Immersion® TouchSense® Gaming Control Electronics
RoHS Compliant Version

COEM-GCE-*config-HF*

User Manual
December 1, 2007
Revision 1.3

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1. Overview

1.1. Capabilities

The *Immersion TouchSense Gaming Control Electronics* is an integrated microprocessor based solution for advanced force feedback control. It contains all of the functionality required for you to build, configure, and test force feedback peripherals. It is fully DirectX compliant, and offers Universal Serial Bus (USB) for communications. **This User Manual describes the overall capabilities of the controller. However, many of the possible configurations require custom firmware and custom drivers to be enabled.** Contact Immersion for more information regarding your configuration needs.

Figure 1: Picture of COEM-GCE-x-HF
Actual components vary by configuration

Features of the *Immersion TouchSense Gaming Control Electronics* are summarized in the following table:

Category	Value
Host	
Protocols	TouchSense A2; DirectX compliant
Communications	Universal Serial Bus v1.1 (chapter 9 and suspend compliant)
Operating Systems	Windows XP
Power and Amplification	
Digital Power Supply	Via USB Bus
Amplifier Power Supply	• 24VDC nominal +/- 10% • Regulated or Unregulated DC linear supply • Power supply must support circulation currents and up to 35V applied to output via motor back-EMF • Power supply protected by controller-integrated diode
Force Feedback Output	2 PWM channels, 8-bit each
Output Power	24V, 5A / per channel peak
Max Continuous Current	Subject to thermal fuse holding (default is 3.75A for 2 minutes)
Back-EMF Withstand	• 6A max at 40% duty cycle for up to 30 seconds max • 3A max at 100% duty cycle for up to 30 seconds max
Ambient Temperature	10C to 50C
Supported Motors	
Type	DC brush type, VCM
Resistance	2 ohms min, 15 ohms max [theoretical range, not fully tested]
Inductance	0 mH min, 25 mH max [theoretical range, not fully tested]
Position	
Input Axes Support	4 axes analog, 2 axes quadrature encoder
Resolution	10 bits analog, 16 bits encoder (10 bit internal calculations)
Velocity Derivation	2 axes analog, 2 axes encoder
Binary Inputs	
Switches	4x4 switch matrix (16 total) standard
Force Disable	Externally controlled digital input
Regulatory	
Compliance	RoHS

PCB Flammability grade	94V-0

Table 1: Immersion TouchSense Gaming Control Electronics (COEM-GCE-x-HF) Features

1.2. Configurability

The *Immersion TouchSense Gaming Control Electronics* is provided in standard and custom configurations. The Configuration Worksheet in section 4.2, *Appendix 2 – Configuration Worksheet*, is used as a tool to understand the particular need of the target system. Please work with Immersion to accurately complete this worksheet

2. Hardware Overview and Connections

2.1. Mounting the Board

The TouchSense Board should be rigidly mounted on all four corners using number 4, M2.5 or M2.6 screws or nylon board locks (Richco LCBS-L-5-01 or equivalent). The board dimensions and mounting hole pattern are shown in the following figure:

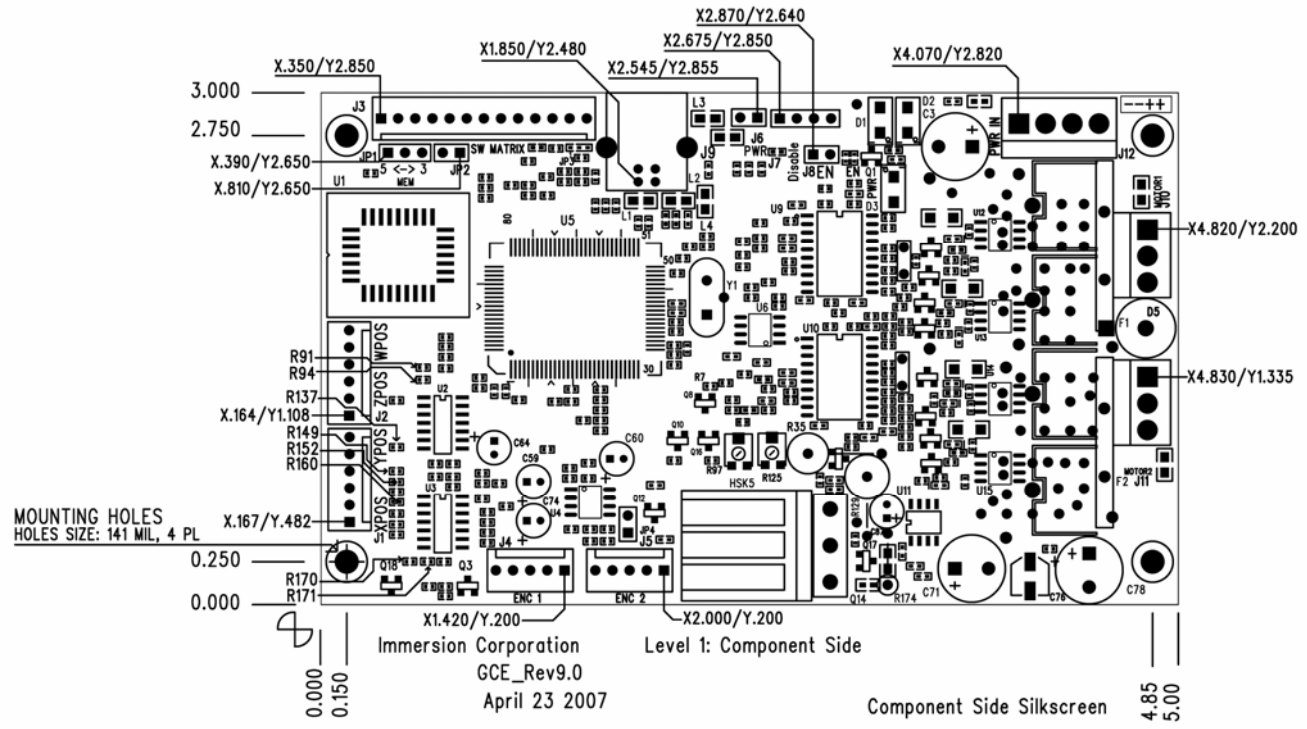


Figure 2: COEM-GCE-x-HF Dimensions and Mounting Pattern [inches]

Be sure that there is ample room above and below the board to prevent short circuits with any conductive surfaces. Allow for 1.25" [32mm] headroom above the board and .5" [13mm] clearance below the board.

2.2. Power Connection

The COEM-GCE-x-HF is dual-supply powered. The USB connection provides power to the microprocessor section as a 100mA bus powered device. A 24VDC power supply separately powers the motor amplifier. If a USB hub is used in your system, it must be able to allocate 100mA to the TouchSense Gaming Control Electronics as the digital electronics on the board receive power through USB. The

amplifier section may require up to 10A for two motors at 5A each. The 24VDC power input is through the two or four pin power header at J12. **Pin 3 and pin 4 connect to "Positive" and pin 1 (square pad) and pin 2 connect to "Ground"**. It is important to get this polarity correct, as incorrect connection will cause damage to the board. With the custom population of a four-pin connector, all four pins (two to power, two to ground) can be used in high-current applications.

2.3. Universal Serial Bus Connection to PC

The TouchSense Gaming Control Electronics communicates with a PC compatible computer Universal Serial Bus (USB). The board contains a B-type jack to connect the board with a standard full speed USB A-B cable. The system is fully USB (1.1 or 2.0) compliant. The USB Type B connector is located at J9.

2.4. Positional Input Axes

Position input to the TouchSense Gaming Control Electronics is provided through four analog to digital converters and/or two optical encoder inputs. The A/D converters are connected to headers J1 and J2. There is conditioning circuitry on the both inputs that allows the signal to be scaled, and the primary input through header J1 also provides rate of change information to be determined and used for damping effects.

2.4.1. Analog Inputs

Up to four analog position inputs are supported. Although the analog inputs can be any type of sensor, the most common form is a potentiometer. In a typical analog joystick or analog steering wheel application the primary X and Y sensors are connected to the J1 header. For a stick, both of these are used for position. For a wheel, X is used for position and Y is used as the brake. Additional sensors can be connected to the J2 header. For a wheel, Z is usually the throttle and W is the clutch. The six pin headers provide two pins each for power and ground, so the pots can be wired up individually. The pinouts are shown in the following table.

J1		J2	
Pin	**Signal**	**Pin**	**Signal**
1	Power	1	Power
2	X Signal / Position	2	Z Signal / Throttle
3	Ground	3	Ground
4	Power	4	Power
5	Y Signal / Brake	5	W Signal / Clutch or Rudder
6	Ground	6	Ground

Table 2: Analog Header Pinouts (J1 & J2)

You can check the voltage polarity versus movements by using the Immersion Studio developer tool or the Windows Control Panel (Game Controllers).

The COEM-GCE-x-HF also contains conditioning electronics that may be used to expand the dynamic range of an analog input sensor. This is useful for the case where a potentiometer may only move through a small portion of its range of travel. For example: if a 300° pot is used in a joystick that only moves +/- 30°, it is only utilizing 20% of its range. If a 3.3 volt signal is used across the device, the output swing might be 1.2 to 2.2 volts, significantly less than the desired 0.0-3.3 volt full swing signal. The Immersion microcontroller can perform auto-scaling to compensate for this reduced range, but the resolution will then suffer.

The ideal way to compensate for this reduced range is to use the amplifier built into the signal conditioning circuit. By selecting the correct resistors [R160 & R152 for X-axis (wheel position); R170 & R171 for Y-

axis (brake), R94 & R91 for Z-axis (throttle); R137 & R149 for W-axis (clutch or rudder)], the sensor range can be expanded as governed by the following formulas:

Gain(x) = 1 + (R160/R152)
Gain(y) = 1 + (R170/R171)
Gain(z) = 1 + (R94/R91)
Gain(w) =1 + (R137/R149)

In the example above, selecting R160 and R170 to be 20KΩ resisters and R152 and R171 to be 10KΩ, will yield a gain of 3.0. This would have the effect of expanding the output range from 1.0 volt to 3.0 volts, also centered about 1.7V; yielding an output of 0.2 to 3.2 volts. It is important to realize that this gain stage will also amplify the deviation from center position, so a misalignment of 0.2 volts (center of 1.9 instead of desired 1.7) would be increased to 0.6 volts (center of 1.9v, range of 0.7 to 3.3V saturation). If you can not accurately dial in the center position, you may need to decrease your gain to ensure that neither end of the sensor saturates.

The unity gain configuration of the COEM-GCE-x-HF board is achieved by leaving R152, R171, R91, and R149 open.

2.4.2. Digital Encoders

Alternatively, or additionally, up to two optical encoders can be used for position input. The encoder connectors are J4 (X, or primary) and J5 (Y or secondary). The five pin headers provide pins for power and ground, so the encoders can be wired up individually. The pinouts are shown in the following table:

Pin	Signal
1	Ground
2	Not used
3	Channel A
4	Power
5	Channel B

Table 3: Encoder Header Pinouts – J4 [X, or primary] & J5 [Y, or secondary]

You can check the voltage polarity versus movements by using the Immersion Studio developer tool or the Windows Control Panel (Game Controllers). If the polarity is backwards, then swap the wires connected to Channel A and Channel B.

2.5. Digital Switch Inputs and Digital Outputs

The TouchSense Gaming Control Electronics supports up to 16 digital switch inputs. With standard firmware, these are accessed through a 4x4 switch matrix header, J3. This matrix works by alternately pulling low (scanning) four I/O pins (J3: 1-4), and then reading the four sense pins (J3: 5-8). If the button connecting the scanned pin and the sense pin is closed, it will register as the corresponding value from 1-16. This is a 9 pin connector with the 4 scan pins, 4 sense pins, and a ground pin (if only 4 sense lines are needed, the other pole of the switch can be connected to the ground pin, pin 9 when supported with appropriate firmware). It is populated on the J3 footprint pins 1 through 9. These values are shown in the matrix table below:

Signal (pin #)	Scan 1 (1)	Scan 2 (2)	Scan 3 (3)	Scan 4 (4)
Sense 1 (5)	*1*	*5*	*9*	*13*
Sense 2 (6)	*2*	*6*	*10*	*14*
Sense 3 (7)	*3*	*7*	*11*	*15*
Sense 4 (8)	*4*	*8*	*12*	*16*

Table 4: Digital Input Switch Matrix (J3) Configuration and Resulting Output

If you plan on using more than four switches, and hence more than one scan line, you must supply diodes in line with the switches. This prevents a switch from back-driving the other scan lines. A suitable circuit is shown in the following figure [note that the connector designation is J3, not J5]:

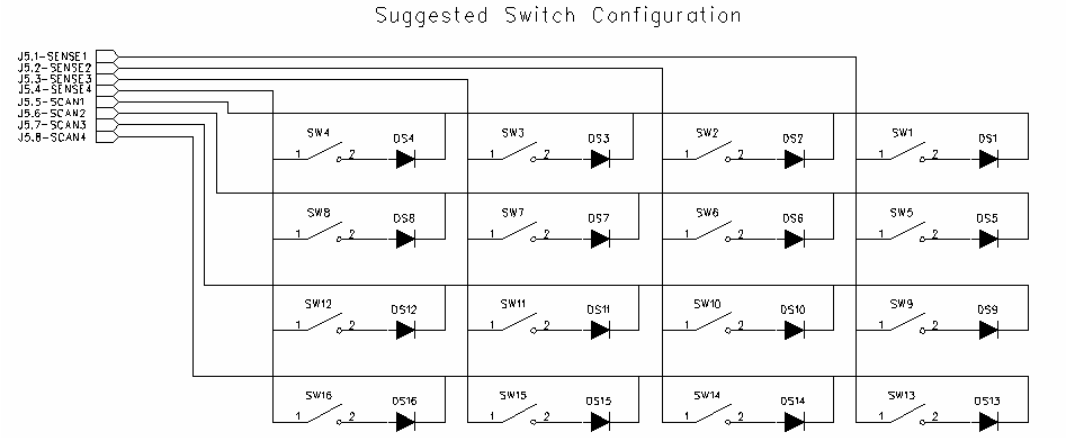


Figure 3: Digital Input Switch Matrix Connection Diagram

2.6. Force Disable

The TouchSense Gaming Control Electronics includes a Force Disable circuit to disable amplifier output, if desired. The Force Disable signal is pulled high internally and must be tied to ground to enable the amplifier. This signal is accessible on header J7. This header also provides +5VDC clock pulse signal to power active sensor circuits such as optical, magnetic, or inductive sensors. The pinouts of the Force Disable header are:

Pin	Signal
1	5VDC
2	Pulse
3	Force Disable
4	Ground

Table 5: Force Disable Header (J7) Pinouts

2.7. Motor Amplifier

The Immersion Gaming Control Electronics contain two high current amplifiers for use in either wheel (single axis of output) or stick (two axes of output) applications. The control board will be supplied in either a single or dual axis output configuration. J10 (primary) and J11(secondary) are the motor headers and the motor power leads should be connected to pins 1 and 2. Pin 3 is provided to optionally ground the motor case for improved EMI performance. The motor selected for use should be rated for the maximum 30 second average current commanded by the game or control application. The motor dynamic resistance should be greater than 20V / peak motor current.

Note: By default, in order to protect the motor windings from damage due to sustained overdriving, Immersion installs a resettable average current thermal fuse that automatically will shut down the amplifier if the limits of the fuse are exceeded over an unreasonable amount of time (2 minutes). The

default fuse value is 3.75A. Contact Immersion for more information regarding custom thermal fuse component population.

Warning: Overdriving the motor beyond its constant current rating may damage the motor and/or amplifier. It is the responsibility of the user to validate any overdrive scheme with each gaming application / motor combination.

Warning: The time delay nature of the thermal fuse will allow short circuits to cause damage to the controller. To protect against this possibility, you may elect to install a slow-blow fuse on one of the motors leads. Be sure to use an appropriate current rating above the peak current draw of your motor(s).

In addition, a current scale factor resistor R55 (axis 1) and R100 (axis 2) can be custom populated to set the current scale factor for the amplifier. A 3.75A wheel application requires R55 = 3.00K (1% tolerance), while a 5A wheel application requires R55 = 4.22K (1% tolerance). The absolute maximum current for each axis is 5 amps.

2.8. Jumper Settings

The Immersion Gaming Control Electronics has three user configurable jumper connectors for customizing specific design and development. The function of each jumper connector is listed in the following table:

Jumper	Description
JP1	For selecting either +5V or +3.3V to EEPROM. Connect pin 1-2 for +5V operation. Connect pin 2-3 for +3.3V operation.
JP2	Enable/disable write capability from processor U1 to the Flash device at U2. Connect pin 1-2 to enable writing. Please contact Immersion for Flash support firmware and programming details. Leave open to write-protect the Flash device.
JP4	Reset jumper for shutting down voltage regulator U5. Connect pin1-2 to disable the voltage regulator. Leave open to allow normal operation of the voltage regulator.

Table 6: Description of Jumper Settings (JP1, 2, 4).

2.9. LED Indicators

Three LED indicators are provided:

- D1 (the Mode LED) is illuminated and flashing when the Gaming Control Electronics board is enumerated and the driver is functional. D1 is illuminated solid when the Gaming Control Electronics board is communicating with a host application. An external mode indicator LED may be connected to the board by populating J8 with a 2 pin header on 0.1 inch centers and connecting the anode of a 6mA nominal indicator LED to pin 1 and the cathode to pin 2. This header is not populated by default in most configurations of the controller.

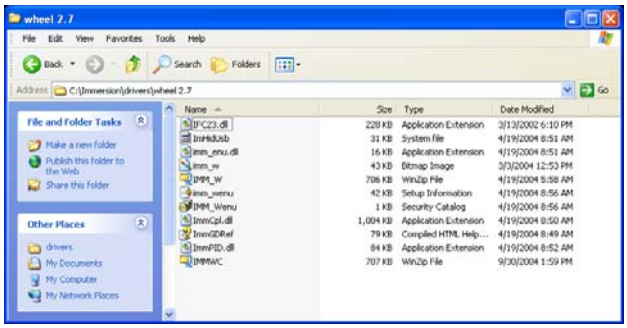
- D2 is illuminated when USB power is available.

- D3 is the motor power indicator LED and is illuminated when motor power is applied. An external motor power indicator LED may be connected to the board by populating J6 with a 2 pin header on 0.1 inch centers and connecting the anode of a 6mA nominal indicator LED to pin 1 and the cathode to pin 2. This header is not populated by default in most configurations of the controller.

3. Typical Setup and Driver Installation for a Single Axis Wheel

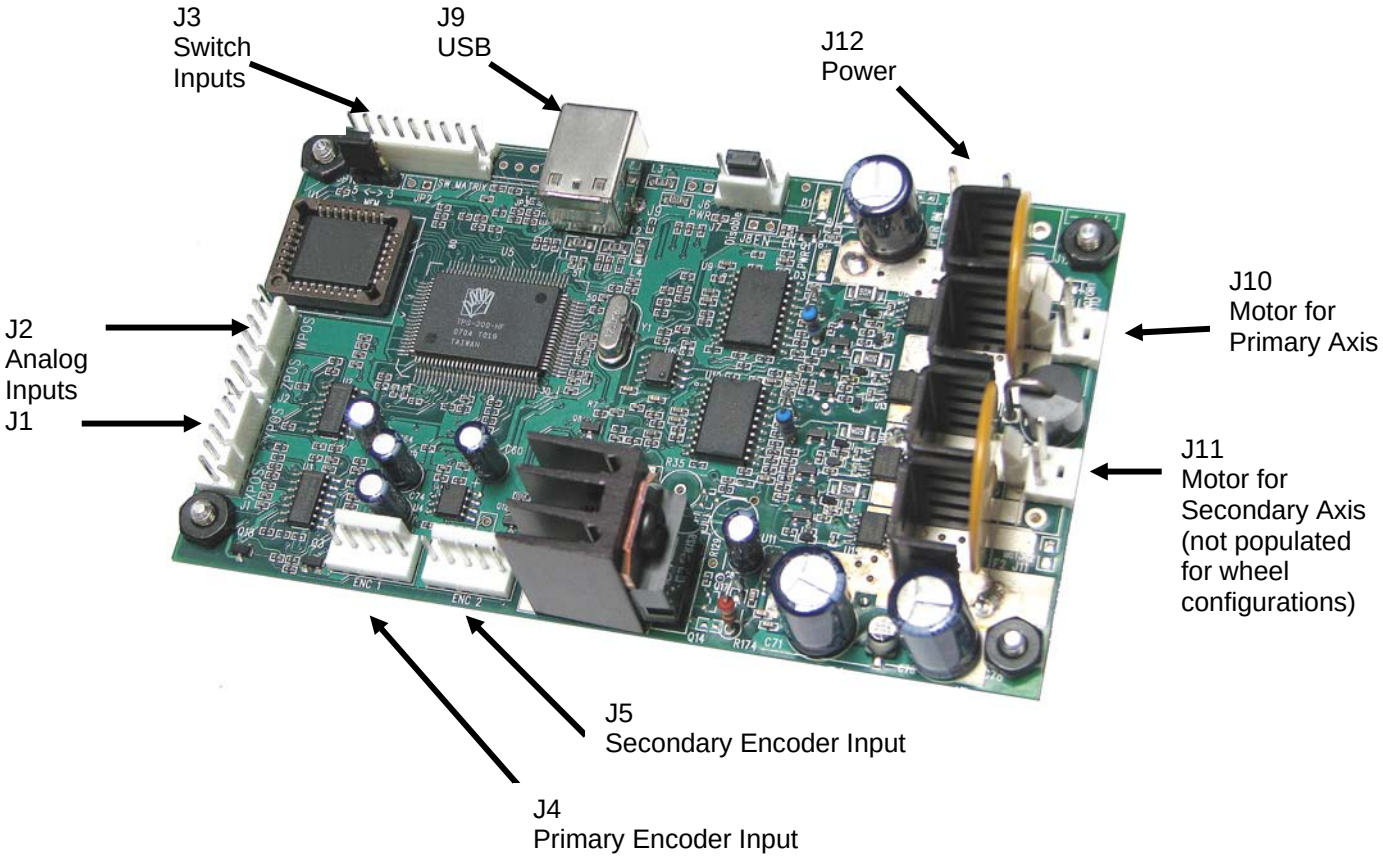
3.1. Step 1 – Extract Driver Software

Extract the driver file provided by Immersion to a local directory on your Windows PC.



3.2. Step 2 – Connect your system to the COEM-GCE-x-HF controller

Using this picture as a guide, connect your system to the controller in the order listed below:



Note: Actual components vary by configuration

1) **Encoder:** If you have an encoder providing position input, connect the encoder to header J4. The pinouts are:

Pin	Signal
1	Ground
2	Not used
3	Channel A
4	Power
5	Channel B

2) **Analog Input:** If you have analog position inputs, typically via potentiometers, connect them to headers J1 and J2. The pinouts are:

J1		J2	
Pin	**Signal**	**Pin**	**Signal**
1	Power	1	Power
2	X Signal / Position	2	W Signal / Throttle
3	Ground	3	Ground
4	Power	4	Power
5	Y Signal / Brake	5	Z Signal / Clutch or Rudder
6	Ground	6	Ground

3) **USB:** Connect the USB cable to the board (header J9) and your computer

4) **Power supply:** Connect the 24V power supply to header J12. Pin 3 and pin 4 connect to "Positive". Pin 1 (square pad) and pin 2 connect to "Ground". *Note: Incorrect polarity or voltage will damage the boards.*

5) **Main power:** Check that the power supply is configured for your country. If purchased from Immersion, the supply has a slide switch to select 110 / 220 v. Plug the power supply into the mains power.

****** Do not connect the motor yet. There is a software calibration process first. ******

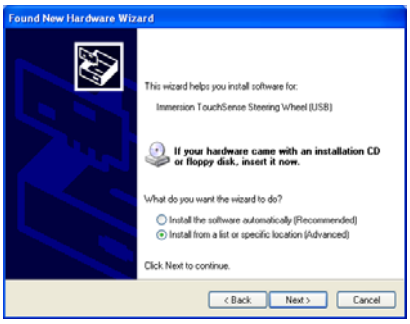
3.3. Step 3 – Driver Installation

***** Note: The following screen captures depict a typical steering wheel installation under Windows XP Professional, SP2. Your installation may vary from these screens based on your version of Windows and any firmware customization that Immersion has provided. For some firmware implementations, Windows will automatically install a default HID driver for the controller. This default HID driver will provide position input only, but will not supply force feedback output. If this occurs, you will need to manually update that driver with the Immersion provided driver. Please contact Immersion for assistance with installing the correct driver.*****

1) After connecting USB and power, Windows should detect a new device. You will receive a corresponding message in the TaskBar, such as:
   a. *Found New Hardware: TouchSense Analog Steering Wheel*
   b. *Found New Hardware: TouchSense Digital Steering Wheel*
   c. *or Found New Hardware: Immersion TouchSense Steering Wheel (USB)*

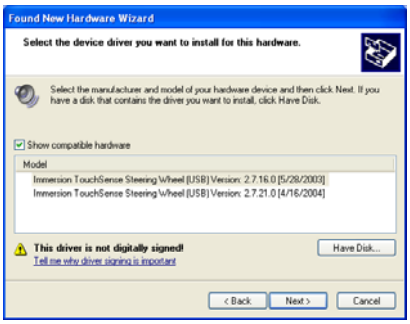
2) The Found New Hardware Wizard should appear. If it does not appear, skip to Section 3.4 below, *Found New Hardware Wizard Does Not Launch.*

   At the prompt "Can Windows connect to Windows Update…" select 'No', and 'Next'

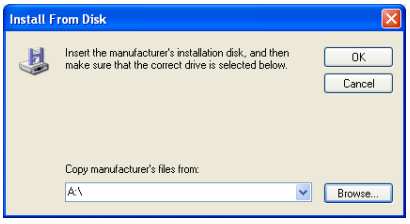


3) Select 'Install from a specific location (Advanced)' and then 'Next'

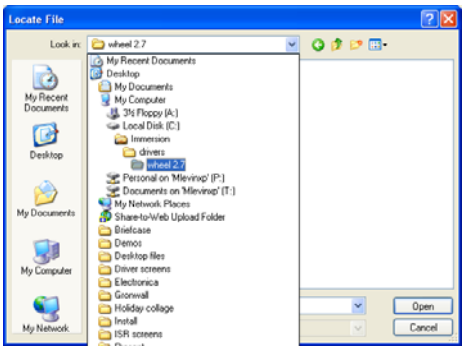
4) Select 'Have Disk…'. The Wizard will then ask you to insert a disk



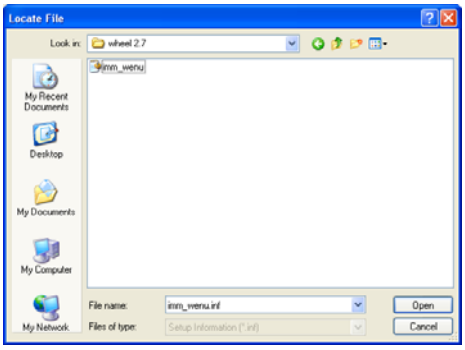
5) Select 'Browse'



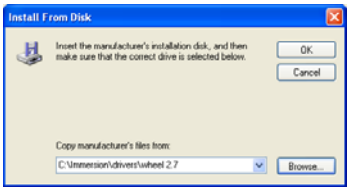
6) Browse to the path where you extracted the driver in Step 1 – Extract Driver Software



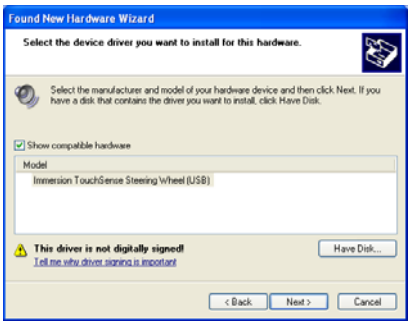
7) When you select 'Open', you should see the file with the driver name provided by Immersion at the bottom of the Configuration Worksheet in section 4.2 below. Select this driver and then "Open".



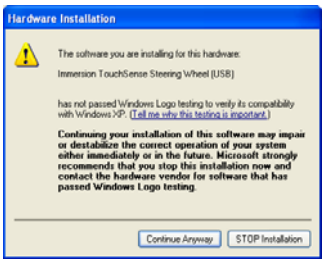
8) The Install from Disk screen will open with the correct path. Select 'OK'.



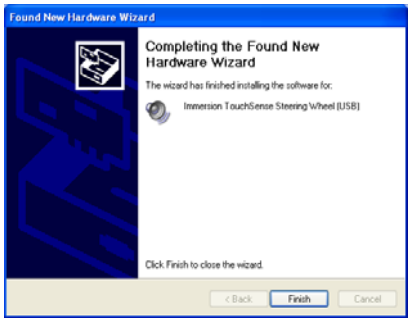
9) The Wizard should show something similar to "Immersion Steering Wheel (USB)". Select 'Next'. The Wizard will start to copy the driver files.



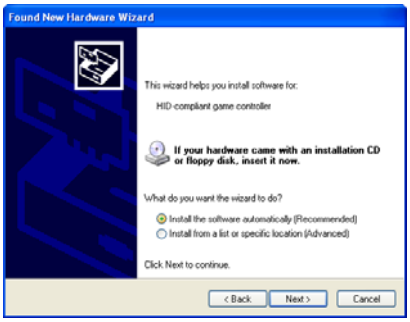
10) You may get a screen warning that the driver is not digitally signed. Select 'Continue Anyway.



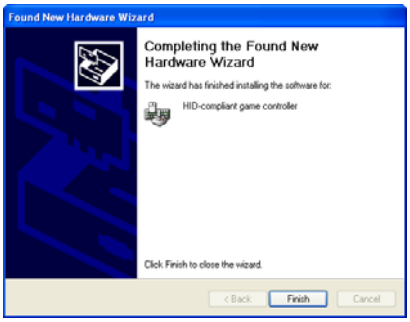
11) After a few minutes it should complete the operation.



12) At this point, you may get another Found New Hardware Wizard for a HID. Select Install the software automatically (Recommended) and Next

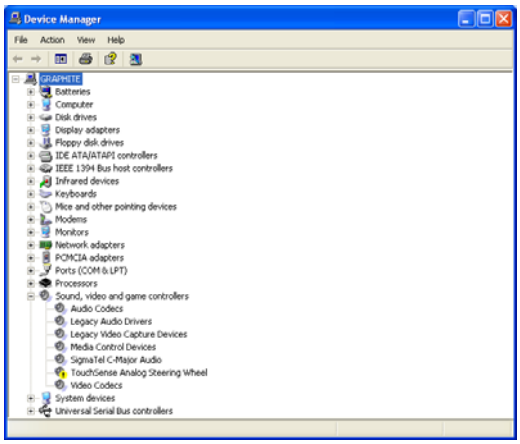


13) When it has finished, proceed to Section 3.5 below, *Step 4 – Test & Calibration.*



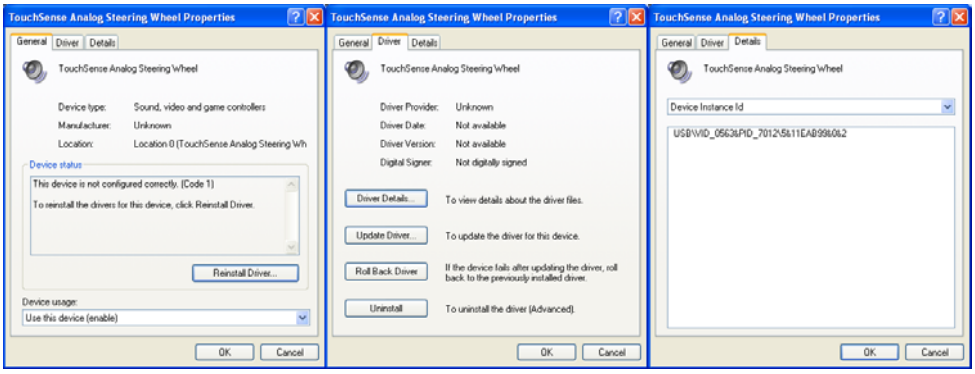
3.4. Found New Hardware Wizard Does Not Launch

If the "Found New Hardware Wizard" does not launch automatically, follows these instructions:



1) Right Click on My Computer on your Desktop or in the Start Menu. Select Properties. Select the Device Manager. Under *Sound, video, and game controllers* you should see a (Immersion) TouchSense Analog (or Digital) Steering Wheel (or similar device)

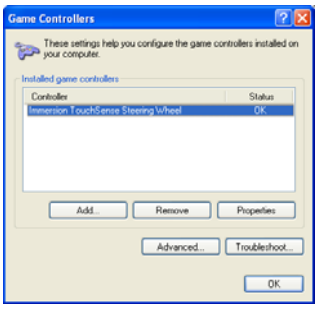
2) Examine the Properties of the (Immersion) TouchSense Analog (or Digital) Steering Wheel (or similar device show in the following three screen captures:



Note: In the ID screen, verify that the VID and PID values correspond to your configuration worksheet values. Please contact Immersion if either of these values is different.

3) If the PID is the same as the value on your configuration worksheet, you can update the driver manually and follow the procedures above from Section 3.3 item 2) above.
4) Once the driver has been successfully installed, you can proceed to the next section, *Step 4 – Test & Calibration.*

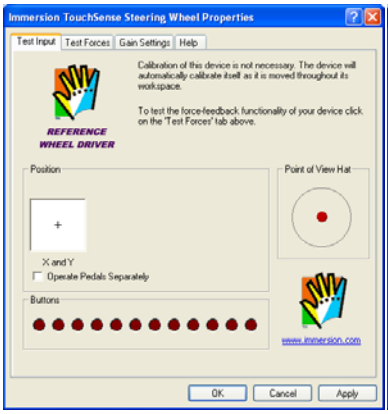
3.5. Step 4 – Test & Calibration

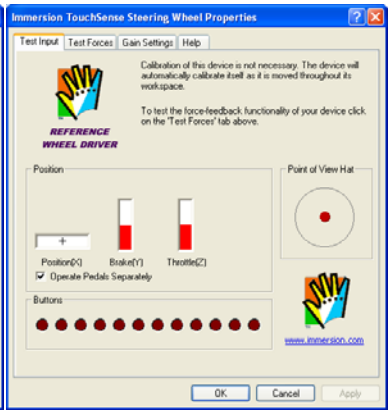


1) From the Windows Start Menu, open the Control Panel. Within the Control Panel listing, open Game Controllers. You should see the Immersion Steering Wheel (USB) (or similar device) listed. Select 'Properties'.

2) An Immersion Control Panel should appear. If desired for your application, select 'Operate Pedals Separately'.

3) Calibrate the wheel (or primary control axis) by moving it left and right. You should see the '+' cursor moving to both ends of the range. Make sure that moving the wheel (or primary control axis) left corresponds to a leftward motion of the cursor. If they are backwards you will need to swap the A & B channels of the encoder or swap the polarity of the potentiometer connections.

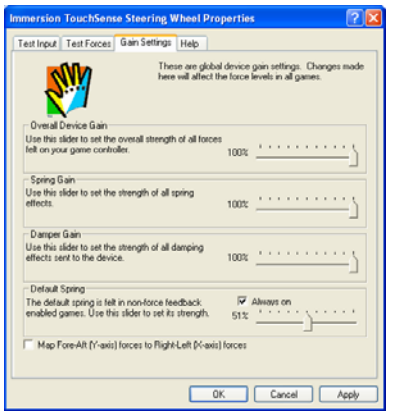




4) If you have pedals connected, they can also be calibrated. If they are moving backwards, you will need to swap the power and ground pins of that particular pedal. Please unplug and replug the USB connector after swapping the pins before validating pedal operation. If any pedal is not connected, the input may 'float' and the cursor may flicker. This is not a problem, however you can ground the potentiometer input pin with a jumper if you prefer.

5) Open the Gain Settings tab. Make sure that Default Spring is <u>not</u> Always On. The Default Spring magnitude should default to 13%.

6) Power down the board; you will get an error saying connection has been lost. Leave the main Game Controllers window open. Connect the motor to header J10. Power the board back up. The Steering Wheel should reappear in the Game Controllers window. You should not have any forces at this time.



7) Select Properties and recalibrate the device (left & right) from the Test Input tab. Go to the Gain Settings tab

8) Set the Default Spring to a low value (10%-25%); then ***hold on to the wheel tightly*** and check 'Always On'

9) The wheel should do one of two things:
   a. Generate a spring towards the center
   b. Turn left or right to the stops

   If the wheel now has is a centering spring, then the motor polarity is correct. If it forces to one side, you need to swap the motor polarity.

10) You are now ready to drive!

4. Appendices

4.1. Appendix 1 – Mating Connectors

The following table lists connectors that mate with the connectors found on a standard configuration of the Immersion TouchSense Gaming Control Electronics (COEM-GCE-x-HF). Custom configurations may have difference connectors.:

Connector	Description	Type	Manufacturer	Part #
J1, J2	Potentiometers	6 pin, .100 space, locking ramp	Molex	22-01-3067
J3	Switches	9pin, .100 space, locking ramp or 13 pin, .100 space, locking ramp	Molex	22-01-3097
J4, J5	Encoders	5 pin, .100 space, locking ramp	Molex	22-01-3057
J6	Power LED	2 pin, .100 space, locking ramp NOTE: 2 pin header for this connector is not populated in most configurations.	Molex	22-01-3027
J7	Force Disable	4 pin, .100 space, locking ramp	Molex	22-01-3047
J8	Mode LED	2 pin, .100 space, locking ramp NOTE: 2 pin header for this connector is not populated in most configurations.	Molex	22-01-3027
J9	USB Connector	Full speed USB 1.2 or 2.0 A-B cable	Various	
J10, J11	Motor Power	3 pin motor header	Molex	09-50-8031
J12	Power	2 or 4 pin power header	Molex	09-50-8021 or 09-50-8041
	All .100 spacing Terminal Pins		Molex	08-50-0114
	All .100 spacing Terminal Pins		Molex	08-50-0106

Table 7: Mating Connectors – Manufacturers and Part Numbers

4.2. Appendix 2 – Configuration Worksheet

Immersion® TouchSense® Gaming Control Electronics Configuration Worksheet

CONFIGURATION ID _____

Product Information

Manufacturer	
Product Model	
Company URL	
Tech Support URL	

Configuration ID and version Details

Driver ID / version	
FW ID	
PCB BOM ID	
QA Date / initials	

General Configuration

Product Type ☐ Joystick ☐ Wheel ☐ Other (specify _____)

USB Vendor ID ☐ *4 hex chars* **Alternate USB Vendor ID** ☐ *4 hex chars*

USB Product ID ☐ *4 hex chars* **Alternate USB Product ID** ☐ *4 hex chars*

Position Input (Analog)

X - Primary
This input is (select one) ☐ used, or ☐ not used.
The name for this input is ☐ (Joystick X or Y, Steering, Throttle, Brake, Clutch, or Rudder)
If a steering input, there are ☐ degrees of turning supported, lock-to-lock.
The potentiometer is ☐ Kohms. The 3.3V default range is ☐ Vmin to ☐ V max

Y - Secondary
This input is (select one) ☐ used, or ☐ not used.
The name for this input is ☐ (Joystick X or Y, Steering, Throttle, Brake, Clutch, or Rudder)
If a steering input, there are ☐ degrees of turning supported, lock-to-lock.
The potentiometer is ☐ Kohms. The 3.3V default range is ☐ Vmin to ☐ V max

Z - Tertiary
This input is (select one) ☐ used, or ☐ not used.
The name for this input is ☐ (Joystick X or Y, Steering, Throttle, Brake, Clutch, or Rudder)
If a steering input, there are ☐ degrees of turning supported, lock-to-lock.
The potentiometer is ☐ Kohms. The 3.3V default range is ☐ Vmin to ☐ V max

W - Quatenary
This input is (select one) ☐ used, or ☐ not used.
The name for this input is ☐ (Joystick X or Y, Steering, Throttle, Brake, Clutch, or Rudder)
If a steering input, there are ☐ degrees of turning supported, lock-to-lock.
The potentiometer is ☐ Kohms. The 3.3V default range is ☐ Vmin to ☐ V max

Position Input (Encoder)

Primary
This input is (select one) ☐ used, or ☐ not used.
The name for this input is ☐ (Joystick X or Y, Steering, Throttle, Brake, Clutch, or Rudder)
If a steering input, there are ☐ degrees of turning supported, lock-to-lock.
The encoder is made by ☐, part number ☐, with ☐ counts per revolution.

Secondary
This input is (select one) ☐ used, or ☐ not used.
The name for this input is ☐ (Joystick X or Y, Steering, Throttle, Brake, Clutch, or Rudder)
If a steering input, there are ☐ degrees of turning supported, lock-to-lock.
The encoder is made by ☐, part number ☐, with counts per revolution.

Velocity Scaling The maximum damping velocity (X for wheel, X+Y for stick) is ☐ seconds lock to lock.

Binary Input and Output

Switch Inputs There are ☐ switch inputs, connected via the switch inputs.
Hat Switch There are ☐ hat switches connected via the switch inputs.
Outputs There are ☐ digital outputs.
Force Disable The Force Disable input is ☐ used, or ☐ not used.

Amplifier

Current The current to each output channel is ☐ A peak, and ☐ A continous.
Power Supply The power supply is ☐ Meanwell S-150-24, or ☐ (specify).