VT5376

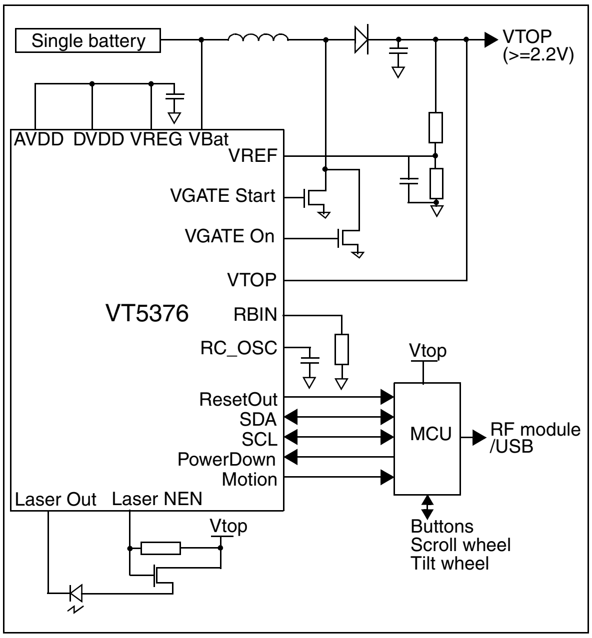
Ultra-low power motion sensor for optical finger navigation and laser mice

Features

- Ultra-low power performance and high speed/high accuracy motion detection (1 m/s, 20 g)
- Optional on-chip power management scheme (RUN/IDLE1/IDLE2/SLEEP)
- On-chip boost-converter controller enables a complete autonomous single AA/AAA-type battery supply application
- Very low quiescent and operating current mode for battery life saving
- I^2C interface, with fast polling rate capability for high end applications (report rate up to 1 per ms)
- Internal oscillator
- CPI programmable up to 3200 CPI
- On-chip ADC for battery level reporting
- Laser drive circuitry, fault detection scheme and safety features
- Versatile usage: the sensor is designed to operate with a companion microcontroller, and can be used for any laser/LED mouse system
- Optimized for wireless applications (27 MHz/2.4 GHz/BT).
- RoHS (lead-free) package

Applications

- Fingermice applications for mobile phones, remote controls or MP3 players
- Ultra-low power wireless laser mouse, 27 MHz, 2.4 GHz and Bluetooth
- Also suitable for laser USB mouse applications



Description

This device is intended to fit into any 2-chip application (companion MCU) and offers the best compromise between application cost, power and performance.

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1 Motion performance

The sensor can operate with a VCSEL or LED (visible and IR), and when bundled with the appropriate optics subsystem is able to track motion on a wide range of surfaces up to speeds of 1 m/s (40 ips), and to detect acceleration of up to 20 g. The sensor achieves this top speed with very low drift and high accuracy.

Note: Although this device features an UltraLowPower motion detection machine, the power saving has not been achieved by compromising tracking accuracy.

1.1 Technical specifications

Table 1. Technical specifications

Parameter	Description
Resolution	Programmable up to 3200 CPI
Pixel size	30.4 µm
Array size	20 x 20 pixels
Frame rate	up to 4000 fps
Tracking performances	Laser or LED: 1m/s Very low drift.
Supply voltage	1 to 1.6V(1), 1.8V direct drive or 2.2 to 3.3V
Operating temperature	0°C to 60°C
Package type	7 mm x 7 mm x 1.4 mm 32 lead LOQFP (Low profile Optical Quad Flat Pack)

1. Using internal boost converter controller.

1.2 Battery life management

The battery life management (in no motion state) can be done manually where the external MCU is the master and controls the sensor state with its POWERDOWN pin (default mode).

Alternatively, the sensor can manage its own power states. In no motion, it cycles through IDLE and SLEEP modes automatically without any intervention from the MCU.

Therefore, by using the sensor's automatic power management, the MCU can be fully switched OFF in the case of no motion allowing for extra power savings, and resulting in a very simple driver firmware design.

1.2.1 Manual power management using POWERDOWN pin

In this mode, the chip is woken-up by pulling the POWERDOWN pin low. When doing so both the analog and DCDC engines are woken up in a programmed sequence. The POWERDOWN pin can then be pulled high straight away as the sensor undergoes just a single frame sequence.

1.2.2 Automatic power management using the internal timer

In this mode, after having written the initialization I^2C command, the POWERDOWN pin must be left high at all times.

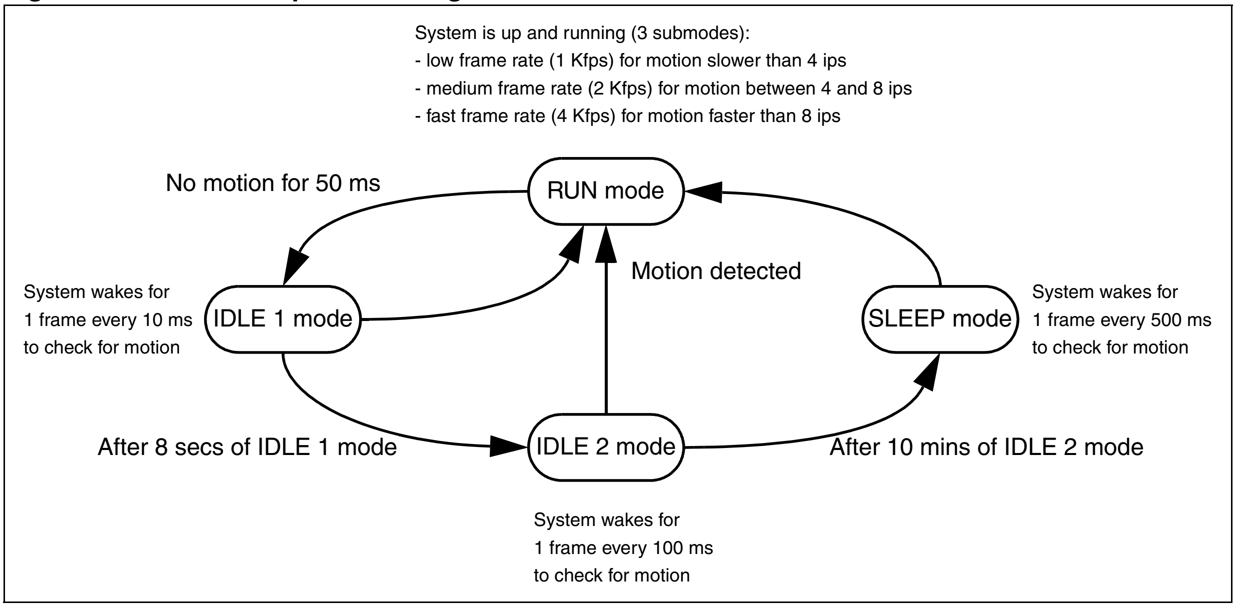
In running mode, the motion engine operation is basically the same as the manual power management mode, however, in the case of no motion (after a set time) the chip now has the ability to put itself to sleep for a determined period of time. This mode features the usual modes: RUNNING, IDLE1, IDLE2 and SLEEP, with on-chip preprogrammed time constants (firmware).

If no motion is detected the VT5376 will in turn cycle to IDLE1/IDLE2 then SLEEP. In each of these modes, the behavior is a single frame operation; the RC timer is programmed to wake up for the next period then the sensor goes to sleep. The MOTION pin will go high if motion is detected. The sensor will remain in RUN mode until the host has polled all motion data.

In this automatic power management mode, the external MCU can set itself to STDBY and just wait for the MOTION pin to come up, hence saving power in the no motion condition. This enables the application MCU firmware to be simplified as much as possible.

The VT5376 automatic power management has a four state power scheme; RUN, IDLE1, IDLE2 and SLEEP, see *Figure 1*.

Figure 1. Automatic power management



RUN mode is the mode where the whole system is up and running. This mode has three submodes, dependant on the mouse velocity: 1K fps (for motion slower than 4 ips), 2K fps (for motion between 4 ips and 8 ips) and 4K fps (for motion faster than 8 ips).
As long as there is motion the mouse will remain in this state.

After 50 ms of mouse inactivity the mouse goes into the IDLE 1 mode. In this mode, the system wakes up every 10 ms for 1 frame 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.

After 8 seconds of IDLE 1 mode, the system then goes into IDLE 2 mode where it wakes up for 1 frame every 100 ms. After 10 minutes of no activity the system 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.

Table 2. Automatic power management(1)

	PowerDown pin(2) high	
	Motion detected	No motion detected
Motion pin (output)	High	Low

1. Write 1 to register 0x05 bit [0].
2. PowerDown pin not used in automatic power management and should be pulled high AFTER VT5376 I^2C initialization command.

Table 3. Manual power management(1)

	PowerDown pin(2) high (sensor asleep)		PowerDown pin(2) low (sensor awake)	
	Motion detected	No motion detected	Motion detected	No motion detected
Motion pin (output)	Low	Low	High	Low

1. Write 0 to register 0x05 bit [0].
2. PowerDown is an input pin.

2 Power supply options and power consumption

2.1 Power options

There are three different power options for the VT5376:

- 1.8V direct drive
- 2.2V to 3.3V external supply to Vtop
- one battery supply (1V to 1.6V) to Vbat

2.1.1 External supply (1.8V direct)

In this instance, the internal DCDC controller is bypassed and voltage regulators turned off. The sensor should be supplied with a single regulated 1.8V +/- 0.1V (connected to DVDD, AVDD, VBAT, VREG and VTOP).

2.1.2 External supply (2.2V to 3.3V)

With this option Vtop is to connected to an external 2.2V to 3.3V supply.

The internal DCDC controller is bypassed but the internal voltage regulator is on which supplies the sensor with 1V8 (DVDD, AVDD, VBAT and VREG to be connected together).

2.1.3 One battery (1V to 1.6V)

The sensor includes a DCDC controller to supply the laser/LED. This allows the overall sensor system to operate from a single AA or AAA battery supply voltage (from 1.6V down to 1V) without the need for an external step-up convertor device. This gives a simple and low power/low cost system design.

Table 4. Typical power supply and power consumption

	Run			IDLE1	IDLE2	SLEEP
	4000 fps	2000 fps	1000 fps			
Total @ ITop (sensor + Laser/LED)	5.8 mA	3.5 mA	2.4 mA	0.3 mA	0.15 mA	0.1 mA

Note: 1 DCDC efficiency from single battery cell to Vtop (typical 2.2V) is around 70%.

2 Maximum load on Vtop is 25 mA

3 Electrical characteristics

3.1 Supply voltages - 1.8V direct drive

Note: This bypasses the DCDC controller and internal regulator.

Table 5. Supply voltages(1)

Symbol	Parameter	Min.	Typ.	Max.	Unit
VTOP	Boosted supply	1.7	1.8	1.9	V
VBAT	Supply from single AA cell	1.0	1.8	1.9	V
AVDD	Analog supply	1.7	1.8	1.9	V
DVDD	Digital core supply	1.7	1.8	1.9	V
VREG	Digital core supply	1.7	1.8	1.9	V

1. DVDD, AVDD, VBAT, VTOP and VREG connect together externally.

3.2 Supply voltages - Vtop

Note: This uses the internal regulator.

Table 6. Supply voltages

Symbol	Parameter	Min.	Typ.	Max.	Unit
VTOP	Boosted supply	2.2	3.0	3.3	V
DVDD, VREG	Internal regulated supply(1)	1.75	1.8	1.85	V

1. Connect DVDD/VREG externally to AVDD and VBAT.

3.3 Supply voltages - from 1 AA battery

Note: This uses the internal DCDC controller.

Table 7. Supply voltages

Symbol	Parameter	Min.	Typ.	Max.	Unit
VBAT	Supply from single AA cell	1.0	1.25	1.6	V
VTOP	Boosted supply(1)	2.0	2.2	2.6	V

1. Value defined by resistors ratio.

3.4 Logic IO

Table 8. **Digital IO electrical characteristics**

Symbol	Parameter	Min.	Typ.	Max.	Unit
CMOS digital inputs (PowerDown, SDA and SCL)					
V_{IL}	Low level input voltage	0		0.3*VDD	V
V_{IH}	High level input voltage	0.7*VDD		VDD + 0.3	V
I_{IL}	Low level input current			-1	µA
I_{IH}	High level input current			1	µA
CMOS digital outputs (Reset_out, Motion, SDA, SCL)					
V_{OL}	Low level output voltage (4mA load)			0.3*VDD	V
V_{OH}	High level output voltage (4mA load)	0.7*VDD			V

Note: 1 VDD = 1.8V

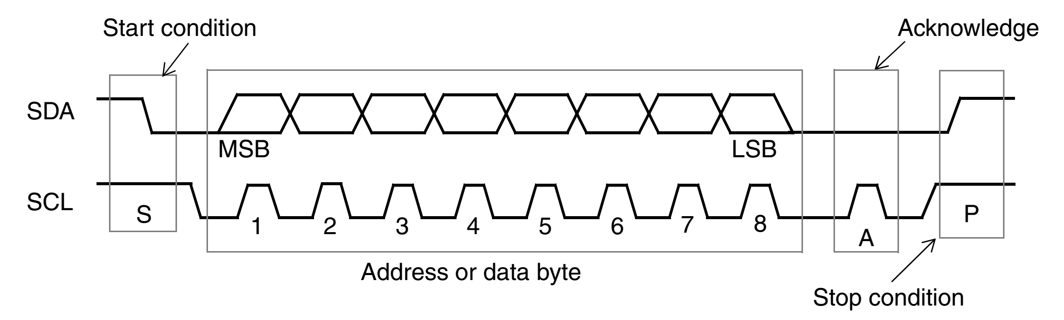
2 Digital inputs are 5V tolerant.

4 Interface

The interface is 400 kHz I^2C, with very fast polling rate for high CPI applications (down to 1 ms period).

4.1 Protocol

Figure 2. Serial interface data transfer protocol



4.2 Data format

Information is packed in 8-bit packets (bytes) always followed by an acknowledge bit. The internal data is produced by sampling sda at a rising edge of scl. The external data must be stable during the high period of SCL. The exceptions to this are start (S) or stop (P) conditions when SDA falls or rises respectively, while SCL is high.

The first byte contains the device address byte which includes the data direction read, (R), ~write, ($\overline{W}$), bit.

Figure 3. VT5376 serial interface address

0	0	1	0	0	0	0	R/$\overline{W}$

The byte following the address byte contains the address of the first data byte (also referred to as the index).

4.3 Message interpretation

All serial interface communications with the sensor must begin with a start condition. If the start condition is followed by a valid address byte then further communications can take place. The sensor will acknowledge the receipt of a valid address by driving the SDA wire low. The state of the read/~write bit (lsb of the address byte) is stored and the next byte of data, sampled from SDA, can be interpreted.

During a write sequence the second byte received is an address index and is used to point to one of the internal registers. The serial interface will automatically increment the index address by one location after each slave acknowledge. The master can therefore send data bytes continuously to the slave until the slave fails to provide an acknowledge or the master terminates the write communication with a stop condition or sends a repeated start, (Sr).

As data is received by the slave it is written bit by bit to a serial/parallel register. After each data byte has been received by the slave, an acknowledge is generated, the data is then stored in the internal register addressed by the current index.

During a read message, the content of the addressed register is then parallel loaded into the serial/parallel register and clocked out of the device by SCL.

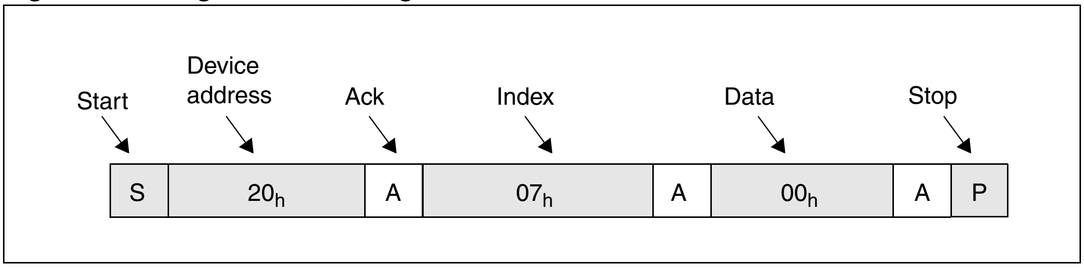
At the end of each byte, in both read and write message sequences, an acknowledge is issued by the receiving device. A message can only be terminated by the bus master, either by issuing a stop condition, a repeated start condition or by a negative acknowledge (NAck) after reading a complete byte during a read operation.

4.4 Type of messages

4.4.1 Single location, single data write

When a random value is written to the sensor, the message will look as shown in *Figure 4*.

Figure 4. Single location, single write

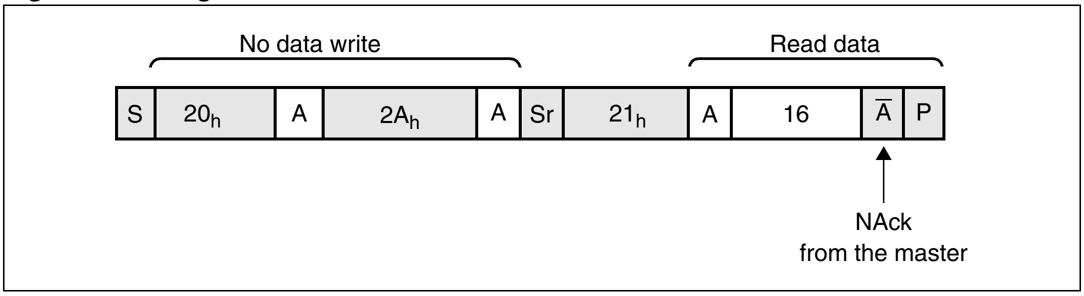


The R/W bit is set to zero for writing. The write message is terminated with a stop condition from the master.

4.4.2 Single location read

When a location is to be read, but the value of the stored index is not known, a write message with no data byte must be written first, specifying the index. The read message then completes the message sequence. To avoid relinquishing the serial to bus to another master a repeated start condition is asserted between the write and read messages. In the example in *Figure 5*, the X motion vector scaling value (index 0x2A) is read.

Figure 5. Single read



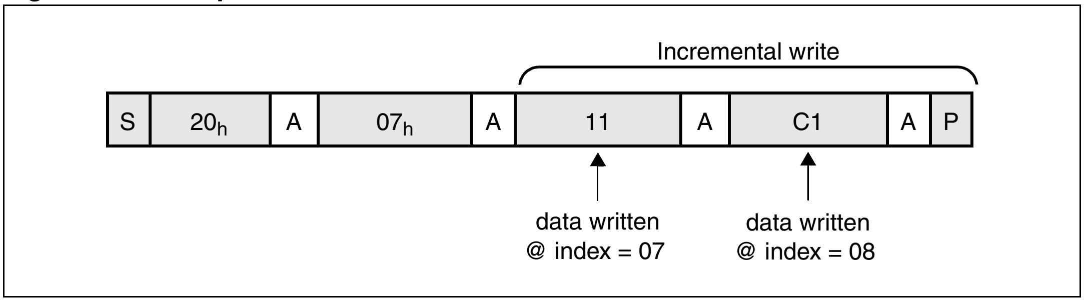
As mentioned in the previous example, the read message is terminated with a negative acknowledge ($\overline{A}$) from the master.

4.4.3 Multiple location write

It is possible to write data bytes to consecutive adjacent internal registers without having to send explicit indexes prior to sending each data byte.

Note: An auto-increment write is assumed if no stop condition occurs.

Figure 6. Multiple location write



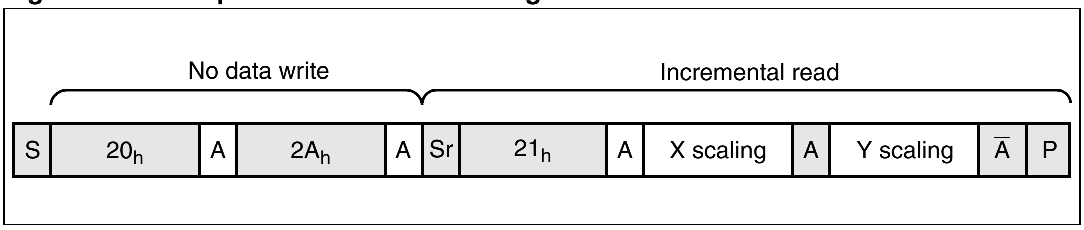
4.4.4 Multiple location read: reading motion value example

Multiple locations can be read within a single read message. An auto-increment write is assumed.

Note: 1 Registers are read until the master Nacks the data.

2 When reading 0x21/0x22 (X/Y motion data), a multiple read must be performed as both registers are cleared after a each read.

Figure 7. Multiple location read: reading motion



5 I^2C control register map

Table 9. I^2C control register map

Index address	Bits	Name	R/W	Default	Description
0x00	[7:0]	Device Hardware revision	RO	00h	HW revision: set by the mask set revision
0x01	[7:0]	Device Soft revision	RW	01h	FW revision: is updated every time internal firmware of minor revision is done.
0x05	[0]	Automatic Power management	RW	0h	When set, the device controls its own power mode state machine in no motion condition. If not set, POWERDOWN controls the state of the device (standby/run)
	[1]	Laser Selected	RW	0h	When set, the device sets all internal variables to optimize the system for laser illumination. If set, LASER_OUT is actived to direct drive a VCSEL, and LASER_NEN controls its power supply switch. If not set, LASER_NEN becomes the LED_ON signal, toggling at frame rate.
	[2]	Use External Supply	RW	0h	1: The device switches its internal 1.8 V regulator off, and assumes 1.8 V will be supplied at all times to Vtop, DVDD and AVDD. VBat can also be supplied by the same 1.8V or from a single battery. 0: Device uses internal regulators (Vtop must be set >= 2.2V).
	[3]	Host Config Done	RW	0h	This bit must be set to 1 to indicate to the chip that the boot configuration of the sensor (mainly this register) is complete, and it can start motioning.
	[5]	LED DAC driven	RW	0h	If set to 1, and the chip is set in LED mode, then the LED is direct driven by the internal DAC.
	[7]	FW idle state	RW	0h	If enabled the MCU firmware will go into an idle mode (I^2C commands still available).

Table 9. I²C control register map (continued)

Index address	Bits	Name	R/W	Default	Description
0x0A	[7]	Force Laser Out ON	RW	0h	If set to 1, this sets the LASER_OUT DAC always ON (instead of toggling normally). This mode is provided in case the DAC current needs calibrating. To confirm this mode, register 0x0D will also need to be written to (complement data).
	[6:0]	DAC current setting	RW	7Fh (laser) 00h (LED)	Sets DAC current setting. To validate the setting, register 0x0D will also need to be written to (complement data). With Rbin = 12 KΩ, 0x7F: 3.4mA 0x00: 10mA.
0x0B	[0]	Laser Drive Enable	RW	0h	0: Current source OFF 1: Enable current source
	[1]	Laser NEN Out	RW	1h	Laser NEN pin state Note: This command is only valid if bit [5] is 1
	[2]	Laser NEN OD Enable	RW	1h	0: LASER_NEN 1.8V capable CMOS 1: LASER_NEN - OpenDrain 5V tolerant Note: This command is only valid if bit [5] is 1
	[3]	Force Laser Out High	RW	0h	0: Normal operation, LASEROUT set by DAC 1: Set to 1 to detect short to GND on LASER_OUT
	[4]	Laser comp Enable	RW	0h	0: Disable fault detection comparators 1: Enable fault detection comparators
	[5]	Laser NEN trk led n	RW	0h	0: LASER_NEN replaced by TRK_LED pulse (LED) 1: LASER_NEN controlled by bits [1] and [2] (Laser)
	[6]	Laser Bias Enable	RW	0h	0: Disable bias current source 1: Enable bias current source Note: valid only if bit [7] is high
	[7]	Laser Bias Ctrl	RW	0h	0 : Laser bias is driven the same way as laser drive (DAC) 1 : Laser bias is controlled with laser_bias_enable signal (bit [6])

Table 9. I^2C control register map (continued)

Index address	Bits	Name	R/W	Default	Description
0x0C	[5]	Rbin Low	RO	0h	0: Rbin above threshold 1: Rbin below threshold (shorted to GND) Note: if Laser_Comp_Enable (reg 0x0B, bit [4]) = 0, Rbin_Low=1
	[6]	Laser Low	RO	0h	0: Laser OUT above LOW threshold 1: Laser OUT below LOW threshold (shorted to GND). Note: if Laser_Comp_Enable = 0, Laser_Low = 1
	[7]	Laser High	RO	0h	0: Laser OUT below HIGH threshold 1: Laser OUT above HIGH threshold (shorted to VDD). Note: if Laser_Comp_Enable = 0, Laser_High = 1
0x0D	[7]	Force Laser Out ON (Compl)	RW	1h	If set to 0, this sets the LASER_OUT DAC always ON (instead of toggling normally). This mode is provided in case the DAC current needs calibrating. To confirm this mode, register 0x0A will also need to be written to (complement data).
	[6:0]	DAC current setting (Compl)	RW	00h (laser 0x7F (LED)	Sets DAC current setting. To validate the setting, register 0x0A will also need to be written to (complement data). With Rbin = 12 Kohms, 0x00: 3.4mA 0x7F: 10mA
0x21	[7:0]	X_motion	RO		This register holds the overall X movement data since last polling was done. Value is 8 bit 2's complement.(1)
0x22	[7:0]	Y_motion	RO		This register holds the overall Y movement data since last polling was done. Value is 8 bit 2's complement.(1)
0x23	[0]	X Overflow	RO	0h	This register records if the X-motion integrator has reached its limit.
	[1]	Y Overflow	RO	0h	This register records if the Y-motion integrator has reached its limit.
	[3]	No Motion	RO	0h	This bit is asserted if both X/Y integrators are empty

Table 9. I²C control register map (continued)

Index address	Bits	Name	R/W	Default	Description
0x27	[0]	Invert X	RW	0h	Allows X to be inverted(2)
	[1]	Invert Y	RW	0h	Allows Y to be inverted(2)
	[3]	Swap XY	RW	1h	Replaces X with Y and Y with X
	[5]	Test Pattern Enabled	RW	0h	0: Normal mode 1: Diamond shape pattern
	[6:7]	Test Pattern Speed	RW	0h	Diamond test pattern speed - 0x0 : motion = 127 max speed 0x1 : motion = 64 0x2 : motion = 32 0x3 : motion = 16
0x29	[7:0]	Min_features[13:6]	RW	0000_0100	This register represents the feature threshold below which motion is no longer valid (in this case, the device reports "0" motion). This is linked to the value reported in registers 0x31/0x32
0x2A	[7:0]	Scaling for X motion vectors	RW	0001_0000	Sets resolution as CPI: 8: 400 CPI, 16: 800 CPI 32 = 1600CPI, 64 = 3200CPI Assuming lens magnification of x0.5
0x2B	[7:0]	Scaling for Y motion vectors	RW	0001_0000	Sets resolution as CPI: 0x08: 400 CPI 0x10: 800 CPI Assuming lens magnification of x 0.5
0x31	[15:8]	Features count	RO		Feature count report: the higher the value, the more distinctive features the surface requires, for the motion detection machine to operate reliably.
0x32	[7:0]		RO		
0x41	[7:0]	Exposure [8:1]	RW	80h	Exposure value in 2 x CLK12 period units. eg. max exposure value of FF = 42.5uS LED on time
0x43	[4]	Auto Expo En	RW	1h	Auto exposure enable
0x47	[7:0]	Vbat converted data	RO		This register holds the current converted data from the Vbat input voltage. The data range is as follows: 0000_0000: Vbat = 0.6 V 1111_1111: Vbat = 1.6 V The response is linear for each value in between. ADC step: 1V/256 = 3.9 mV

Table 9. I²C control register map (continued)

Index address	Bits	Name	R/W	Default	Description
0x4F	[7:0]	Exp max value	RO		This registers holds the maximum pixel value (before CDS) for the current frame. It shows if some pixels are saturated or not.
0x61	[7:0]	IMAGE[7:0]	RO		This register contains the pixel value when the frame dump feature has been activated (reg 0x62, bit 0). To read the 400 pixels from the captured frame, the register must be read 400 consecutive times.
0x62	[0]	Frame dump mode enable	RW	0h	If set to 1, the device will capture a single frame. When the frame is captured and ready to be downloaded using reg 0x61, bit 2 (frame ready) is set.
	[1]	Frame dump start	RO	0h	Bit is set at start of frame dump
	[2]	Frame ready for download		0h	This bit is asserted when the captured frame is ready to be downloaded using reg 0x61. When frame download is complete, bit 3 is reset.
	[3]	Frame upload complete		0h	This flag is set when all 400 pixels have been read by I²C host.
	[4]	PCI Test enable	R/W	0h	If set Motion, Laser_NEN, Reset_Out and VGate_On become PCI data ouptuts (QCLK, FST and 2 bits serial data).
0x82	[1]	Timer ITR enable	R/W	1h	Timer interrupt enable.

1. Internal ACCUMULATOR is reduced from this value every time it is read.
2. Default changes to 1 for a laser system after *host_config_done* (that is, system set up for optics without a lens).

6 Laser

6.1 Direct laser drive and calibration

The sensor includes a 7-bit DAC and an output current source.

The DAC value must be set using two I2C commands after power-up (default is MIN = 3.4mA, with Rbin = 12KΩ).

To allow VCSEL output power measurements to be done, the user can set the laser out (normally strobed during operation) to be continuously on using an I^2C command. This feature is optional and is designed to offer maximum flexibility.

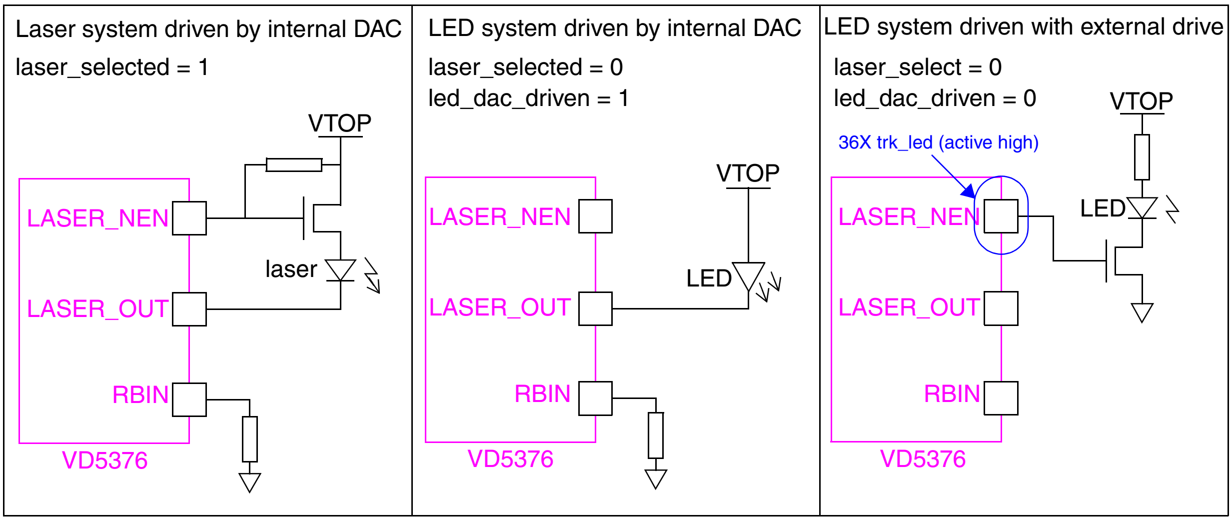
Alternatively, the Idac maximum (up to 13 mA) and minimum values can be changed by adjusting the Rbin value (for example, with Rbin = 24 KΩ, Idac max = 5 mA and Idac min = 1.7 mA).

Idac max is set by the formula:

Idac (max) = 120/Rbin (result in mA, Rbin in KΩ)

No external driver is required, just a FET power switch controlled by LASER_NEN signal.

Figure 8. Application schematics using Laser or LED (driven with internal DAC or external current source)



6.2 Laser or led system managed by host (external micro)

The host must first select LED or LASER (bit [1] of register 0x05).

- LED

  The host must select if the LED is to be driven by the internal DAC or an external current supply using bit [5] of register 0x05 (led_dac_driven). Bit [3] of register 0x05 (host_config_done) then needs to be set.

  – Case internal DAC drive: VT5376 sets the maximum current from the DAC and the system starts running.

  – Case external drive: VT5376 powers down its laser_drive and the led_on signal is present on the LASER_NEN pin.

- LASER

  The host must first decide whether to perform LASER fault detection (described in *Section 6.3*) then set bit [3] of register 0x05 (host_config_done).

  If the system passes the laser fault detection (or laser fault detect was not performed), the host can then adjust the LASER DAC current by writing a value to bits [0-6] in register 0x0A AND writing its complementary value to bits [0-6] of register 0x0D, if the values are not compatible the VT5376 applies the minimum DAC current.

6.3 Laser fault detection and safety feature

The sensor includes a set of diagnostic features that can be carried out at power-up (before setting host_config_done). The tests listed below can be selected.

- Check LASER_OUT is not shorted to VDD (LASER_OUT < 1.2V).

  – Enable DAC and disable OUT_HIGH switch by writing 0xF7 to register 0x0B (Top_ laser_setting), then make force_laser_out_on = 1, by writing 0x01 to bit 7 of register 0x0A (Top_laser_DAC_setting), and 0 to it's complementary bit (bit 7) in register 0x0D (Top_laser_Dac_setting_C). Finally read bit 6 of register 0xC to ensure that laser_low = 1.

    External LASER_NEN switch must be fitted in order to make LASER_OUT go below 0.4V.

- Check LASER_OUT and RBIN are not shorted to GND (LASER_OUT and RBIN > 0.4V).

  – Disable DAC and enable OUT_HIGH switch (force_laser_out_high = 1) by writing 0xFE to register 0x0B (Top_laser_setting). Then read register 0x0C (Top_laser_diagnostics) to ensure that bit 7 (laser_high) is set to 1 and bit 5 (Rbin_low) is set to 0.

If the result of these tests is a pass then the MCU can set the laser system as follows:

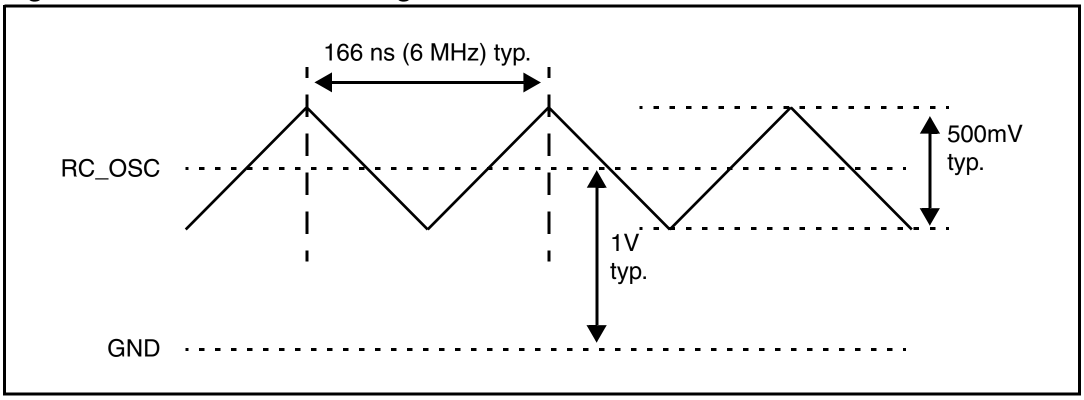
1. Set bit [3] of register 0x05 (host_config_done).
2. Write 0x25 (laser_drive and laser_nen enable) in register 0x0B (Top_laser_setting).
3. Write the required DAC value (bits 0-6) in register 0x0A (Top_laser_DAC_setting) ensuring that force_laser_out_on = 0. Write the 1's complement value of the above setting in register 0x0D (Top_laser_Dac_setting_C).

7 General features

7.1 Device clocking

The device integrates its own oscillator. It does not require an external Xtal or resonator, instead it requires only an external capacitor of 33 pF. The accuracy of this cap will determine the accuracy of the internal clock. Excluding the capacitor accuracy, the frequency will be accurate within 10% range.

Figure 9. VT5376 RC_OSC signal



7.2 Battery level monitoring

The device includes an 8-bit ADC that translates the VBAT voltage into an 8-bit value that can be read using I^{2}C. The external MCU can upload this value and take any action required.

7.3 Resolution setting (counts/inch)

Due to an accurate on-chip interpolation process, the device operates below the pixel resolution. This enables the user to easily select any desired resolution with a simple register write.

Note: Different resolutions can be applied to X and Y. This could be useful in case of optical non-symmetry or distortion.

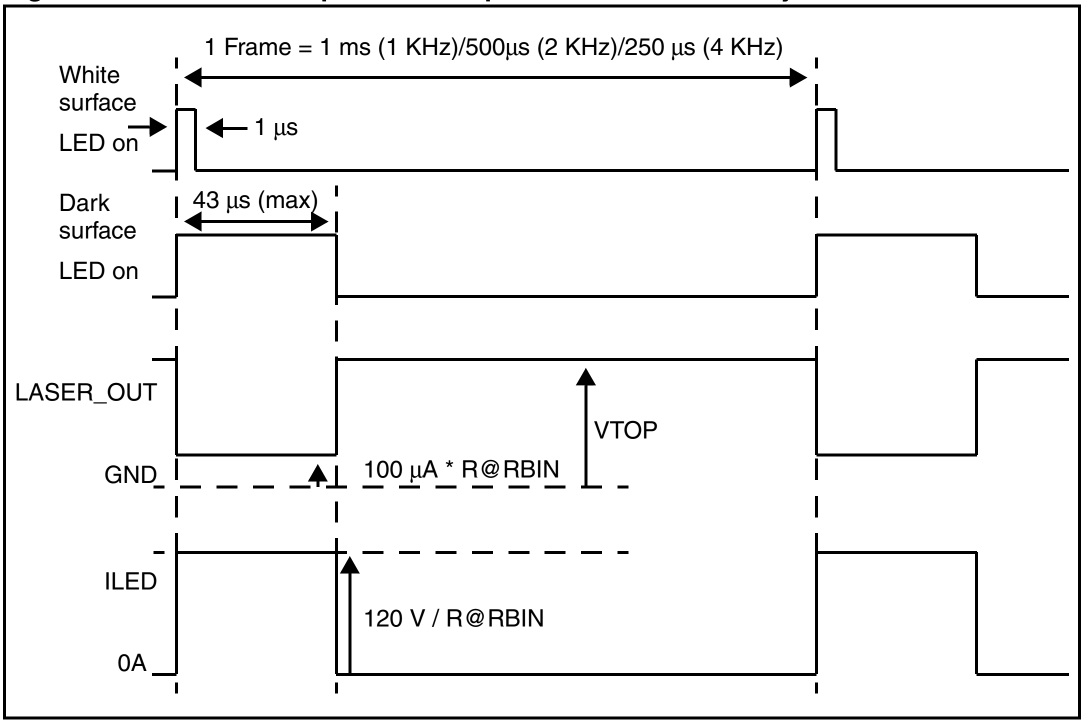
7.4 RESET_OUT pin

This pin can be used in a system where the VT5376 generates the overall application power supply, including the MCU (for example, a wireless mouse with VBat supplied by a 1 x AA battery, see *Section 3.3 on page 8*).

RESET_OUT goes high once the VT5376 supply (that is, internal regulators and DCDC) is up and running. In automatic power management mode (see *Section 1.2 on page 4*), the RESET_OUT pin can be used to tell the MCU to come out of reset. Alternatively, it could be replaced by a simple wait routine in the MCU firmware, before any I^{2}C commands are written to the VT5376.

7.5 Automatic exposure

Figure 10. Automatic exposure example - laser/LED driven by internal DAC



7.6 Image (frame) capture

It is possible to capture an image and download it using a simple I^{2}C write/read sequence. This is useful to calibrate optics during pre-production or to perform basic tests.

In order to achieve this, the user must:

1. Put the firmware into IDLE by setting bit 7 of register 0x05 (fw_idle_state).
2. Disable the motion engine controller by clearing bit 1 of register 0x82 (timer_itr_enable).
3. Enable frame dump mode by setting bit 0 of register 0x62 (frame_dump_mode_enable).

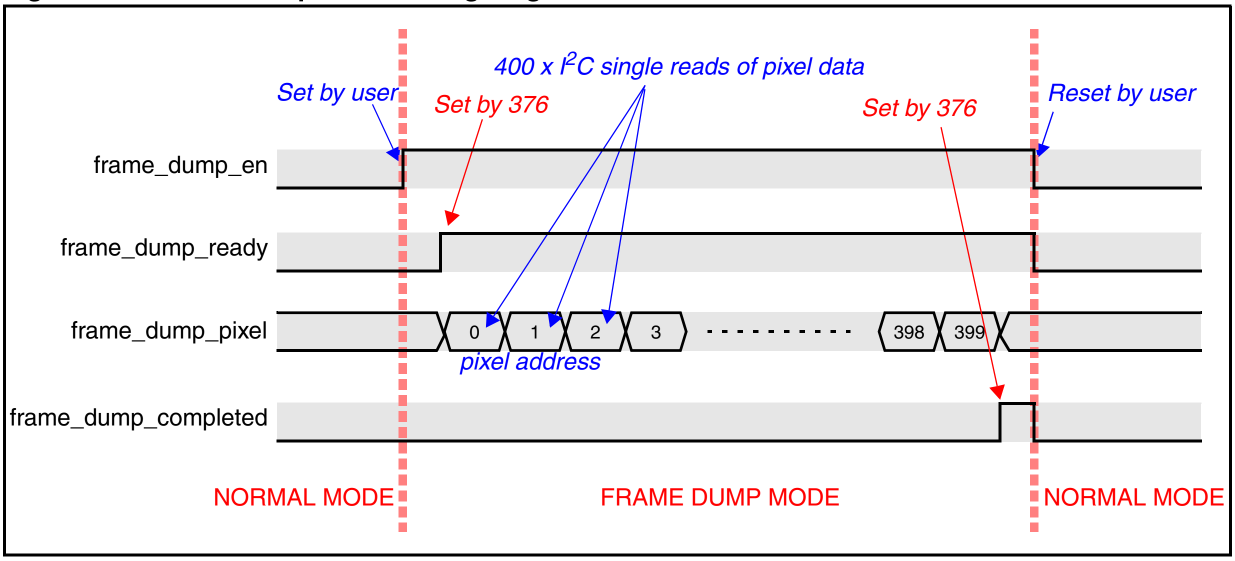
The VT5376 resets the sensor, enables the DCDC, runs a single frame sequence and stores it into an internal RAM. Once this process is complete, the VT5376 signals that the image is ready for download, by asserting bit 2 in register 0x62 (frame_ready_for_download).

When this flag is asserted, the user can download the 400 consecutive pixels by reading register 0x61 (image) 400 consecutive times.

When all the pixels have been read, the VT5376 signals the end of the process by setting bit 3 in register 0x62 (frame_upload_complete).

To resume normal operation the user should reset bit 0 in register 0x62 to exit the frame dump mode, take the firmware out of Idle by resetting bit 7 of register 0x05 and set bit 1 of register 0x82 to enable the motion controller.

Figure 11. Frame dump mode timing diagram



7.7 Image streaming

To enter this test mode, set bit 4 of registry 0x62 to 1 (PCI_test_enable).

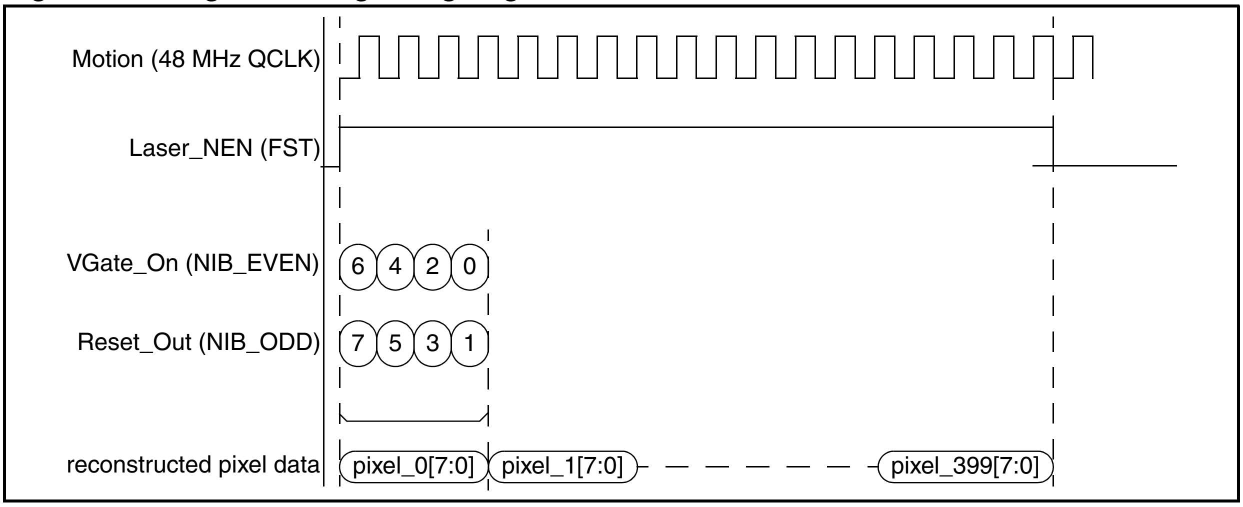
In this mode, the pins VGATE_ON, RESET_OUT, LASER_NEN and MOTION are used to output serially fast video data in the form of 2 bits nibble + FST and QCLK.

On receipt of an FST (LASER_NEN) rising edge, NIB_EVEN (VGATE_ON) and NIB_ODD (RESET_OUT) output data every 48 MHz clock cycle. The signals should be sampled 10 ns after the FST rising edge, and then every 20.8 ns exactly, during 400 x 4 = 1600 cycles.

Groups of four consecutive NIB_EVEN and NIB_ODD must then be repackaged together to form a single 8-bit pixel data. This format enables the pixels to be output at the same frame rate as normal operation, and keeps I^{2}C available to access the usual register settings.

For more details on image streaming please refer to the *VT5376 Image System User Manual*.

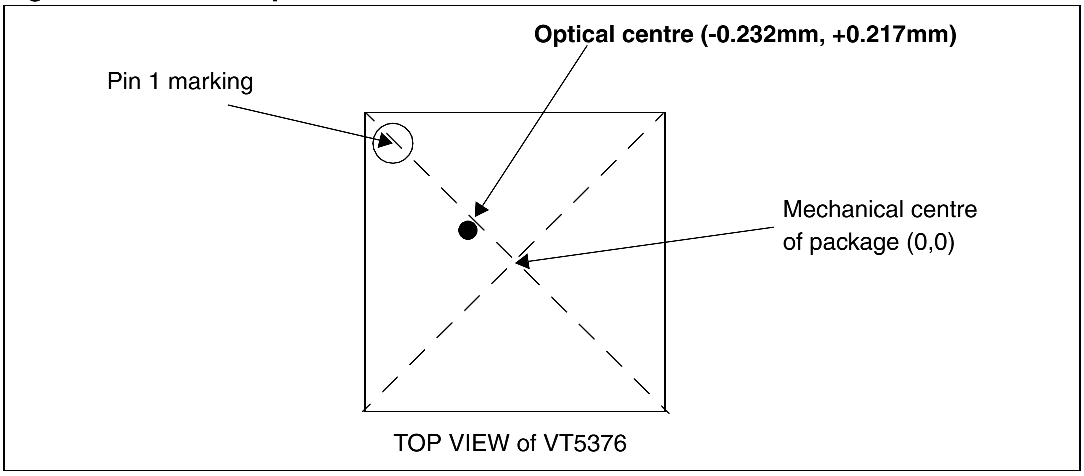
Figure 12. Image streaming timing diagram



7.8 Optical centre

The optical centre of the VT5376 is **not** in the centre of the package. It is offset by -0.232 mm in the X axis and +0.217 mm in the Y axis with respect to the centre of the package as shown in *Figure 13*. The PCB designer must take this into account when laying out the PCB.

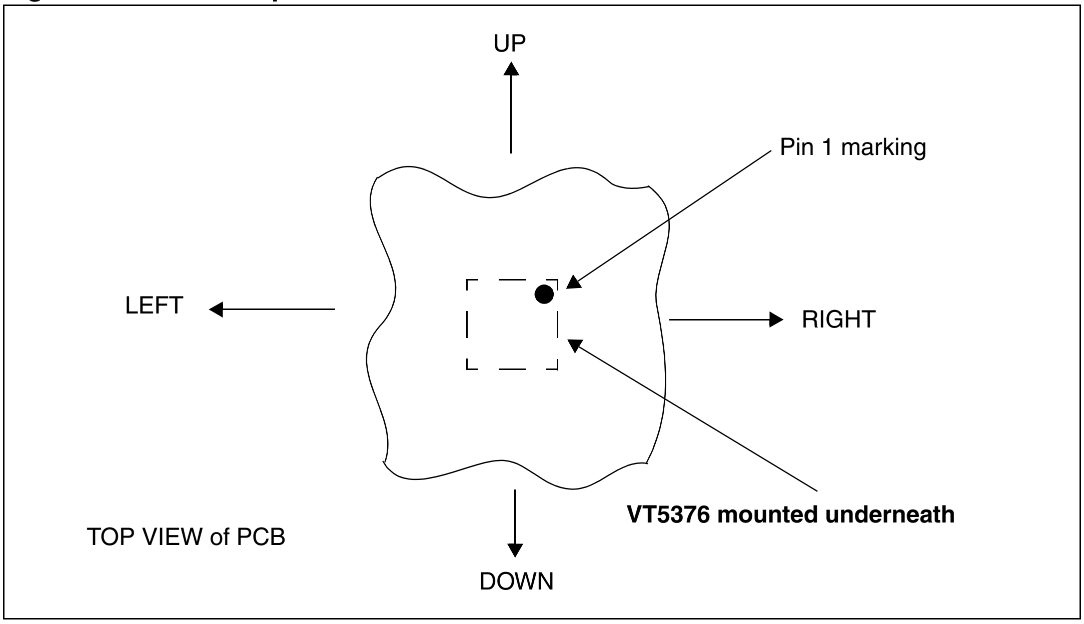
Figure 13. VT5376 optical centre



7.9 Sensor orientation on PCB (with lens)

The VT5376 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 14*.

Figure 14. VT5376 optical centre



8 Typical application

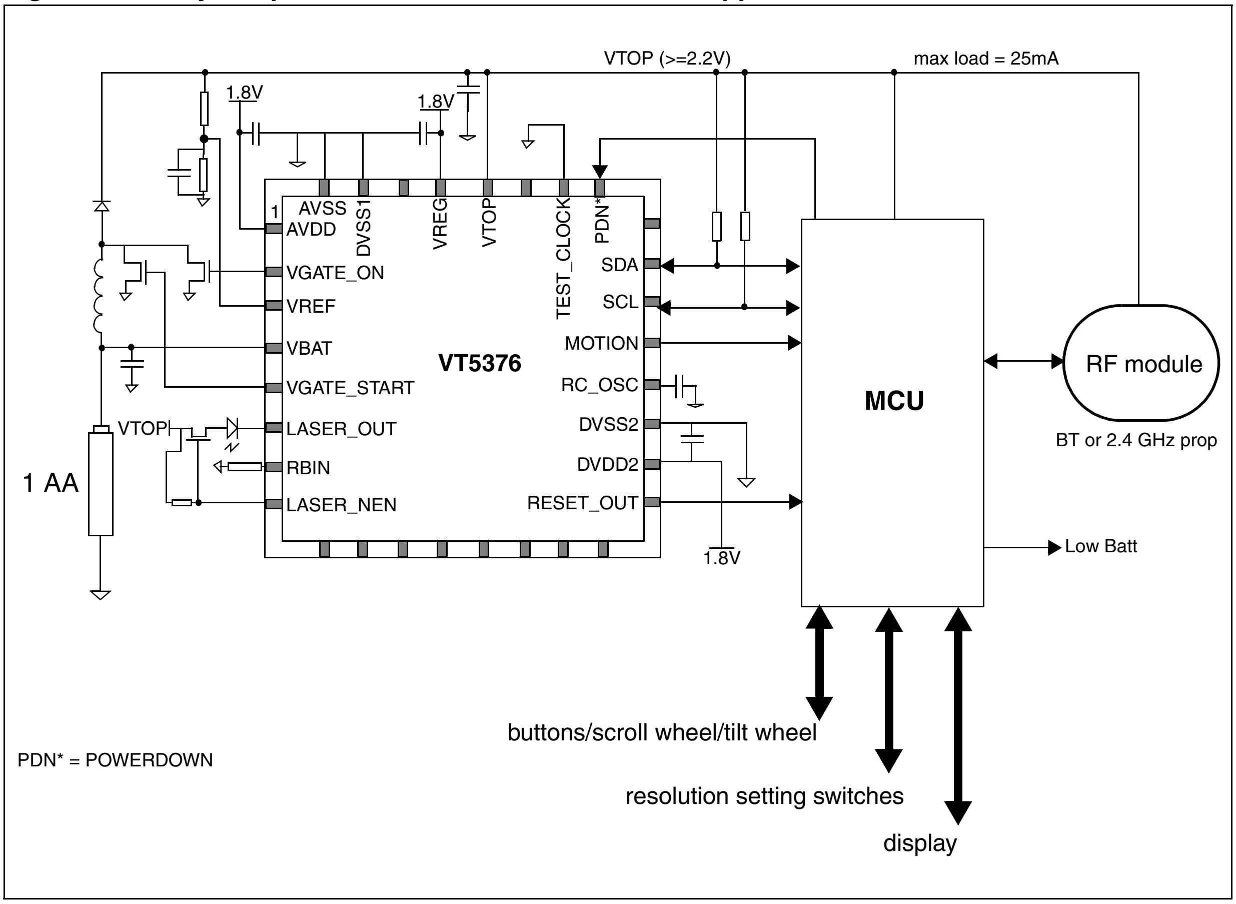


Figure 15. Very low power and low cost wireless laser application

8.1 Overall 2.4 GHz mouse power consumption example

Assumptions

- VCSEL, MCU and 2.4 GHz Tx operate from 2.2 V
- MCU consumes 1 mA in running mode and 50 uA in standby mode. In no motion period, it remains in standby until it receives an interrupt from the VT5376, indicating that MOTION has been detected.
- 2.4 GHz Tx consumes 10 mA, but data is sent by bursts of 500 µs every 5 ms (that is Nordic nRF2402).
- Maximum current is delivered to VCSEL (10 mA strobed).
- DCDC efficiency is 70%
- Ambient temperature

Table 10. Power supply and typical power consumption

	Run			IDLE1	IDLE2	SLEEP
	4000 fps	2000 fps	1000 fps			
Total @Vbat (1.25 V)	18 mA	12 mA	9.3 mA	0.59 mA	0.29 mA	0.24 mA

Using STMicroelectronics battery life model, these values would enable the mouse to operate for 12 months from two AA batteries in parallel.

9 Pinout

Figure 16 shows the pin layout and *Table 11* provides the pin descriptions.

Figure 16. Pinout

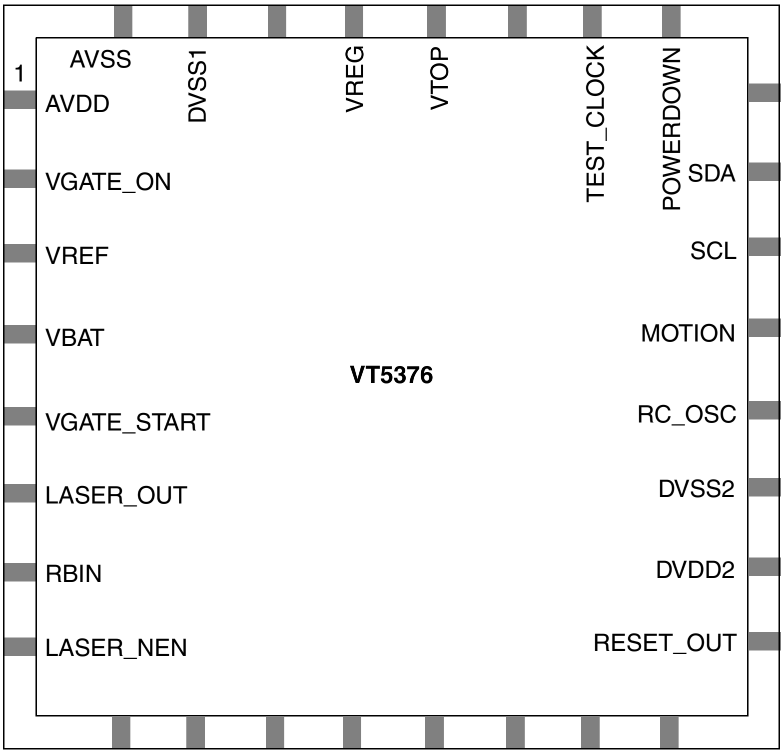


Table 11. VT5376 pin description

Pin	Pin name	Type	Description	Comment
1	AVDD	PWR	1.8 V analog supply	See *Section 2.1 on page 7*, *Section 3.1 on page 8* and *Section 3.2 on page 8*.
2	VGATE_ON	I/O	Digital IO	Used in 1 battery mode, see *Figure 15 on page 24*.
3	VREF	ANA	Analog ref input	To set VTOP in 1 battery mode, see *Figure 15 on page 24*. Tie to DVDD in ext supply mode (see *Section 2.1 on page 7*).
4	VBAT	PWR	Single battery supply	See *Section 2.1 on page 7*, *Section 3.1 on page 8* and *Section 3.2 on page 8*.
5	VGATE_START	ANA	Output	Used in 1 battery mode, see *Figure 15 on page 24*.

Table 11. VT5376 pin description (continued)

Pin	Pin name	Type	Description	Comment
6	LASER_OUT	ANA	Laser/LED drive set by internal DAC	See *Section 6.1 on page 18*.
7	RBIN	ANA	Sets maximum laser/led current	Resistor on RBIN pin sets max/min DAC current. See *Section 6.1 on page 18*.
8	LASER_NEN	I/O	Laser enable	Enables laser suply in laser mode. Or in LED external mode is used as LED on signal. See *Section 6.1 on page 18*.
17	RESET_OUT	I/O	Digital Output	Can be used in 1 battery mode, see *Section 7.4 on page 20* (1.8V only).
18	DVDD2	PWR	1.8 V regulated digital supply	See *Section 2.1 on page 7*, *Section 3.1 on page 8* and *Section 3.2 on page 8*.
19	DVSS2	PWR	Digital Ground	
20	RC_OSC	ANA	6 MHz Oscillator capacitor	Connect 33 pF to ground, see *Section 7.1 on page 20*.
21	MOTION	I/O	Digital Output	high = motion detected low = no motion. 1.8V only, see *Table 2* and *Table 3 on page 6*.
22	SCL	I/O	Digital IO	5V tolerant, See *Chapter 4 on page 10*.
23	SDA	I/O	Digital IO	5V tolerant, See *Chapter 4 on page 10*.
25	POWERDOWN	I/O	Digital Input	See *Section 2.1 on page 7*, *Table 2* and *Table 3 on page 6*.
26	TEST_CLOCK	I/O	Digital IO	Not used, connect to DGND.
28	VTOP	PWR	Power supply for internal regulators	See *Chapter 2 on page 7* and *Chapter 3 on page 8*.
29	VREG	PWR	1.8 V regulated supply	See *Section 2.1 on page 7*, *Section 3.1 on page 8* and *Section 3.2 on page 8*.
31	DVSS1	PWR	Digital ground	
32	AVSS	PWR	Analog ground	

Note: All other pins are Not Connected.

10 Package mechanical data

Figure 17. TQFP32 clear resin body 7.0 x 7.0 x 1.40 footprint 1.0

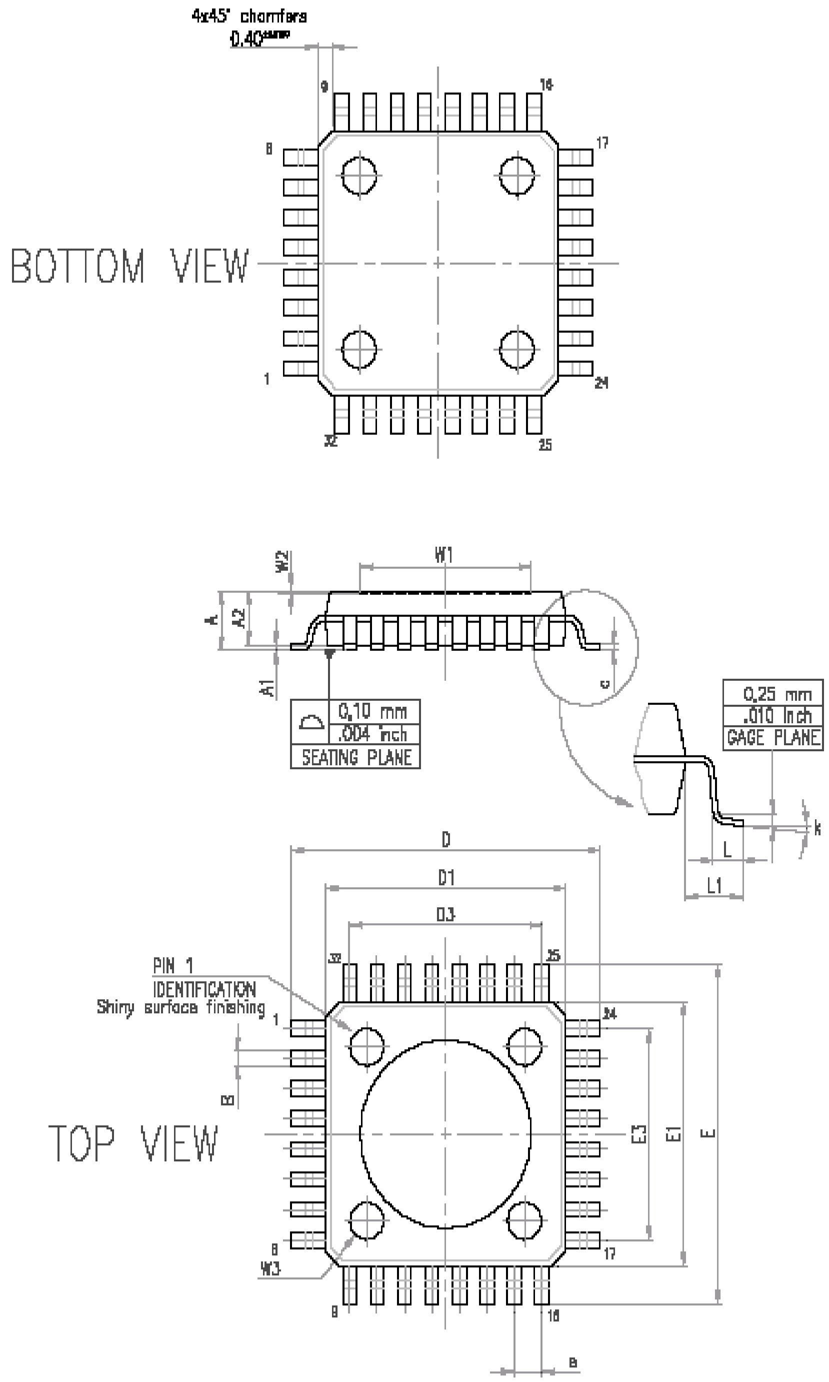


Table 12. TQFP dimensions (mm)

Reference	Minimum (mm)	Typical (mm)	Maximum (mm)
A			1.600
A1	0.050		0.150
A2	1.350	1.400	1.450
B	0.300	0.370	0.450
c	0.090		0.200
D		9.000	
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		0.650	

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 pin 1 identification is not an engraved ejector.*

10.1 TQFP package guidelines

The IC can be exposed a maximum of two 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 is ROHS compliant.

For full handling guidelines, contact STMicroelectronics (document reference 7310263).

11 Ordering information

Table 13. Ordering information

Order code	Package	Packing
VT5376V032	TQFP32 OPTO 7 mm x 7 mm x 1.4 mm	Tray

Table 14. Evaluation boards ordering information

Order code	Description
STV-376-E01	USB2 VT5376 high-speed imaging system evaluation board
STV-376-E02	VT5376 sensor in a full-speed wired laser mouse evaluation board
STV-376-E03	VT5376 sensor in a low-speed wireless laser mouse evaluation board

11.1 ECOPACK®

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK® is an ST trademark.

12 Revision history

Table 15. Document revision history

Date	Revision	Changes
27-Sep-2007	1	Initial release.
09-Sep-2008	2	Updated
07-Dec-2009	3	Updated – *Table 1: Technical specifications on page 4* – *Table 2: Automatic power management on page 6* – *Table 3: Manual power management on page 6* – *Chapter 2: Power supply options and power consumption on page 7* – *Chapter 3: Electrical characteristics on page 8* – *Figure 9: VT5376 RC_OSC signal on page 20* – *Section 7.4: RESET_OUT pin on page 20* – *Section 7.5: Automatic exposure on page 21* – *Table 11: VT5376 pin description on page 26*
19-Jan-2010	4	Removed Preliminary information banner.