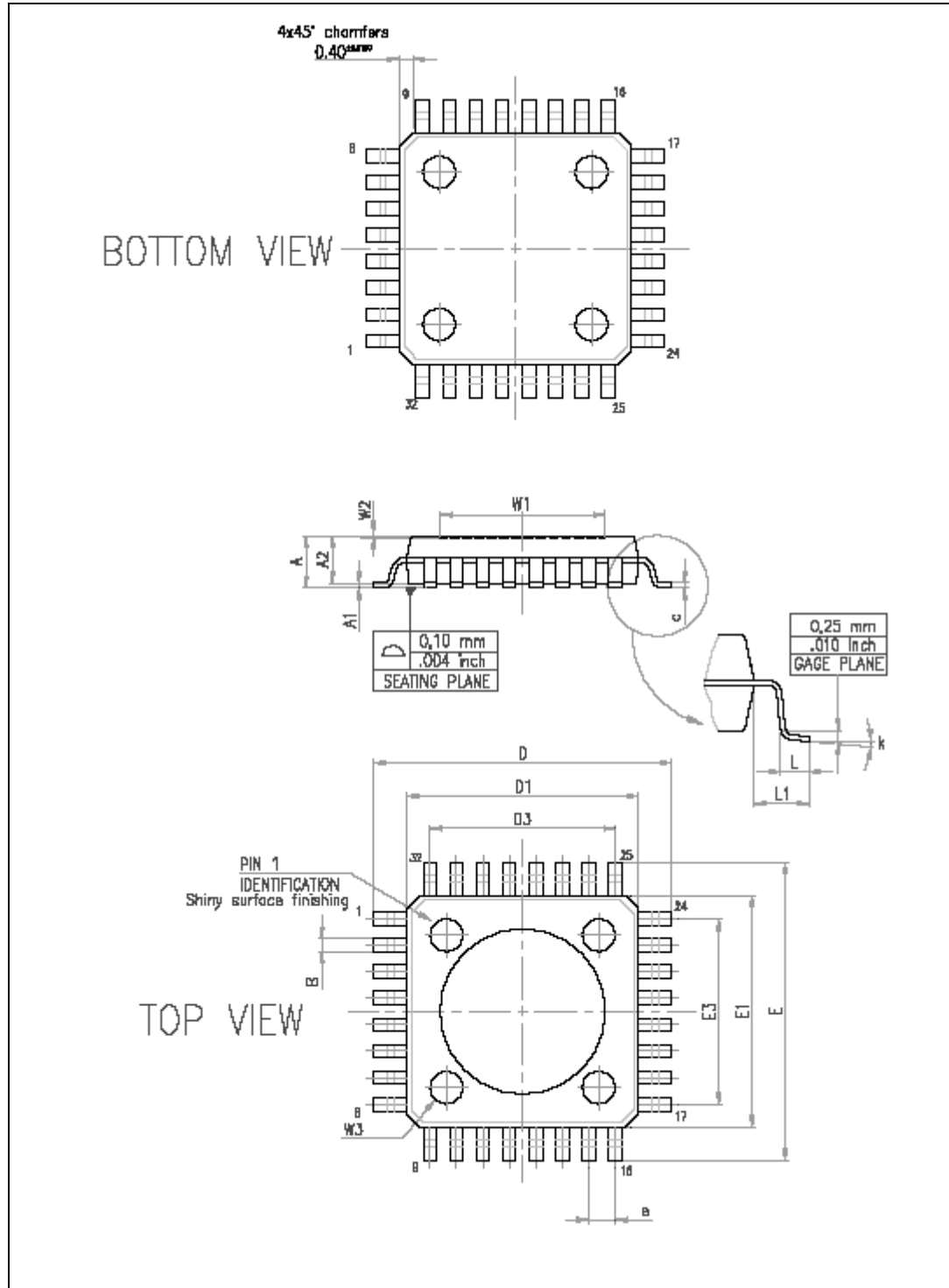


Table 7. LQFP dimensions (mm)

Reference	Min. (mm)	Typ. (mm)	Max. (mm)
A			1.600
A1	0.050		0.15
A2	1.350	1.400	1.450
B	0.300	0.370	0.450
c	0.090		0.200
D		9.00	
D1		7.000	
D3		5.600	
e		0.800	
E		9.000	
E1		7.000	
E3		5.600	
L	0.450	0.600	0.750
L1		1.000	
k	0d	3.5d	7d
W1		5.000	
W2		0.065	

- Note:
- 1 Surface finish W1 is 0.07 Ra.
 - 2 Ejectors are on 5.2 mm square for both top and bottom package.
 - 3 On top package, only the identification for pin one is not an engraved ejector.

8.1 LQFP package guidelines

The IC can be exposed a maximum of 2 times to an IR/Convection reflow solder process having a temperature profile peak of no higher than 240° C.

The package/chip are lead free and ROHS compliant.

For full handling guidelines please contact ST (doc no. 7310263).

9 Ordering information

Table 8. Order Codes

Part number	Description
VT5365V032	Optical mouse sensor

10 Revision history

Table 9. Document revision history

Date	Revision	Changes
14-Mar-2007	1	Initial release.

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