THOR-LX / HIIIr Instrumentation and Wiring

4.1 Overview of Instrumentation and Wiring

The THOR-LX / HIIIr assembly is capable of carrying a total of 20 channels of data per leg. **Figure 4.1** is a plot showing the relative location of all the instrumentation for THOR-LX / HIIIr. (Note: The knee shear and knee rotation instruments are not shown in this figure.) The layout of the instrumentation in the lower extremity was designed to maintain the high-degree of modularity, which was one of the main design goals. Each instrument has an individual lead wire to allow for easy removal and insertion for calibration and inspection.

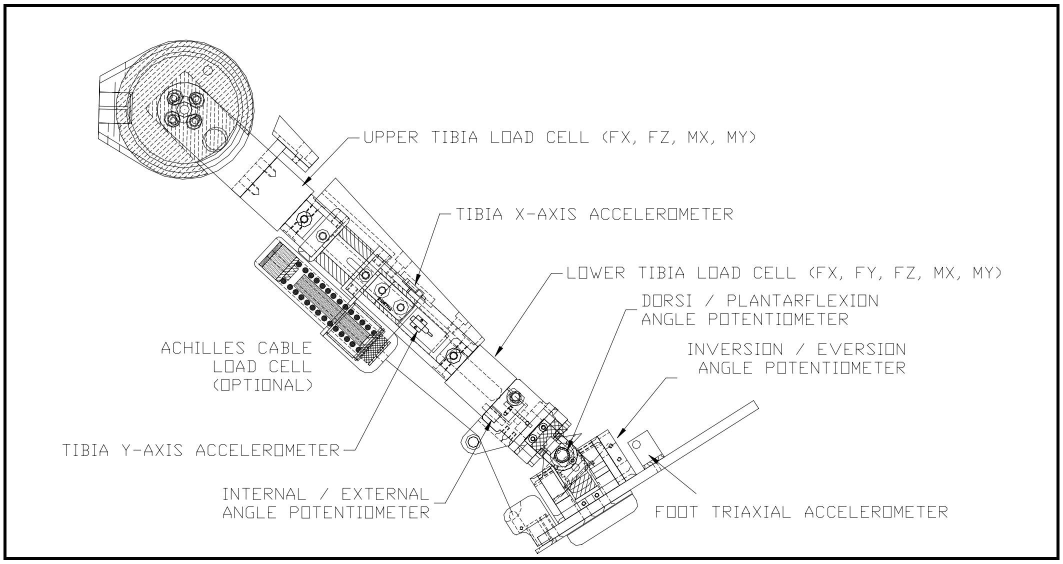

Figure #4.1 - THOR-LX / HIIIr Instrumentation

4.1.1 Available Instrumentation

The THOR-LX / HIIIr unit is currently capable of supporting the following instrumentation:

Knee	Knee Shear (Displacement) Knee Rotation
Lower Ex.	Upper Tibia Load Cell (4 Channels) Lower Tibia Load Cell (5 channel) Tibia Acceleration (X, Y) Achilles Tendon Load Cell Ankle Joint Rotation Potentiometers (X, Y, Z) Foot Acceleration (X, Y, & Z)

4.1.2 Instrumentation Description

Knee: The THOR-LX / HIIIr Knee assembly is instrumented with a miniature string potentiometer to measure the knee translation (shear) along the given axis of motion.

Lower Extremity: The THOR-LX / HIIIr assembly is instrumented with a pair of tibia load cells, located at the top and bottom of the tibia tube. These load cells provide the primary loading data for the lower leg structure which includes the Forces in the X, Y and Z, as well as the Moments in the X and Y. Three rotary potentiometers are used to measure the rotation of the ankle joint about the X, Y, and Z axes. A uniaxial load cell can be installed to measure the Achilles Cable tension. Finally, five uniaxial accelerometers, two singles and a set of three on a mounting block, provide data on the acceleration of the tibia and foot assemblies.

4.1.3 Standard Instrumentation Specifications

Table 4.1 shows the typical vendor reference for the instrument.

Table 4.1

Instrument	**Vendor Reference**
Uniaxial Accelerometer	Entran # EGE-73BQ-2000HD Endevco # 7264-T
Rotary Potentiometer	Contelec # PD210-4B
Upper Tibia Load Cell	Denton # 4353J
Lower Tibia Load Cell	Denton # 4929J
Knee Shear String Potentiometer	Space Age Controls# 150-0121 VR, VL

4.2 Wire Routing and Strain Relief for THOR- LX / HIIIr Instrumentation

The wire routing and strain relief for the instrumentation in the THOR-LX / HIIIr assembly is fairly straightforward. Each instrument is first strain relieved to a mechanical component to prevent damage to the wiring during testing. Then the wires are grouped into bundles and further strain relieved at various points in the assembly. The skin was designed to provide a wire channel up each side of the tibia assembly, as described in Section 3.2.2, Step #35 describes this routing and provides a photo. Additional information is provided for each instrument below:

Upper Tibia Load Cell: The wire from this load cell exits through the hole provided at the rear of the tibia skin - just below the knee. The hole is at the top of the tibia skin zipper assembly.

Lower Tibia Load Cell: The wire from this load cell is routed up the right side of the lower leg and is bundled with the wires from the Y & Z axis rotary potentiometers. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee.

Tibia Uniaxial Accelerometers: The wires from these accelerometer units exit the right side of the tibia guard and are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. See **Figure 4.2** for additional details.

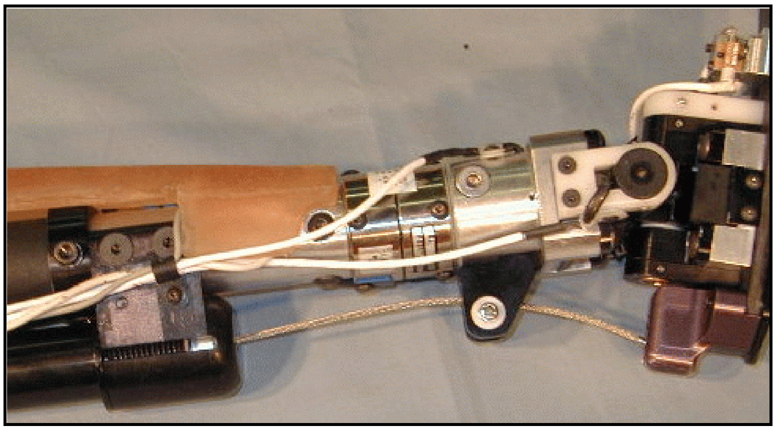

Figure #4.2 - Tibia Uniaxial Accelerometers

Foot Triaxial Accelerometer Array: The wires from this accelerometer cube exits the molded foot cavity to the left and are bundled with the X-axis potentiometer wire and strain relieved to the front left side of the Y axis bearing housing with a 1/4" wire clamp using a #6-32 x 3/8" BHSCS {5/64}. **Figure 4.3** shows additional details of this wire routing. A small amount of slack must be provided in this wire between the instrument and the strain relief to allow for dorsi / plantar flexion motion of the foot. These wires are then routed up the left side of the leg tube and are strain relieved to the left side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin below the knee.

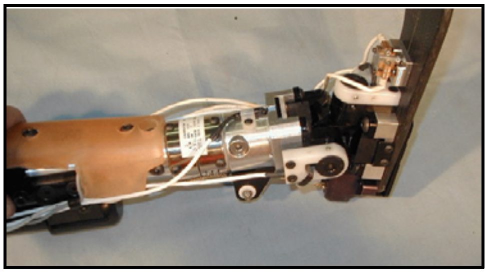 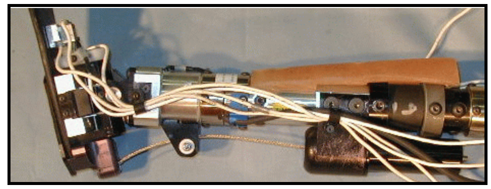

Figure 4.3 - Foot Accelerometer and X-axis potentiometer routing

X axis rotary potentiometer: This wire is strain relieved to the potentiometer housing with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. This wire is bundled with the foot triaxial accelerometer wires and strain relieved again at the front left side of the Y axis bearing housing with a 1/4" wire clamp using a #6-32 x 3/8" BHSCS {5/64}. A small amount of slack must be provided in this wire bundle between the instruments and the strain relief to allow for dorsi / plantar flexion motion of the foot. These wires are routed up the left side of the tibia tube and strain relieved to the left side of the Achilles Spring Tube Base using a 1/4" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 4.3** for additional information.

Y axis rotary potentiometer: This wire is strain relieved to the potentiometer housing with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. This wire then runs up the right side of the leg and is bundled with the wire from the Z axis potentiometer. These wires are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 4.4** for additional information.

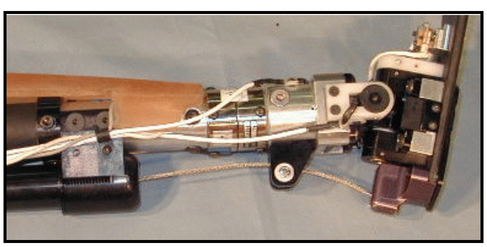 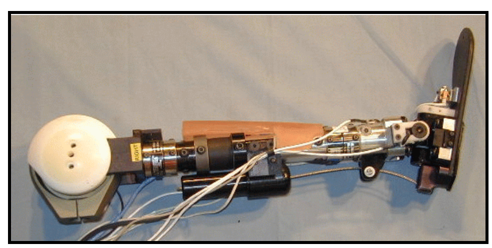

Figure 4.4 - Y & Z Potentiometer Wire Routing

Z axis rotary potentiometer: This wire is strain relieved to the front of the Upper Joint Base with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. The wire is routed up the right side of the lower leg and is bundled with the wire from the Y axis rotary potentiometer. These wires are strain relieved to the right side of the Achilles Spring

Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 4.4** for additional information.

4.3 Wire Markers

In order to keep track of the instrumentation wiring used for the THOR-LX / HIIIr, a wire marking system has been employed. This system involves an alpha-numeric marking strip for each instrument wire and connector wire, as well as, a color coded marker to denote the instrument type. **Table 4.2** below provides a reference to the colors and their meanings.

Table 4.2

Wire Marker Color	Instrument Type
ORANGE	LOAD CELLS
RED	ACCELEROMETERS
BLUE	POTENTIOMETERS

A complete listing of the instrumentation and related wire markers is provided in **Table 4.3** for reference. Please refer to the notes at the bottom of the table for further information.

Table 4.3

THOR COMPONENT AND SENSOR	WIRE
	MARKER
KNEE	
Knee Rotation	K@{Blue}RP
Knee Shear Displacement	K@{Blue}SD
LOWER EXTREMITY	
Lower Tibia Load Cell (Fx, Fy, Fz, Mx, My)	LT@{Orange}**
Upper Tibia Load Cell (Fx, Fz, Mx, My)	UT@{Orange}**
Ankle Rotation	AK@{Blue}R*

Notes:

Colors in { } indicate a blank space of the corresponding color.
* Above indicates X, Y, OR Z axis
** above indicates Force X,Y,Z or Moment X,Y,Z (i.e. FX, MX)
# Above indicates POT # 1, 2, OR 3
@ Above indicates L or R for Left or Right

4.4 THOR-LX / HIIIr Instrumentation Wiring

Based on the user's preference and requirements, the THOR-LX / HIIIr unit can be supplied with either of the two possible wiring options described below. Select the description that matches your configuration and follow the wiring instructions.

4.4.1 THOR-LX / HIIIr Wiring Option #1

The THOR-LX / HIIIr units may be sold with the instrument wires left unterminated (bare ends) for the individual users to attach the connector of their choice. This allows the user to select the appropriate connector to mate with their DAS system. All of the load cells and accelerometers will be provided with their own individual calibration sheets which contain the necessary wiring information. For the rotary potentiometers, refer to the wiring directions provided below.

Ankle- X Rotary Potentiometer (marked AKL{Blue}RX or AKR{Blue}RX)
Ankle- Y Rotary Potentiometer (marked AKL{Blue}RY or AKR{Blue}RY)
Ankle- Z Rotary Potentiometer (marked AKL{Blue}RZ or AKR{Blue}RZ)
Knee Shear Potentiometer (marked KL{Blue}RP or KR{Blue}RP)

Function	Wire Color
+ Excitation	Red
- Excitation	Black
+ Signal	Green

4.4.2 THOR-LX / HIIIr Wiring Option #2

As an alternative, the manufactures may supply the THOR-LX / HIIIr units pre-wired with 4 pin LEMO connectors to mate with a set of connector wires as described below. This option is particularly advantageous if numerous test labs will be sharing the same leg, or the labs will use different DAS systems which have incompatible connectors. Several sets of bundle wires can be made up for a single leg set which will allow compatibility with various DAS connector configurations. In this wiring option, all of the THOR-LX / HIIIr instrumentation is pre-wired with male 4 Pin LEMO connectors. The Connector Wires feature a mating 4 pin LEMO connector on one end to fit the THOR-LX / HIIIr unit's LEMO connectors and a bare wire at the other end. The bare end of the connector wire can be soldered to the appropriate connector necessary for mating with the testing laboratory data acquisition system. Each connector wire is individually marked to mate with a specific instrument on the lower extremity. **Table 4.4** describes the correct wire color assignments for the connector wires. This table should provide all of the necessary information to correctly wire the appropriate mating connectors for the laboratory data acquisition system.

TABLE 4.4

Ankle- X Rotary Potentiometer (marked AKL{Blue}RX or AKR{Blue}RX)
Ankle- Y Rotary Potentiometer (marked AKL{Blue}RY or AKR{Blue}RY)
Ankle- Z Rotary Potentiometer (marked AKL{Blue}RZ or AKR{Blue}RZ)
Knee Shear Potentiometer (marked KL{Blue}RP or KR{Blue}RP)

Function	Wire Color
+ Excitation	Red
- Excitation	Black
+ Signal	Green

Upper Tibia Load Cell (marked UTL{Orange}**and UTR{Orange}**)
where ** indicates Fx, Fz, Mx, or My

Lower Tibia Load Cell (marked LTL{Orange}**and LTR{Orange}**)
where ** indicates Fx, Fy, Fz, Mx, or My

Forces:

Axis:	Function:	Wire Color:
X, Y*, Z	+ Excitation	Red
	- Excitation	Black
	+ Signal	Green
	- Signal	White

Moments:

Axis:	Function:	Wire Color:
X, Y	+ Excitation	Red
	- Excitation	Black
	+ Signal	Green
	- Signal	White

* Lower Tibia Load cell includes Fy capability.

4.5 Instrumentation Excitation and Ground Requirements

For all of the instrumentation on the THOR-LX / HIIIr, the excitation voltage and ground requirements are supplied below. The instrumentation for this unit was designed to have the same excitation requirements - thus simplifying the power requirements. The current requirements are minimal, i.e. 100 mA per instrument is sufficient.

All + Excitation Terminals must be connected to a 10.00 (+/- 0.05) V DC power supply.
All - Excitation Terminals must be connected to a ground (i.e. 0.0 V DC) source.
All Ground Terminals must be connected to a ground (i.e. 0.0 V DC) source.
All Shield Wires (which connect through the LEMO connector) must be terminated to ground at the DAS end of the wire.

4.6 Data Acquisition

The proper connection of the THOR-LX / HIIIr instrumentation to the laboratory data acquisition system is essential to the correct measurement of the various forces, moments, accelerations and deflections. **Table 4.5** provides a reference to the proper data acquisition requirements for each channel. These requirements include the channel configuration and range requirements for each of the instruments.

The data acquisition channel configuration defines how to measure the voltage difference for the output of each channel. For all of the instruments of the THOR-LX / HIIIr unit, the channel configuration is either differential or referenced single-ended. The term DIFF denotes a differential configuration in which the + Signal lead is connected to a HI Input Channel and the - Signal lead is connected to a LO Input Channel. The data acquisition system is then configured as a differential input to measure the voltage difference between the HI and LO channel inputs.

WARNING: DO NOT CONNECT THE - SIGNAL LEAD TO GROUND OR THE INSTRUMENTATION MAY BE PERMANENTLY DAMAGED.

For typical data acquisition systems, differential input configurations require two channels of the data acquisition system for each instrument channel (i.e. a HI and LO channel for each axis of a load cell, etc.). All of the load cells and accelerometers used in the THOR-LX / HIIIr instrumentation require a differential configuration for the proper data acquisition.

The term RSE denotes a Referenced Single-Ended configuration in which the + Signal lead is connected to a HI input channel. The data acquisition system is then configured as a referenced single-ended input to measure the voltage difference between the HI channel input and the ground reference.

In addition to the channel configuration, the other critical information needed to setup the data acquisition for the THOR-LX / HIIIr is the expected output voltage range for each of the instruments. This output voltage range is used to adjust the individual channel sensitivity of the data acquisition system to obtain the highest possible data resolution. The use of the output voltage ranges listed in the table will insure that none of the data is clipped for extreme loading that may occur.

Table 4.5

THOR COMPONENT AND SENSOR	DAQ Configuration	Output Voltage Range
LOWER EXTREMITY		
Lower Tibia Load Cell (Fx, Fy, Fz, Mx, My)	DIFF (5 CH)	-30 to 30 mV
Upper Tibia Load Cell (Fx, Fz, Mx, My)	DIFF (4 CH)	-30 to 30 mV
Ankle Rotation	RSE	0 to 10 V
Knee Shear Displacement	RSE	0 to 10 V
Uniaxial Accelerometer	DIFF	-30 to 30 mV

4.7 THOR-LX / HIIIr Instrumentation - Polarity

The THOR-LX / HIIIr instrumentation system was designed to conform to the SAE J211 polarity system.

Table 4.6

INSTRUMENT LOCATION	SAE Dummy Manipulations for Load Cell Polarity	THOR-LX Polarity
Knee Rotation (Left)	Extension	N/A
Knee Shear Displacement (Left)	Hold Femur in Place, Tibia Forward	+
Upper Tibia (Left: Force X-axis)	Tibia Forward, Knee Rearward	+
Upper Tibia (Left: Force Z-axis)	Tibia Downward, Femur Upward	+
Upper Tibia (Left: Moment X-axis)	Ankle Leftward, Hold Knee in Place	+
Upper Tibia (Left: Moment Y-axis)	Ankle Forward, Hold Knee in Place	+
Lower Tibia (Left: Force X-axis)	Ankle Forward, Knee Rearward	+
Lower Tibia (Left: Force Y-axis)	Ankle Rightward, Knee Leftward	+
Lower Tibia (Left: Force Z-axis)	Ankle Downward, Knee Upward	+
Lower Tibia (Left: Moment X-axis)	Ankle Leftward, Hold Knee in Place	+
Lower Tibia (Left: Moment Y-axis)	Ankle Forward, Hold Knee in Place	+
Tibia Acceleration (X axis)	Tibia Forward	+
Tibia Acceleration (Y axis)	Tibia Right	+
Achilles Tendon Load Cell - Left	Tension in Cable	N/A
Ankle Left X-axis Rotation	Eversion	+
Ankle Left Y-axis Rotation	Dorsiflexion	+
Ankle Left Z-axis Rotation	Internal Rotation	+
Foot Acceleration (X axis)	Foot Forward	+
Foot Acceleration (Y axis)	Foot Rightward	+
Foot Acceleration (Z axis)	Foot Down	+
Knee Rotation (Right)	Extension	N/A

Knee Shear Displacement (Right)	Hold Femur in Place, Tibia Forward	+
Upper Tibia (Right: Force X-axis)	Tibia Forward, Knee Rearward	+
Upper Tibia (Right: Force Z-axis)	Tibia Downward, Femur Upward	+
Upper Tibia (Right: Moment X-axis)	Ankle Leftward, Hold Knee in Place	+
Upper Tibia (Right: Moment Y-axis)	Ankle Forward, Hold Knee in Place	+
Lower Tibia (Right: Force X-axis)	Ankle Forward, Knee Rearward	+
Lower Tibia (Right: Force Y-axis)	Ankle Rightward, Knee Leftward	+
Lower Tibia (Right: Force Z-axis)	Ankle Downward, Knee Upward	+
Lower Tibia (Right: Moment X-axis)	Ankle Leftward, Hold Knee in Place	+
Lower Tibia (Right: Moment Y-axis)	Ankle Forward, Hold Knee in Place	+
Tibia Acceleration (X axis)	Tibia Forward	+
Tibia Acceleration (Y axis)	Tibia Right	+
Achilles Tendon Load Cell - Right	Tension in Cable	N/A
Ankle Right X-axis Rotation	Inversion	+
Ankle Right Y-axis Rotation	Dorsiflexion	+
Ankle Right Z-axis Rotation	External Rotation	+
Foot Acceleration (X axis)	Foot Forward	+
Foot Acceleration (Y axis)	Foot Rightward	+
Foot Acceleration (Z axis)	Foot Down	+