Duo 773

Dual Microprobe System

INSTRUCTION MANUAL

Serial No.______________________

100608

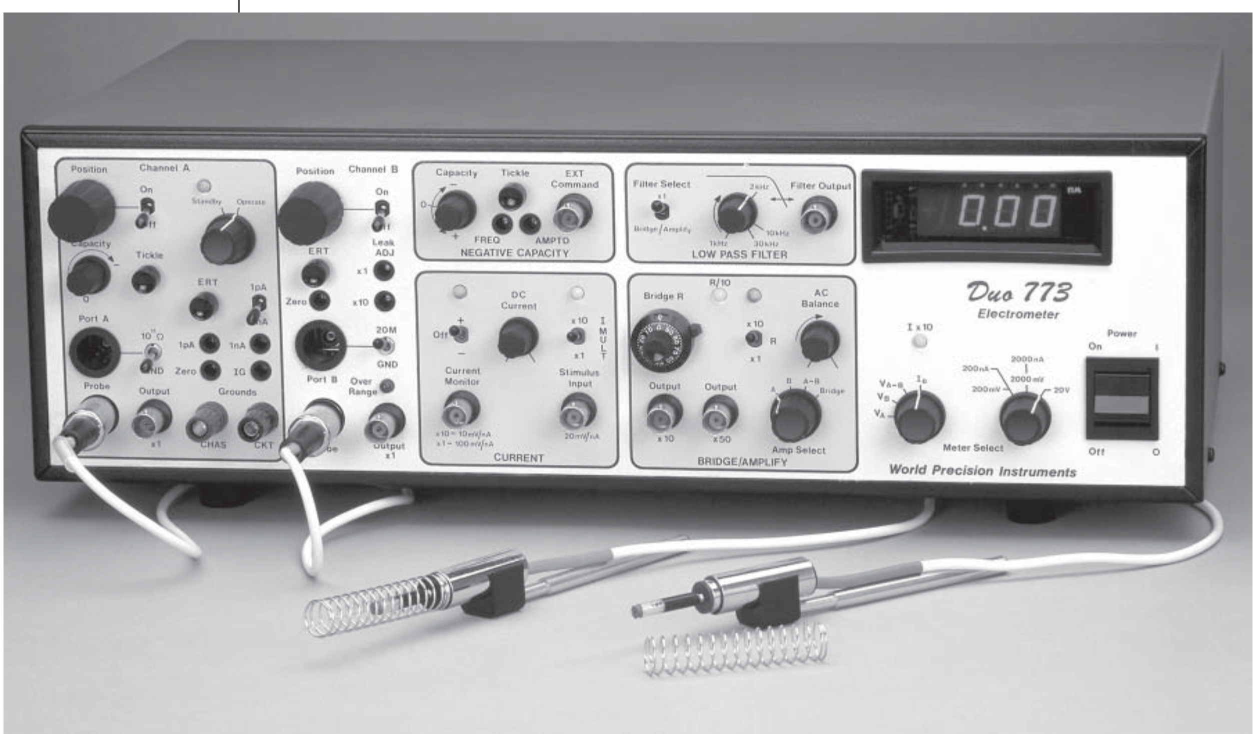
World Precision Instruments

Contents

INTRODUCTION

Duo 773 combines WPI's very high impedance active probe and the Intra 767 wide band electrometer to form a dual channel and/or differential probe system for use with very high resistance microelectrodes used in intracellular ion activity measurements. Duo 773 includes well known WPI features such as the cell "Tickler", low and high current injection, bridge electrode resistance compensation and test ports for WPI's miniature gold plated active probes. Duo 773 also includes new features such as an audio and visual overload warning, a continuously tuned low pass filter and an LED digital voltmeter.

NOTE: An optional configuration of the Duo 773 allows for the use of two low impedance balanced probes (712P). This configuration must be special ordered from the factory.



FRONT PANEL CONTROLS AND CONNECTORS

Probe A Sector (10^{15} Ohm probe)

Position*:* This 10 turn knob is operative only when the adjacent On/Off toggle switch is toggled to the On position. Over its full range this control can move the DC level of the probe signal ±300 millivolts. When the On/Off switch is Off, the "raw" electrode potential is available.

Standby/Operate: In the Standby position, an active electronic clamp keeps the probe tip at or near zero millivolts thus protecting the headstage from drifting to excessively high voltages.

Capacity: A variable shunt capacitance compensation control. As this control is rotated clockwise, electrode shunt capacity is effectively reduced and the probe tip will respond more quickly to fast signals. If the control is moved too far, the system will oscillate. One may safely leave this control at zero.

Tickle: An electrical oscillation is initiated by this push button. This can often be used to impale cells. Tickle oscillation can also be effected by applying a shorted input (e.g., with a standard foot switch) to the CHANNEL A TICKLE input connector on the rear panel.

ERT: " Electrode Resistance Test" (ERT) will inject either a 1 pA or 1 nA DC current through an electrode with which to estimate its resistance. The magnitude of these currents can be adjusted by the screwdriver adjustments marked 1 pA and 1 nA located just below the ERT button. The toggle switch 1pA/1nA selects which DC current value will flow.

Port A: The tip of the active probe can be inserted into this receptacle for leakage current and zero adjustment.

IG: Screwdriver adjustment compensates probe zero position.

Zero: Used to zero probe reading when probe is grounded and "position" is off (Factory set — adjustment by user is not recommended).

10^{11} Ohms/GND: The tip of the active probe, when inserted into the test port, can be switched from GND (ground) to a grounded 10^{11} Ohm resistor.

Grounds, CHAS, CKT: Panel connectors for chassis (CHAS) or mains ground and circuit (CKT) ground respectively. The preparation should normally be connected to CKT ground via an appropriate electrode.

Output X1: Probe A unmagnified output signal.

Probe B Sector

Leak ADJ X1, X10: Screwdriver adjustment controls for probe zero position and probe leakage current for X1 and X10 IMULT (multiplication) respectively.

Zero: Used to zero probe reading when probe is grounded and "position" is off (Factory set — adjustment by user is not recommended).

Port B: The tip of the active probe can be inserted into this receptacle for leakage current and zero adjustment.

20M/GND: The tip of the active probe, when inserted into the test port, can be switched form GND (ground) to a grounded 20 Mohm resistor.

ERT: Electrode resistance test (ERT) is a push button which injects +1 nanoampere of current through the probe tip.

Position <–––> On/Off: The Probe Output voltage level can be varied using this ten turn control if the On/Off switch is On. In the Off position no variable positioning of the Probe Output signal is possible.

Over Range: This red lamp will light if the Probe Output signal exceeds ± 10 volts. An audible signal will also be heard.

Negative Capacity Sector

Capacity: A variable shunt capacitance compensation control. As the control is rotated clockwise, electrode shunt capacity is effectively reduced and the probe tip will respond more quickly to fast signals. If the control is moved too far, the system will oscillate. One may safely leave this control at 0.

Tickle: Pushing this button results in an audible electrical oscillation at the tip of the probe. Amplitude (AMPT) and frequency (FREQ) of tickler oscillation can be adjusted by screwdriver adjustment of these controls. Tickle oscillation can also be effected by applying a voltage of 4 V DC or more to the EXT COMMAND input connector (front panel) or the CHANNEL B TICKLE (rear panel).

Current Sector

DC Current: Probe tip current can be varied from zero to 50 nanoamperes, by rotating the DC Current knob clockwise, if the +/Off/ - switch is switched to plus or minus (green lamp will light) with I MULT in the X1 position.

Probe tip current can be varied from zero to 500 nanoamperes if the I MULT switch is in the X10 (3 yellow lamps will light) position.

Stimulus input: An external voltage applied to this connector will cause a proportional current to flow through the probe tip. One nanoampere will flow for each 20 millivolts applied at I MULT X1; 10 nanoamperes per 20 millivolts at I MULT X10.

Current Monitor: A voltage proportional to probe tip current can be monitored from this connector. 100 millivolts equals 1 or 10 nanoamperes depending on the position of the I MULT switch.

Low Pass Filter Sector

Filter Select: Selector switch determines which signal is applied to filter; the x1 Probe Output or Bridge/Amplifier, the X10 differential amplifier.

Filter Output: This low-pass filter is a unity voltage gain amplifier; its upper bandwidth cut off frequency is controlled by the knob adjacent to it marked 1 kHz to 30 kHz.

Bridge/amplify Sector

Amp Select: Selector switch determines if X10, X50 differential amplifier is to be used in the Bridge resistance measuring mode or as probe voltage amplifier.

Bridge R: Ten turn dial, when adjusted for bridge balance, reads electrode resistance in Megohms. If yellow lamp R/10 is lit, R values indicated on dial should be divided by 10. If green lamp, R X10, is activated dial reading should be multiplied by 10. When both lights are on or off at the same time, the R values should be X1.

AC Balance: Transient (square wave edge) bridge balance adjustment.

Digital Panel Meter Sector

Meter Select: Meter selector switch selects voltage of probe A, probe B, A-B or B probe current (IB) plus range switch for probe voltage and current.

POWER: Mains power switch.

A SIMPLE INSTRUMENT TEST

Insert both active probes into Port A and Port B test ports and their cable connector plugs into the appropriate receptacles located just beneath. A probe, **715P**, has a blue color marker and identification band. B probe, **712P**, has a red color marker and identification band. Switch both the 10^{11} OHM/GND and 20 M/GND switches to GND. Rotate capacity compensation knobs counterclockwise (minimum). Plug the instrument power cord into the power line (mains) and turn on the POWER switch. All digits on the panel digital meter should light. Toggle the I MULT switch to x10. Three yellow lamps should illuminate. One is in the current sector above the multiplier switch, one is in the Bridge/Amplify sector, and the third one is located above the meter current and voltage selection switch. Upon observation of the LED's illumination, return the I MULT switch to the x1 position. At this time all three of the yellow 10x LED indicator lamps should no longer be illuminated. Push the Tickle button. An audible tone should be heard (CHB ONLY).

With the Position switches in the Off position and the Meter Select switch in the VB position and range set to 200 mV, the panel meter should read very close to zero millivolts. Precise zero adjustment can be effected by using the Zero screwdriver adjustment in the PROBE sector. Read VA in a similar manner.

Note: It is recommended that Duo 773 be allowed to warm-up for at least 30 minutes before changing any front panel screwdriver adjustment.

OPERATION

Duo 773 includes two probe channels which can be used independently or differentially. Channel A is a very high input Z probe electrometer often used for measurement with ion selective micropipette electrodes. Probe A can also be used for normal intracellular measurements as well. Channel B can be paired with Channel A to provide a micropipette "reference" electrode when a pair of microelectrodes are inserted into the same cell. Probe B has all the necessary features to perform intracellular measurements by itself as well.

The following discussion will take the user through a "dry" test of model 773 and attempt to relate this to the "wet" measurements with which the user will most often be involved. Channel B will be described first.

Channel B Operation

1.0 Measuring and recording Potentials:

1.1 Electrodes: The primary task of an intracellular voltmeter is the accurate and stable measurement of potentials in fluid electrolyte media. Usually, reversible electrodes such as Calomel or Silver/Silver Chloride are used to connect an electrolyte filled micropipette and a companion ground wire to the preparation. The WPI electrode holder supplied with this instrument contains an Ag/AgCl half cell which will exhibit a low and stable voltage difference when measured against a similar cell in a medium containing chloride ions.*

1.2 Perform the Simple Instrument Test described above. Switch the 20 M/GND switch to the 20 M position. This places a 20 M Ohm resistor between the probe tip and ground. This resistor will act as a pseudo-electrode in the description which follows. The digital panel meter (DPM) may shift a small amount from zero mV because of a small current leak at probe tip. By adjusting Leak ADJ X1with a screwdriver, restore the DPM reading to zero. The situation at this point is analogous to inserting the tip of a fluid filled micropipette electrode into an electrolyte bath containing an appropriate ground reference half-cell electrode. Electrodes, however also exhibit an electrode "tip" potential difference of several millivolts owing to the fluid junction potential at the electrode tip. This can be compensated by "offsetting" the Probe Output. Switch the Position On/Off switch to On. Note that rotating the Position control can displace the meter reading over a wide range. Connect the Probe

Output connector to an oscilloscope or pen recorder and observe the same effects on the oscilloscope or recorder trace.

2.0 Electrode Resistance Test:

2.1 With the Position control adjusted to zero mV, push the ERT (electrode resistance test) button. A one nanoampere DC current then flows through the electrode to ground. The digital panel meter (DPM) will read 1 millivolt per Megohm of electrode resistance. The reading obtained is an accurate measure of the 20 M Ohm pseudo electrode wired into the test port. Note that the "20 M ohm" is not exactly 20.0 M. If the Position control is displaced a few millivolts from 0, pressing the ERT button will "displace" the reading 1 mV per Megohm from the resting DC level. Switch the Meter Select switch to I and press ERT again. The meter will indicate 1.0 nA (electrode positive).

3.0 Injecting Current:

3.1 In a manner identical to the electrode resistance test above, current can be injected through the probe tip to ground with polarity, amplitude and waveform linearly proportional to an external voltage command applied at the Stimulus Input connector. In addition, DC current can be applied from an on board DC Current source. These currents will be "constant", ie; independent of electrode resistance, unless the probe input voltage range of + 10 volts (approximately) is exceeded.In that event, an audible and visual Over Range warning will occur. A signal instantaneously proportional to current can be monitored at the Current Monitor output terminal. The digital panel meter displays DC current only.

3.2 Apply a 100 millivolt square wave of 100 Hz from a pulse generator such as WPI's A 310 stimulator or Omnical 2010 voltage calibrator to the Stimulus Input connector. I MULT should be in the X1 position and DC Current knob in the minimum (counterclockwise) position. +/Off/- switch in the Off position. View the Probe Output signal on an oscilloscope. With the probe connected to ground via the 20 M Ohm test "electrode", one should see approximately a 100 mV square wave. This results from an effective Stimulus Input conversion factor of 1 nanoampere per 20 millivolts, yielding a 5 nanoampere amplitude current square wave that flows through the electrode resistance.

Notice that the square wave edges are somewhat rounded. This results from the "electrode" shunt capacity. If the Capacity control is advanced slowly, the square wave edge will become progressively sharper.

3.3 Toggle the +/Off/-control to + (green lamp turns on) and slowly advance the DC current knob clockwise. Note that the DC level of the oscilloscope trace rises in the positive direction. Reverse the polarity to - and note that the trace will reverse as well. When I MULT is in the X1 range (1 nA per 20 mV applied), the maximum DC current is 50 nanoamperes. In the X10 range (10 nA per 20 mV applied), the maximum is 50 nanoamperes. Note that the internal current generating circuit will saturate if the IxRe product exceeds approximately ± 10 volts. The Over Range lamp will light when input signals exceed the level beyond which current is no longer proportional to Stimulus Input.

3.4 Current can also be monitored by directly viewing the Current Monitor output on an oscilloscope. Connect the oscilloscope to Current Monitor and note that 1 nanoampere will deflect the ʻscope trace 100 mV in the X1 range and 10 mV in the X10 range of the I MULT switch.

4.0 Bridge Compensation:

4.1 Most often, the object of injecting intracellular current is to measure the voltage gradient across cell membrane resulting from transcellular current flow. Since the I x Re electrode voltage drop greatly exceeds the cell membrane voltage signal, it is necessary to subtract the electrode voltage drop from the total voltage signal observed at the Probe Output connector. This is achieved using a differential amplifier in the BRIDGE/AMPLIFY sector on the instrument front panel. This circuit amplifies the difference between the Probe Output and a voltage proportional to the current amplitude. When optimally adjusted, electrode voltage drop can be subtracted from the total electrode signal.

4.2 As in paragraph 3.2 above, apply the same 100 millivolt square wave to the Stimulus Input. Switch Amp Select to Bridge and the R toggle switch to X1. View the signal from the X 10 Output on an oscilloscope. Note that as the Bridge R (ten turn) control is increased from O, the amplitude of the square wave will diminish from about 1 volt to zero after about two clockwise turns. The Bridge R dial will read the same resistance value measured earlier (i.e., approximately 20 Mohm). Adjust the AC (transient) Balance control to reduce the square wave edge artifacts. Note that adjusting the Capacity knob may further reduce the transient artifact.

4.3 Wet Experiments: The electrode should first be balanced (nulled) with its tip placed into the extracellular electrolyte prior to inserting the electrode in the cell. Balance the electrode resistance as in paragraph 4.2 above. One may then proceed to impale cells and pass current through the electrode in a manner appropriate to the experiment. It must be emphasized that while current injection is a most valuable technique it is limited by two shortcomings:

1. Fluid filled microelectrode resistance does not remain constant as the injection current density increases. It is therefore suggested that the electrode be selected with as large a tip diameter as possible consistent with the experimental requirements.

2. The electrode resistance of fluid filled microelectrodes has been shown to change slightly when inserted into cells. Therefore the intracellular electrode resistance is different from the value measured outside.

4.4 Intracellular Electrode R Compensation: A technique for re-balancing the Bridge intracellularly is possible because the cell's membrane time constant is usually much larger than that of the electrode, particularly with the use of shunt capacity compensation ("negative capacity", see paragraph 8.0). Note that in figure 1A above, a step of current through an intracellular micropipette electrode shows an initial fast vertical step which then slows to an exponential rounded edge. The "take-off" point of the single exponential membrane time constant starts from a point displaced from the resting cell membrane potential. If the Bridge R control is adjusted so that the "take-off" starts from the resting cell membrane potential as shown in figure 1B, the Bridge R compensation is presumed to be in proper intracellular balance. The procedure described above is justified because an applied current step produces an initial voltage increment that is due to electrode resistance only, since the membrane capacitance acts at the first instant of time to shunt membrane resistance.

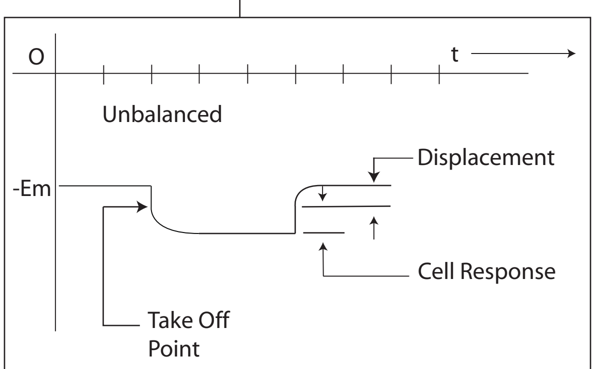


Fig. 1A

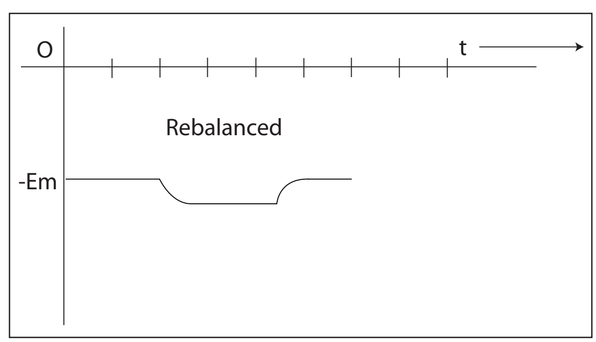


Fig. 1B

5.0 Filtering: The LOW PASS FILTER has a continuously variable cut off frequency with a high frequency roll off of approximately 40 decibels per decade. The cut off frequency dial marking is nonlinear. That is, cut off frequencies of 2 and 3 k Hz occurs near mid-dial setting.

By switching the Filter Select switch, the user may filter the B Probe Output (x1) or the output of the differential amplifier (Bridge/Amplify). The DC voltage gain of the filter is x1.

Note also that low pass filtering is also possible using the electrode Capacity knob. When this knob is moved counterclockwise from the O index mark, positive (shunt) capacitance is added in parallel with the input electrode's resistance.

6.0 Tickle: Many investigators often succeed in penetrating living cells by causing a brief electrical oscillation at the probe tip while the microelectrode tip is gently pressing on the outside of the cell. WPI calls this procedure "tickling". The effect is believed to be piezoelectric. When the Tickle button is pushed briefly, an oscillator is connected to the electrode. The frequency and amplitude of oscillation can be adjusted with a screwdriver at the AMPTD (amplitude) and FREQ (frequency) ports on the front panel. An external voltage command of +5 volts, applied to EXT Command, can also initiate tickling. The Tickler's oscillation is audible. Since the procedure is empirical, the user may wish to adjust frequency, amplitude and duration of the tickle oscillation to his own requirements.

7.0 Negative Capacity: Electrode shunt capacity slows the response of the probe to fast potential changes. It is estimated that 1 picofarad of shunt capacitance is added for each millimeter of electrode immersion in fluid electrolyte. For a given electrode, the procedure described in paragraph 3.2 above can be used to optimally speed up the response time of the electrode. Care must be used when adjusting negative capacity because excessive negative capacity adjustment will cause the probe to oscillate and because increasing negative capacity increases the baseline noise level. A safe and quick adjustment procedure is to adjust the Capacity control 10 to 20 degrees above the O index mark on the panel. Turning the knob counterclockwise towards + increases the shunt capacity. This feature can sometimes be useful as a noise filtering feature. Another technique is suggested in paragraph 3.2 above.

8.0 Grounding: Proper grounding of the experimental preparation is essential in order to obtain accurate recordings with minimal interference from power line induction. A silver-silver chloride electrode with a salt bridge (such as WPI model

RC1T) connected to the CKT ground terminal on the 773 will provide a stable electrochemical reference potential with respect to a fluid electrolyte medium.

Channel A: (10^{15} Ohm probe)

9.0 The primary function of Probe A is the accurate and stable measurement of potential in fluid electrolyte media. Probe A is especially designed to work with very high resistance micropipette electrodes. The procedure in the paragraph below will familiarize the user with the proper operation of Probe A.

9.1 Leakage Adjustment: With Probe A inserted in Port A, switch the 1011 OHM/GND switch to GND. position On/Off switch to Off, Capacity control to O, Standby/Operate switch to Operate and Meter Select switches to VA and 200 mV respectively. The panel digital meter should read 000.0 mV. If there is a small voltage offset, the user may adjust the Zero screwdriver adjustment to zero the DPM. Switch to 1011 Ohms.Note that the meter will move from zero owing to a small leakage current flowing through the probe tip. Each millivolt is equivalent to approx. 10-14 amperes (10 mV = 0.1 pA, 100 mV = 1.0 pA). Careful adjustment of the IG screwdriver adjustment will return the meter reading to zero. Some small fluctuation of the reading is normal.

9.2 Electrode R Test (ERT): To test electrode resistance (in this case, the pseudo-electrode 10^{11} Ohms) switch the 1pA/1nA switch to 1 pA. Push the ERT button and note that the deflection of the meter will be approximately 1 pA x 10^{11} Ohms = 100 millivolts. The ERT using a 1pA test current is satisfactory for electrodes of $10^9 < R < 10^{11}$. For electrodes with lower resistances, the 1 nA test current is advised. **Note particularly**:

A. The 1 pA and 1nA currents used in channel A are approximate (and somewhat affected by ambient temperature). Test current can be readjusted by the user with the screwdriver adjustments labelled 1 pA and 1 nA. Port A can be used for the 1 pA calibration and Port B for the 1nA adjustment (place the A probe in the Port B test port for this setting and use the Port A ERT). Note that 1nA x 20 M Ohms = 20 mV. The exact value of the 20 MOhm resistor has been recorded inside the instrument case.

B. If CKT ground has not been connected to a recorder or oscilloscope or other grounded instrument, the voltage across the 1011 Ohm resistor may fluctuate excessively. This should cease if CHAS ground is connected to CKT ground or if an externally grounded oscilloscope is connected to any of the BNC connectors on the front panel.

C. Note that the ERT test in channel A will exhibit some delay in the probe settling, due to the additional shielding added to the 10^{11} Ohm resistor inside the Duo773. This delay is not normally seen in actual usage.

10.0 Standby Mode: Because the probe is extremely sensitive to charge it is recommended that the user not allow the tip of the probe to become open circuited. For example, when transporting the probe from the test port to the site of measurement. If the probe tip is open circuited the probe tip insulation can acquire a charge which may not dissipate for many minutes. Standby mode, electrically clamps the probe tip to near zero volts so that the probe tip can be safely left disconnected from ground. The user should therefore keep Channel A in Standby when moving the probe, inserting electrodes and generally when handling the instrument. Once the electrode is connected to the probe tip and inserted into a grounded electrolyte solution, the probe can then be switched to Operate.

11.0 Negative Capacity: Electrode shunt capacity slows the response of the probe to fast potential changes. It is estimated that 1 picofarad of shunt capacitance is added for each millimeter of electrode immersion in fluid electrolyte. Care must be used when adjusting negative capacity because excessive negative capacity adjustment will cause the probe to oscillate and because increasing negative capacity increases the baseline noise level. A safe and quick adjustment procedure is to adjust the Capacity control 10 to 20 degrees above the O index mark on the panel. Turning the knob counterclockwise towards O reduces negative capacity. Note that Channel A provides only 10 pF of shunt capacity neutralization.

12.0 Matching Probe Time Constants: When recording differentially inside a cell with two microelectrodes of unequal resistance, large transient artifacts may be generated by rapid changes in cell potential. This is due to very unequal electrode resistance and therefore unequal electrode time constants. This inequality can be compensated by (a) using the low-pass filter to slow the faster (low R electrode) and (b) negative capacity to speed the slower (high R, channel A) electrode so that the two electrodes will track more closely in time. To achieve this electrode match, a low impedance square wave is injected in series with the solution ground electrode while the twin microelectrode is touching the perfusing electrolyte. WPI's Omnical 2010, for example, can provide a 100 mV square wave which will do quite well. The user must then advance the Channel A negative capacity control and diminish Channel B's negative capacity control so as to minimize the amplitude of the transient artifact spikes. If greater filtering is needed for Channel B, use a differential oscilloscope preamplifier and compare Channel A's X1 output against the Filtered Output of Channel B (Filter select X1) to ascertain if this is more effective.

Note: Some instruments, at the user's option, may come equipped with two 712P (red) probes. In that case, Channel A probe would have a resistance of 1012 rather than the 1015 Ohms cited above. An internal switch has been toggled to effect this modification.

13.0 Differential Operation: The differential voltage VA - VB amplified X10 appears at the Output X10 connector when the Amp Select switch is set to A-B. X50 is also available at the Output X 50. The digital panel meter will also display the DC differential voltage when the Meter Select switch is set to VA-B.

SPECIFICATIONS

Channel A:

Active Probe Input R	10^{15} Ohms
Voltage gain	x1 - 0.1%
Output Resistance	100 Ohms
Output Voltage Range	±10 volts
Max. Input Voltage*	±15 volts
Probe input leakage current	10^{-14} Amp. (Adjustable to zero)
Input shunt C compensation	0 to -10 pF
DC Position Adjust Range	±300 mV
Electrode R Test	1 pA, 1 nA test currents
Cell "Tickler"	>8V peak to peak at 1000Hz

Channel B:

Active Probe Input R	> 10^{11} Ohms
Voltage Gain	X 1.0 -0.2% X 10 ±2%
Output Voltage Range	±10 volts
Output Resistance	100 Ohms
Max. Input Voltage*	±15 volts
Probe input leakage current	5 pA max. Adjustable to zero
Input shunt C compensation	+10 to -50 pF
Risetime, 10 to 90%, typ	< 1 µs, direct input, small signal < 25 µs, 20 M Res.w.neg.C comp.
Noise Level, 10 kHz BW	< 50 µV,probe input shorted <200 µV, input 20 MOhmsto GND
DC position adjust range	±300 mV, 10 turns

* Higher input voltages permissable if input current is limited to less than 0.5 mA.

Electrode Current** .... 50 nA per V, I max.=50 nA
50 nA per 0.1V, I max.=500nA

DC Electrode Current .... +/- variable 0 < I < 50 & 500 nA

Electrode R Test .... 1 mV/ M Ohm (IX1); 10mV/ M (IX10)

Electrode Current Monitor .... 100 mV per nA, I MULT X 1
10 mV per nA, I MULT X 10

Electrode R Bridge Range .... 0 < R < 100 MOhms; O < R < 1000 M

R Bridge Amplification .... X 10, X 50

Differential Amplifier Gain .... X 10, X 50

Low Pass Filter .... Cont. variable, 1 to 30 KHz
Roll off = 40 dB per Decade

Cell "Tickler" .... 0 to 15 volts var., 1-8 KHz, var,
External gate feature incl.

LED Digital Panel Meter:

Display.. 31/2 digit LED display

Ranges.. 200 mV, 2000 mV and 20 V
200 nA, 2000 nA (channel B)

Accuracy and Resolution .... ±1 digit

Power .... 120/240 V, 60/50 Hz, 20 VA

Physical Dimensions:

Probe.. Body: 12mm (D) x34 mm (L); tip 2 mm

Instrument .... W=43.2 cm, H=13.4 cm, D=25.4 cm

** Maximum current limited by (I x Electrode R) < 10 volts.

NOTES

1. Duo 773's active probes have been accurately calibrated for operation with this instrument. If probe replacement should become necessary, it is recommended that the entire instrument be returned to an authorized repair facility for complete recalibration.
2. These probes can be damaged by static electricity. It is therefore recommended that the probe tip be connected to an electrical ground terminal (for example, the test ports A and B) when not in use. See particularly paragraph 10.0 for a discussion of the "Standby" mode.
3. Allow the instrument to warm up for at least 30 minutes before making any screwdriver adjustments on the front panel.

Appendix A: Using the 712P (low impedance probe) in Channel A

An optional configuration of the Duo 773 (special ordered from the factory) allows for the use of low impedance balanced probes (712P) in both Channel A an Channel B. The normal configuration allows for one high impedance (715P) electrode in Channel A and one low impedance (712P) electrode in Channel B. A few minor limitations of the optional configuration are worth noting. Even with the optional configuration, a 712P probe in Channel A will not stimulate. Only Channel B can stimulate. Additionally, the Channel A tickle function will only operate at greater than 8V peak to peak At 1000 Hz. it is not adjustable.

NOTE: If this optional configuration is required, the standard Duo 773 amplifier and its probes must be returned to WPI for re-configuration.

If you have the optional configuration, you may use the 712P probe in Channel A. To set up Channel A:

1. Begin with a low impedance (712P) probe that was tested in the Channel B. (See sections 1.2-2.1.)
2. With the power off, remove the probe connector from Channel B Probe connection slot and place it in the Channel A Probe connection slot.
3 Place the headstage of the Channel A 712P probe into Port B. The rest of the calibration tests will be performed with this setup.
4. Turn the Channel A Mode switch to Standby.
5. Turn the Duo 773 Power switch to On.
6. Set the Channel A Position control to Off.
7. Set the Port B to GND.
8. Rotate the Capacity control knob counter-clockwise as far as it will go.
9. Turn the Channel A Mode switch to Operate.
10. Set the left Meter Select knob to V_A.
11. Set the right Meter Select knob to 200mV.

12. Monitor the X1 current output with an oscilloscope. If necessary, increase the range setting temporarily to make these first adjustments.
13. Using a small screwdriver, adjust the Channel A Zero control screw until the meter reads zero.
14. Switch the Port B toggle switch to 20M.
15. Using a small screwdriver, adjust the Channel A IG control screw until the meter reads 0mV.
16. Depress the ERT push button. The meter should read 20mV. If it does not, use a small screwdriver and adjust the Channel A 1nA control screw until the meter reads 20mV.
17. The 1 pA function does not require adjustment, because it does not function with the Channel B probe.
18. Remove the Channel A probe headstage from the Port B. The Duo 773 (optional configuration) is now ready for laboratory use.

Warranty

WPI (World Precision Instruments, Inc.) warrants to the original purchaser that this equipment, including its components and parts, shall be free from defects in material and workmanship for a period of one year* from the date of receipt. WPI's obligation under this warranty shall be limited to repair or replacement, at WPI's option, of the equipment or defective components or parts upon receipt thereof f.o.b. WPI, Sarasota, Florida U.S.A. Return of a repaired instrument shall be f.o.b. Sarasota.

The above warranty is contingent upon normal usage and does not cover products which have been modified without WPI's approval or which have been subjected to unusual physical or electrical stress or on which the original identification marks have been removed or altered. The above warranty will not apply if adjustment, repair or parts replacement is required because of accident, neglect, misuse, failure of electric power, air conditioning, humidity control, or causes other than normal and ordinary usage.

To the extent that any of its equipment is furnished by a manufacturer other than WPI, the foregoing warranty shall be applicable only to the extent of the warranty furnished by such other manufacturer. This warranty will not apply to appearance terms, such as knobs, handles, dials or the like.

WPI makes no warranty of any kind, express or implied or statutory, including without limitation any warranties of merchantability and/or fitness for a particular purpose. WPI shall not be liable for any damages, whether direct, indirect, special or consequential arising from a failure of this product to operate in the manner desired by the user. WPI shall not be liable for any damage to data or property that may be caused directly or indirectly by use of this product.

Claims and Returns

• Inspect all shipments upon receipt. Missing cartons or obvious damage to cartons should be noted on the delivery receipt before signing. Concealed loss or damage should be reported at once to the carrier and an inspection requested. All claims for shortage or damage must be made within 10 days after receipt of shipment. Claims for lost shipments must be made within 30 days of invoice or other notification of shipment. Please save damaged or pilfered cartons until claim settles. In some instances, photographic documentation may be required. Some items are time sensitive; WPI assumes no extended warranty or any liability for use beyond the date specified on the container.

• WPI cannot be held responsible for items damaged in shipment en route to us. Please enclose merchandise in its original shipping container to avoid damage from handling. We recommend that you insure merchandise when shipping. The customer is responsible for paying shipping expenses including adequate insurance on all items returned.

• Do not return any goods to WPI without obtaining prior approval and instructions (RMA#) from our returns department. Goods returned unauthorized or by collect freight may be refused. The RMA# must be clearly displayed on the outside of the box, or the package will not be accepted. Please contact the RMA department for a request form.

• Goods returned for repair must be reasonably clean and free of hazardous materials.

• A handling fee is charged for goods returned for exchange or credit. This fee may add up to 25% of the sale price depending on the condition of the item. Goods ordered in error are also subject to the handling fee.

• Equipment which was built as a special order cannot be returned.

• Always refer to the RMA# when contacting WPI to obtain a status of your returned item.

• For any other issues regarding a claim or return, please contact the RMA department

Warning: This equipment is not designed or intended for use on humans.

** Electrodes, batteries and other consumable parts are warranted for 30 days only from the date on which the customer receives these items.*

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DECLARATION OF CONFORMITY

We: World Precision Instruments, Inc.
175 Sarasota Center Boulevard
Sarasota FL 34240-9258
USA

as the manufacturers of the apparatus listed, declare under sole responsibility that the product(s):

Title: 773

to which this declaration relates is/are in conformity with the following standards or other normative documents:

Safety: EN 61010-1:1993 (IEC 1010-1:1990)

EMC: EN 50081-1:1992
EN 50082-1:1992

and therefore conform(s) with the protection requirements of Council Directive 89/336/EEC relating to electromagnetic compatibility and Council Directive 73/23/EEC relating to safety requirements.

Issued on: 18th February 2000

Dr. Mark P. Broderick	Mr. Glen Carlquist
President and COO	**Production Manager**
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