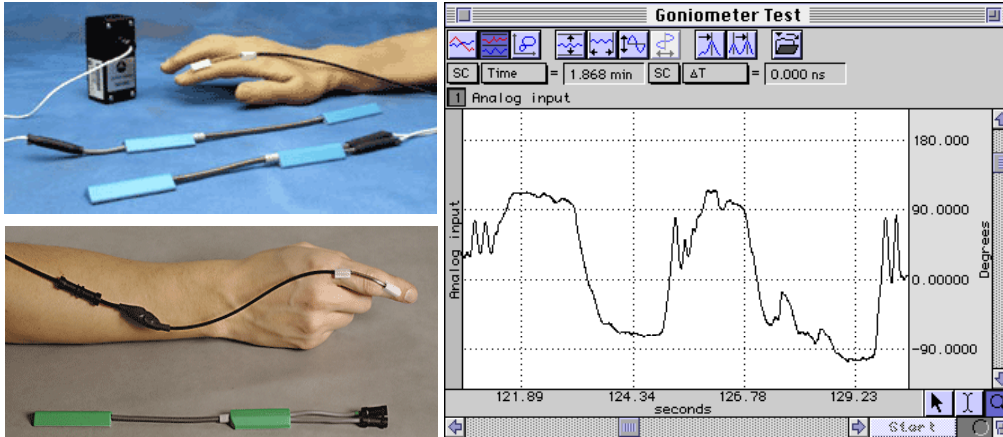


## Application Note 140

## Angular Measurements with BIOPAC Goniometers & Torsiometers



*In the example above, the TSD130A was connected directly to a DA100C amplifier, the DA100C gain was set to 1,000, and AcqKnowledge was used to calibrate the signal to provide angular measurements from approximately +90° to -90°.*

<u>Transducer</u>	<u>MP1XX (DA100C)</u>	<u>MP3X/MP45</u>	<u>TEL100C</u>
Twin-axis Goniometer 110	TSD130A	S20L	SS20
Twin-axis Goniometer 150	TSD130B	S21L	SS21
Torsiometer 110	TSD130C	S22L	SS22
Torsiometer 180	TSD130D	S23L	SS23
Single-axis Goniometer 35	TSD130E	S24L	SS24

BIOPAC Goniometers and Torsiometers are designed for the measurement of limb angular movement. Goniometers transform angular position into a proportional electrical signal. Goniometers incorporate gauge elements that measure bending strain along or around a particular axis.

BIOPAC goniometers are unobtrusive and lightweight, and can be attached to the body surface using double-sided surgical tape (and can be further secured with single sided tape). The goniometers have a telescopic endblock that compensates for changes in distance between the two mounting points as the limb moves. The gauge mechanism allows for accurate measurement of polycentric joints. All sensors connect directly to the BIOPAC Acquisition Unit as part of an MP or BSL System. Activity data can be displayed and recorded, leaving the subject to move freely in the normal environment.

The bending strain is proportional to the sum total angular shift along the axis. Because the bending force is extremely small, the output signal is uniquely a proportional function of the angular shift.

**Twin-axis Goniometers** Dual output devices that can measure angular rotation about two orthogonal planes simultaneously. Goniometers provide outputs to simultaneously measure around two orthogonally rotational axes (e.g. wrist flexion/extension and radial/ulnar deviations).

- wrist or ankle use **TSD130A/SS20L/SS20**
- elbow, knee or shoulder use **TSD130B/SS21L/SS21**

**Torsiometers** Measure angular twisting (as on the torso, spine or neck) as opposed to bending. Torsiometers measure rotation about a single axis (e.g. forearm pronation/supination).

- neck use **TSD130C/SS22L/SS22**
- along the torso or spine use **TSD130D/SS23L/SS23**

**Single-axis goniometer** Measures the angle in one plane only; designed to measure finger joint movement.

- fingers, thumb or toes use **TSD130E/SS24L/SS24**

## ATTACHMENT TO THE SUBJECT

Various combinations of display and recording instrumentation have been carefully developed fulfilling the requirements of specific research applications. Due to the wide range of applications, one method of attachment cannot be recommended. Experience has proven that standard medical adhesive tape is an excellent adhesion method in the majority of cases. Single-sided and double-sided medical tape (such as BIOPAC TAPE1 or TAPE2) should be used for the best results.

- 1) Attach pieces of double-sided tape to the underside of the goniometer endblocks.
- 2) Stick the tape to the subject and allow for the telescoping of the goniometer. The goniometer should be fully extended when the joint is fully flexed.
- 3) Press the two endblocks firmly onto the subject and ensure that the goniometer is lying over the top of the joint. When the joint is extended, the goniometer may present an “oxbow.”
- 4) For additional security, pass a single wrap of single-sided medical tape around each endblock.
- 5) Secure the cable and connector leaving the goniometer with tape to ensure that they do not pull and detach the goniometer.

### *For accurate results from long recordings*

Employ double-sided adhesive between the endblocks and skin, and place single-sided adhesive tape over the top of the endblocks. **No tape should come into contact with the spring.** The connection lead should also be taped down near the goniometer.

### *For applications where quick or rapid movements are involved*

Fit a “sock” bandage over the whole sensor and interconnect lead. This does not apply to the finger goniometer (TSD130E/SS24L/SS24), which has a different working mechanism.

When the goniometer is mounted across the joint, the center of rotation of the sensor measuring element may not coincide with the center of rotation of the joint (for example, when measuring flexion /extension of the wrist). As the joint moves through a determined angle, the relative linear distance between the two mounting positions will change.

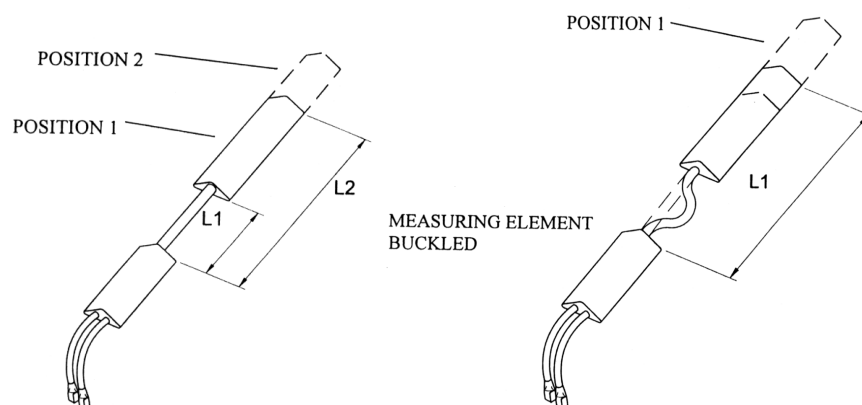
To compensate for this, all sensors are fitted with a telescopic endblock that permits changes in linear displacement between the two endblocks along axis ZZ without the measuring element becoming over-stretched or buckled.

In the free or unstretched position, the distance between the two endblocks is  $L_1$ .

If a light force is applied, pushing the endblocks away from each other, this length will increase to a maximum of  $L_2$ .

When the light force is removed, the distance between the two endblocks will automatically return to  $L_1$ .

This creates several advantages: accuracy is improved; sensors can be worn comfortably and undetected under normal clothing; the tendency for the position of the sensors to move relative to the underlying skeletal structure is reduced.



If a light force is now applied, pushing the two endblocks linearly towards each other, the only way the distance  $L_1$  can decrease in length is if the measuring element buckles.

- Buckling is detrimental to the accuracy of the goniometer and torsiometer sensors, so attachment instructions are provided for the most commonly measured joints (on page 8), to ensure that it does not occur in practice.

There is no universal rule governing which size of sensor is most suitable for a particular joint; this depends on the size of the subject.

In general, the sensor must be capable of reaching across the joint so that the two endblocks can be mounted where the least movement occurs between the skin and the underlying skeletal structure. In certain circumstances, more than one size of sensor will be appropriate.

## WARNINGS

---

1. Take care to handle the goniometer and torsiometer sensors as instructed. Mishandling may result in inaccurate data, reduced equipment life, or even failure.
2. Observe the minimum bend radius value for each goniometer and torsiometer at all times, particularly when attaching and removing the sensors from the subject. Failure to do this will result in reduced equipment life or failure.
3. Never remove the goniometer from the subject by pulling on the measurement element and/or protective spring. Remove the endblocks individually and carefully, making sure not to exceed the minimum permissible bend radius, particularly where the measuring element enters the endblocks.
4. Take care when mounting goniometers to ensure that the measurement element always forms a “simple” bend shape. Accuracy will be reduced if an “oxbow” shape occurs in the element.
5. Do not bend the finger goniometer more than  $\pm 20^\circ$  in the Y-Y Plane or reduced equipment life and/or failure may result.
6. Do not exceed rotations of  $\pm 90^\circ$  about ZZ. Exceeding the torsiometer range may result in a reduction of the life of the unit or failure.
7. Disconnect the transducers from the BIOPAC Acquisition Unit before cleaning or disinfecting goniometers and torsiometers.

## MAINTENANCE & SERVICE

No periodic maintenance is required to ensure the correct functioning of the sensors.

The sensors contain no user serviceable components.

If the sensor fails, it should be returned to BIOPAC Systems, Inc.

- **Please request a Return Merchandise Authorization (RMA) number before returning the sensor and include a description of what has been observed and what instrumentation was in use at the time of sensor failure in the return package.**

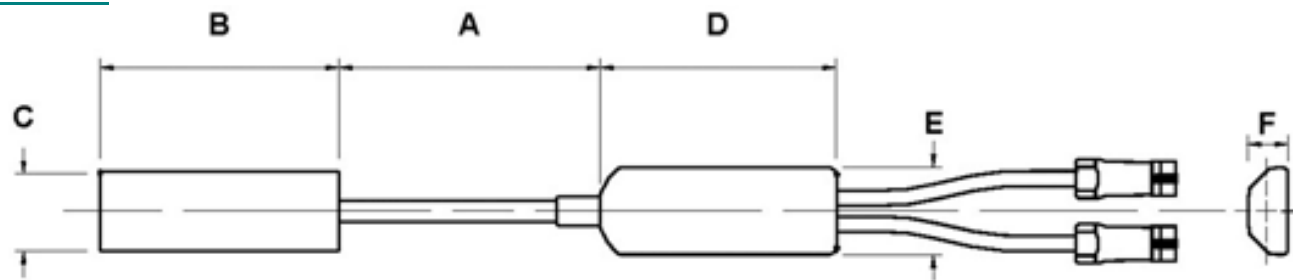
## CALIBRATION

When using all goniometers and torsiometers, **the minimum value of bend radius must be observed at all times**, particularly when attaching and removing the sensors from the subject. Failure to do this will result in reduced unit life or failure.

The sensors have been designed to be as light as possible and the operating force to be a minimum. This permits free movement of the joint without influence by the sensors. The sensors measure the angle subtended between the endblocks. Use the software calibration features (under **Setup Channels**) to calibrate any of the BIOPAC series goniometers.

Each goniometer requires a DA100C amplifier or MP3X/45 analog input per rotational axis. Accordingly, the twin axis goniometers will need two DA100C amplifiers or two MP3X/45 analog channels to simultaneously measure both rotational axes. The recommended excitation voltage is +5 VDC. See the MP Hardware Guide for DA100C Calibration or the BSL Hardware Guide for MP3X/45 input calibration.

**Specifications**



Part #	<i>MP150 or MP100</i>	TSD130A	TSD130B	TSD130C	TSD130D	TSD130E
	<i>Telemetry TEL100C</i>	SS20	SS21	SS22	SS23	SS24
	<i>MP36/36R/35/30/45</i>	SS20L	SS21L	SS22L	SS23L	SS24L
<b>Number of Channels</b>		2	2	1	1	1
<b>Measuring Range</b>		±150°	±150°	±150°	±150°	±150°
<b>Dimensions mm</b>						
<b>A. Maximum</b>		110	150	110	170	35
<b>A. Minimum</b>		70	100	70	115	30
<b>B.</b>		60	70	60	70	18
<b>C.</b>		18	18	18	18	8
<b>D</b>		54	54	54	54	15
<b>E</b>		20	20	20	20	8
<b>F.</b>		9	9	9	9	5
<b>Bend radius (mm) - minimum:</b>		18	18	18	18	3
<b>Weight (g)</b>		23	25	22	23	8
<b>Crosstalk<sup>1</sup></b>		≤ ±5%	≤ ±5%	N/A	N/A	N/A
<b>Nominal Output:</b>		5 μV/ degree normalized to 1 V excitation				
<b>Temperature Zero Drift:</b>		0.15 degrees angle / °C				
<b>Cable length:</b>		6 m (transducer is detachable)				
<b>Endblock height:</b>		cable end 9.4 mm, distal end 8.2 mm				
<b>Transducer type</b>		strain gauge				
<b>Life<sup>2</sup></b>		600,000 cycles minimum				
<b>Accuracy</b>		±2° measured over 90° from neutral position				
<b>Repeatability</b>		better than ±1°				
<b>Analog resolution</b>		infinite				
<b>Operating temperature range:</b>		+ 0°C to +40°C				
<b>Storage temperature range:</b>		-20°C to +50°C				
<b>Operating humidity range:</b>		30% to 75%				
<b>Storage humidity range:</b>		30% to 75%				
<b>Atmospheric pressure range:</b>		operation: 700hPa to 1060hPa		storage: 500hPa to 1060hPa		

<sup>1</sup> Specification of crosstalk for all Biometrics twin axis SG series goniometers is measured over ± 60°. i.e. if a joint is moved through 60° from the neutral position in one plane without movement in the orthogonal plane, then the sensor output in the orthogonal plane may change by a maximum ±3°.

<sup>2</sup> Life test results have been collected by cycling the sensors through movements that would happen during everyday use. For example, placing a sensor on an adult elbow and moving from the neutral position to maximum flexion and back to the neutral position, the unit will function for a minimum of 600,000 cycles.

**OVERVIEW OF THE BIOPAC GONIOMETER SERIES**

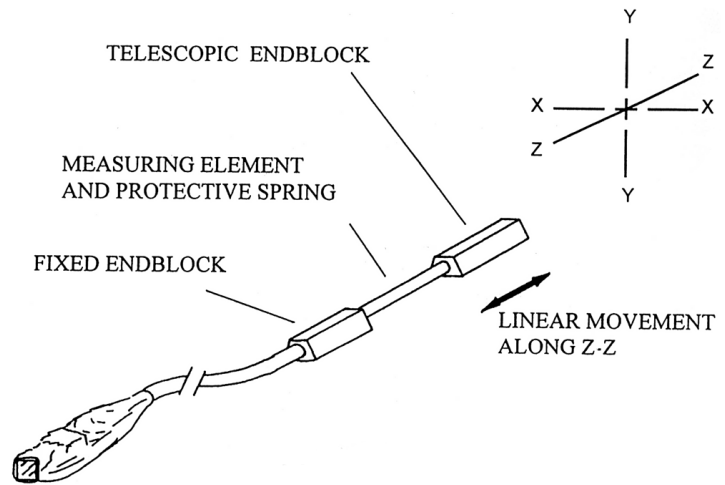
As with all measuring equipment, to correctly interpret the data, understanding the working principles (i.e., what the sensor measures) before use is helpful. BIOPAC Systems, Inc. manufactures three types of sensors:

1.

The single axis finger goniometer permits the measurement of angles in one plane.

Angles are measured when rotating one endblock relative to the other about axis X-X.

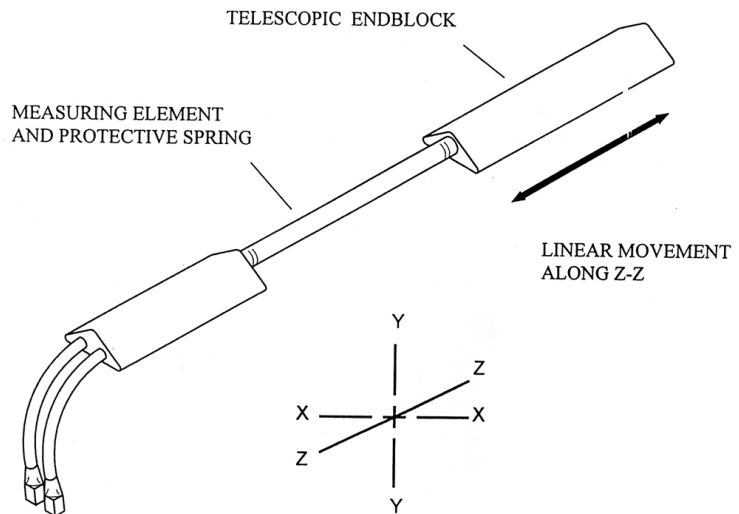
The goniometer is not designed to measure rotations about Y-Y. Any attempt to bend the unit in this way more than  $\pm 20$  from the neutral position will result in a reduction of the life of the unit or failure.



The goniometer does not measure rotations about axis Z-Z, though this movement is permitted without reduced life or damage occurring. This goniometer is designed primarily for the measurement of finger and toe flexion/extension.

2.

The twin axis goniometers permit the simultaneous measurement of angles in two planes, e.g. wrist flexion / extension and radial / ulnar deviation. Rotation of one endblock relative to the other about axis X-X is measured using the gray plug. Similarly, rotation of one endblock relative to the other about axis Y-Y is measured using the blue marked plug.



Assuming the goniometer is mounted correctly (as outlined here), the outputs of the two channels are independent of linear displacements along axis Z-Z.

It should be noted that rotation of one endblock relative to the other around axis Z-Z cannot be measured.

These goniometers function in the same way, and differ only in size.

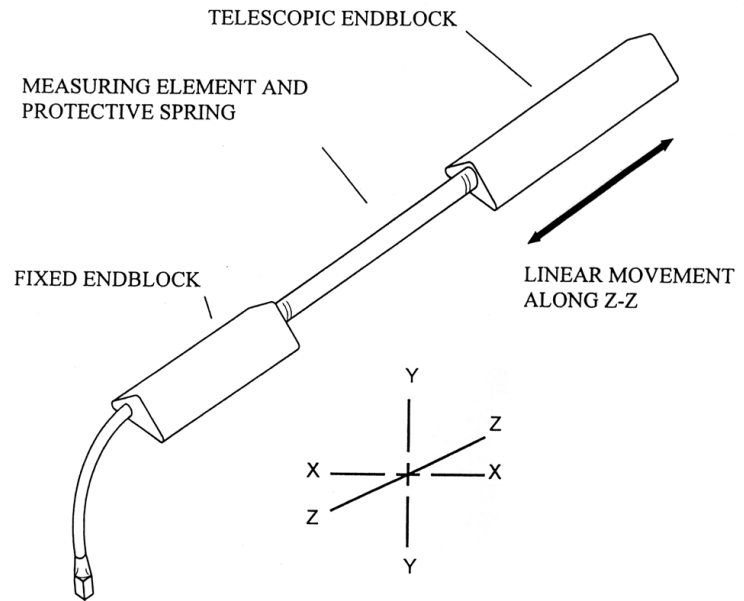
3.

The single axis torsiometers permit the measurement of rotation in one plane, e.g. forearm pronation/supination.

Axial rotation of one endblock relative to the other along axis Z-Z is measured from the gray plug.

If the torsiometer is bent in planes X-X or Y-Y, the output remains constant.

All torsiometers function in the same way, and difference only in size.



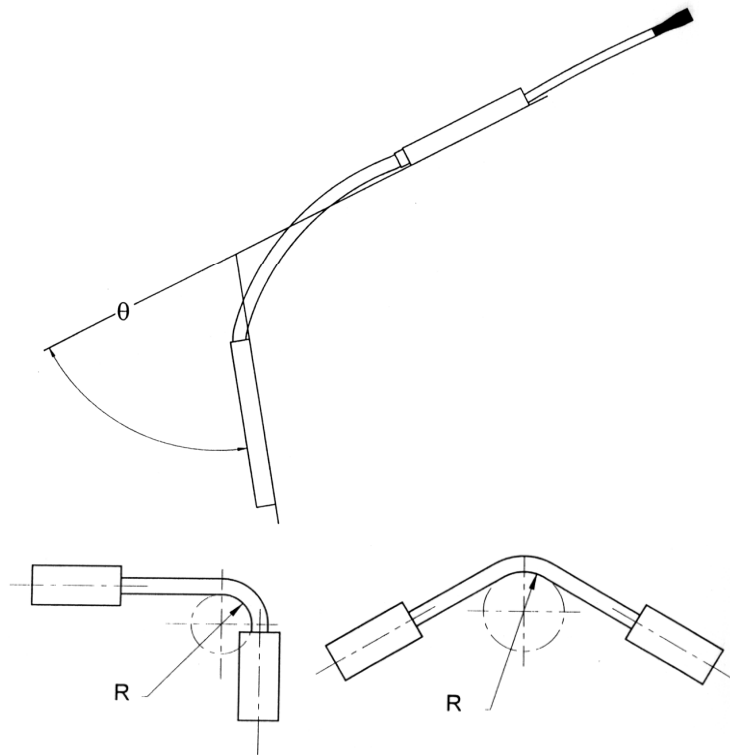
**WARNING!**

Torsiometers measure rotations about ZZ in the range  $\pm 90^\circ$ . Exceeding the range may result in a reduction of the life of the unit or failure.

The working mechanism is the same for all three types of sensors. There is a composite wire between the two endblocks that has a series of strain inside the protective spring gauges mounted around the circumference. As the angle between the two ends changes, the change in strain along the length of the wire is measured and this is equated to an angle. The design is such that only angular displacements are measured.

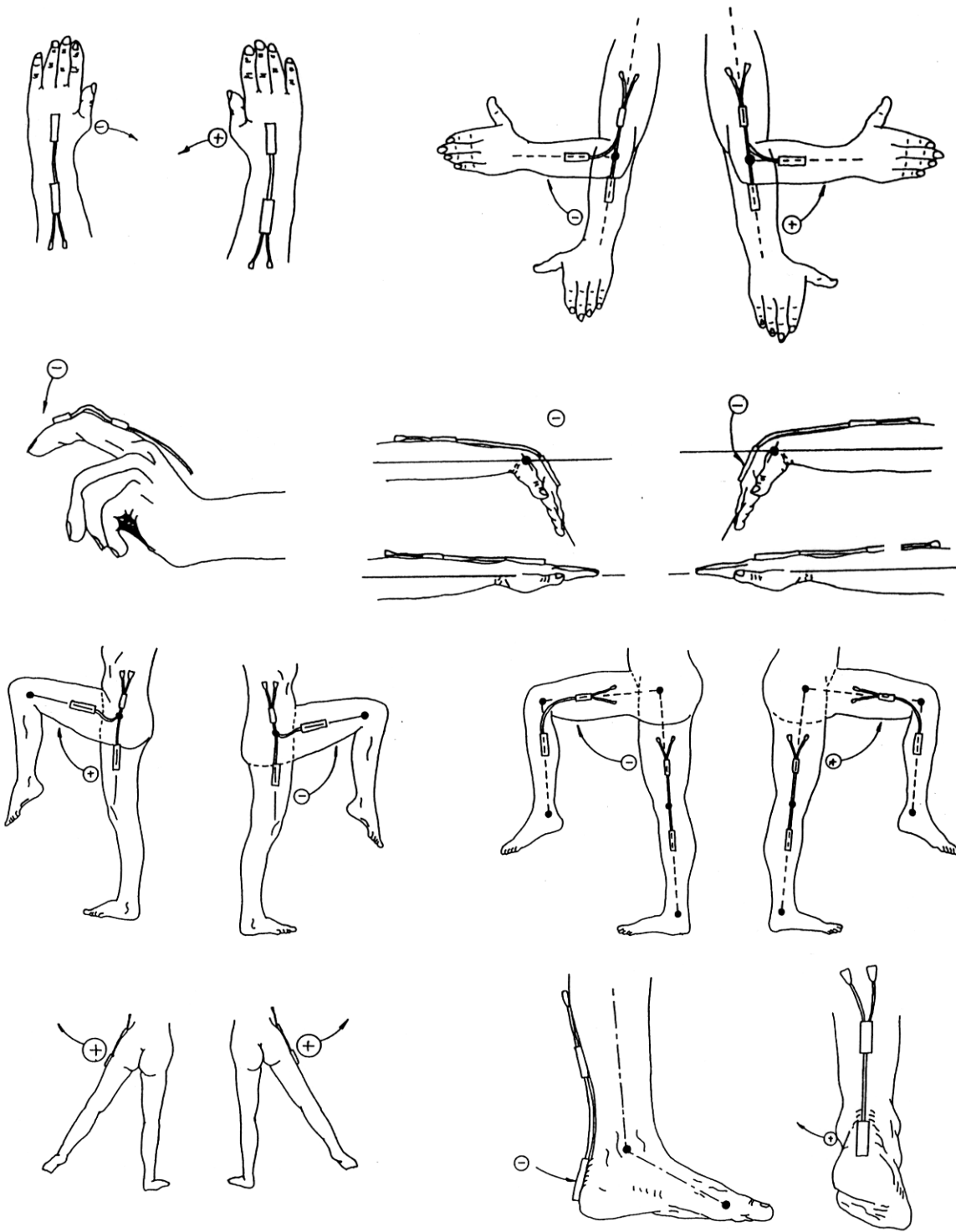
If the two ends move linearly relative to each other, within the limits of telescopic endblock, without changing the relative angles between them, then the outputs remain constant.

The amount of strain induced in the gauges is inversely proportional to the bend radius that the beam is bent around. If the stated minimum permissible bend radius is exceeded then unit life will be reduced or, in severe cases, failure may result.



**SIGN CONVENTIONS**

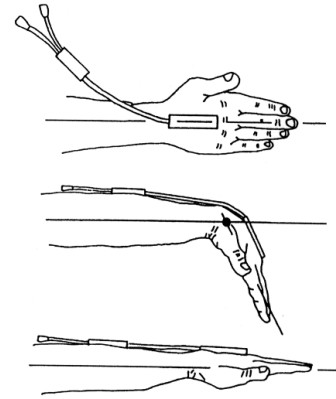
The sign convention for certain joints will differ, depending which side of the body the sensor is attached to. The following figures show sign conventions for the most common joints.



**WRIST – Goniometer TSD130A/SS20L/SS20**

Attach the telescopic endblock to the back of the hand, with the center axis of the hand and endblock coincident (top of figure — viewed in the frontal plane).

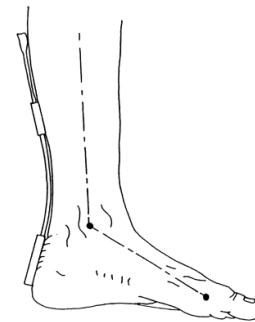
While fully flexing the wrist (middle and bottom of figure), extend the goniometer to Position 2 (as shown on page 2) and attach the fixed endblock to the forearm so that when viewed from the dorsal plane, the axes of the forearm and endblock are coincident. The wrist may now be flexed or extended, abducted or adducted, with the goniometer freely sliding between Positions 1 and 2. Measurement of flexion/extension is obtained from the gray plug, and abduction/adduction is obtained from the blue plug.

**ARTICULAR COMPLEX OF THE FOOT – Goniometer TSD130A/SS20L/SS20**

Attach the telescopic endblock to the back of the heel.

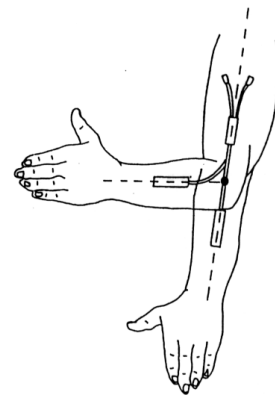
Extend the ankle to the maximum extension anticipated during measurement, and attach the fixed endblock to the posterior of the leg, with the goniometer in Position 1 (maximum length, as shown on page 2) so that the axes of the leg and endblock are coincident.

Flexion/extension of the ankle may now be monitored using the gray plug and pronation/supination using the blue marked plug.

**ELBOW – Goniometer TSD130B/SS21L/SS21**

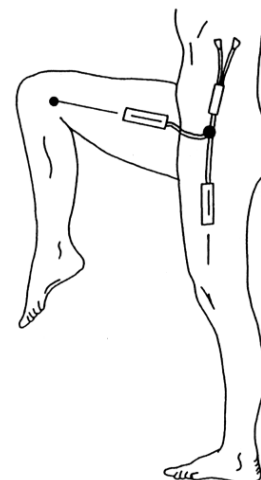
Attach the telescopic endblock to the forearm with the center axis of the endblock coincident with the center axis of the forearm. With the elbow fully extended, move the goniometer to Position 2 (maximum length, as shown on page 2) and attach the fixed endblocks to the upper arm, with the center of the endblock and the center axis of the upper arm coincident.

Now the elbow may be fully extended with the telescopic endblock freely sliding between Positions 1 and 2. Measurement of flexion/extension is obtained from the blue marked plug, and the gray plug is redundant. Note that the telescopic endblock is mounted on the half of the forearm nearest to the elbow joint. Movements of pronation and supination may be made and will affect the measurement of flexion/extension by a small amount.

**HIP – Goniometer TSD130B/SS21L/SS21**

Attach the fixed endblock to the side of the trunk in the pelvic region. With the limb in the position of reference, extend the goniometer to Position 2 (maximum length, as shown on page 2) and attach the telescopic endblock to the thigh, so that axes of the thigh and endblock coincide (when viewed in the sagittal plane, as shown).

The thigh may now be flexed or extended, abducted or adducted, with the goniometer sliding freely between Positions 1 and 2. Measurements of flexion/extension are obtained from the blue marked, and abduction/adduction from the gray plug.

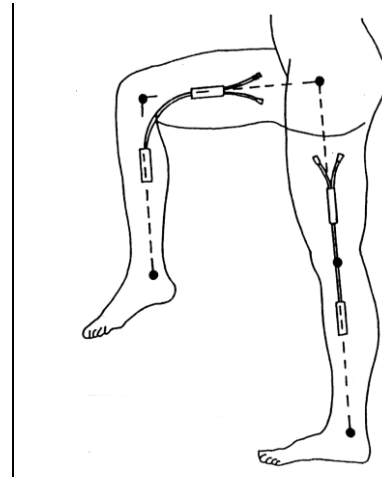




**KNEE – Goniometer TSD130B/SS21L/SS21**

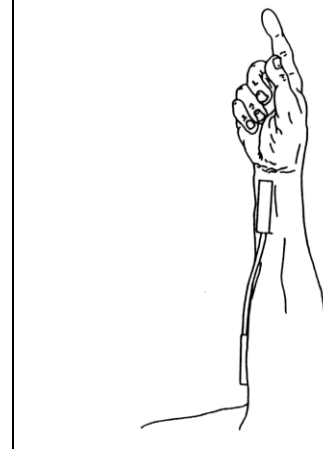
Mount the telescopic endblock laterally on the leg so the axes of the leg and endblock coincide, when viewed in the sagittal plane. With the leg fully extended in the position of reference, extend the goniometer to Position 2 (maximum length, as shown on page 2) and attach the fixed endblock to the thigh so the axes of the thigh and endblock coincide.

The knee may now be flexed or extended with the goniometer freely sliding between Positions 1 and 2. Measurements of flexion/extension may be monitored using the blue marked plug and varus/valgus may be monitored using the gray plug.

**FOREARM PRONATION /SUPINATION – Torsiometer TSD130C/SS22L/SS22 or TSD130D/SS23L/SS23**

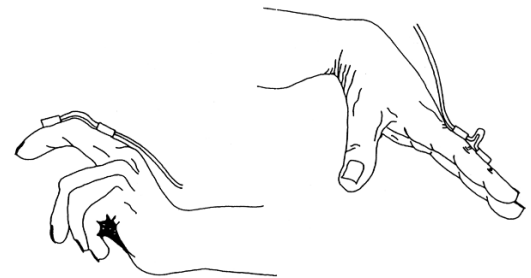
Attach the two endblocks of the torsiometer to the forearm, with the slider mechanism approximately midway between the two extremes.

Measurements of pronation/supination may now be made from the gray plug. Movements of wrist flexion/extension or radial/ulnar deviation will not affect the output.

**FINGERS AND TOES –Goniometer TSD130E/SS24L/SS24**

The single axis goniometer is intended for use on fingers and toes. Angles are measured by rotating one endblock relative to the other about axis X-X (as shown on page 2).

The goniometer is not designed to measure rotations about Y-Y. **Any attempt to bend the unit in this way more than +/-20° from the neutral position will result in reduced unit life or failure.** The goniometer does not measure rotations about the axis Z-Z.



The unit is designed to fit over the joint to be measured and has extremely high flexibility to ensure the instrument does not interfere with normal joint movement. One endblock is attached either side of the joint.

Unlike other BIOPAC Goniometers and Torisometers, and “Z” series sensors, an “oxbow” shape is permitted in the measuring element. This is not detrimental to the results and does not reduce life of sensor. Care should be taken, however, **that the minimum bend radius is not exceeded.**