FLOATING PLANAR ARRAYS AND RESEARCH PRODUCTS

FPA Technology

Floating Planar Arrays

Vacuum FPA Inserter

Titanium Pedestal

18 channel Impedance Tester

Frequently asked questions

User Instructions

Layout Specifications

Our new and truly unique Floating Planar Array (FPA), system is now available with all the flexibility needed to accomplish almost any multi-channel experimental paradigm. Solid core metal conductors make this array suitable for even the most rigorous stimulation protocols as well long term recording.

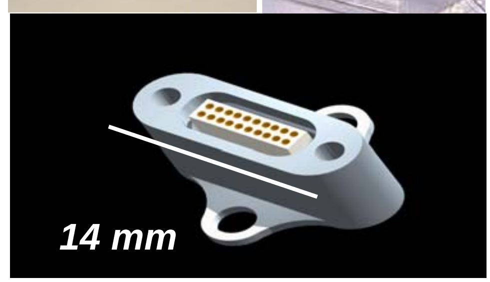
Plexon Inc. is marketing a novel “floating planar array”, FPA, for chronic and acute experimentation along with a titanium pedestal, vacuum inserter tool and 18 channel impedance tester.

Our new FPAs have been developed in cooperation with researchers in Dr. Richard Andersen’s laboratory at Cal Tech, Dr. Philip Troyk at the Illinois Institute of Technology and a NIH grant. These arrays offer the optimum in flexibility allowing the investigator to specify parameters such as the number of electrodes, electrode length, electrode impedance values, metal type, and cable length. Custom geometries and electrode juxtaposition may also be special ordered.

A vacuum inserter tool is being offered to provide an effective method for implanting the arrays. The inserter’s stainless steel cannula is easily attached to a standard micro-minipulator system for implanting the FPA into the brain.

A titanium pedestal is available, which will house a single Omnetics connector. Pedestal designs holding up to 6 connectors will be offered soon for large animal models where multiple FPAs will need to be implanted.

An eighteen channel impedance tester is also being offered that will greatly speed impedance checking of pre and post implanted FPA electrode arrays. The impedance tester has been designed so that extension cables can be specified for other connector styles typically used in Plexon’s other multi electrode and micro-wire array designs.



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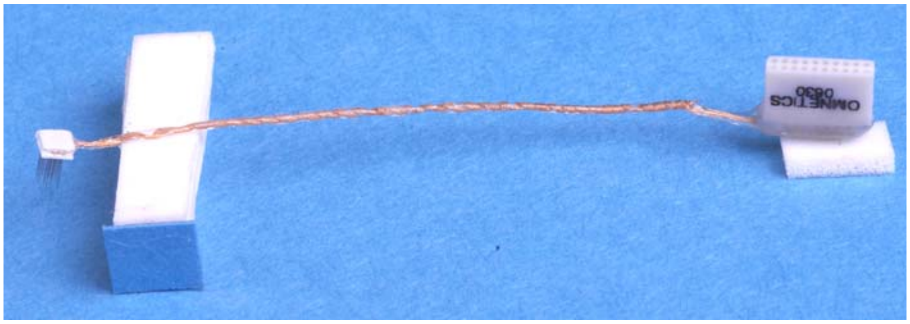
FPA Technology:



The FPA above has three mm long platinum-iridum microelectrodes and a helical cable for flexibility that is five cm long.

Neuroscientists have routinely used metal microelectrodes inserted into the cortex and spinal cord to record and electrically stimulate neural elements for over fifty years. During this time, many electrode designs ranging from single and bundled micro-wires to sophisticated silicon probes have seen various successes in acute and chronic applications. For acute experiments many neuroscientists typically fabricate bundles of micro-wires and insert them into the cortex using micro-drives. As neuroscience research moves towards studying large populations of cells in *chronic* rather than acute experiments, more sophisticated technologies must be employed to provide multi-electrode systems that can satisfy a diverse scope of experimental paradigms.

Chronic experiments, which are carried out over months, or even years, will require intracortical electrodes to serve as a reliable neural interface for both stimulation and recording. The need for arrays to have flexible design characteristics will be necessary to accommodate the varied experimental paradigms and animal models used among neuroscience researchers. Multi-electrode arrays that have regular and irregular electrode-to-electrode geometric spacing, with electrodes set at multiple depths that can record from and stimulate neurons without causing tissue damage or deterioration of the electrodes, are becoming essential tools for many neuroscience investigators. Even in the periphery, emerging studies are investigating arrays of electrodes, inserted into the spinal cord or nerve branches, with irregular electrode spacing, depth, and metal type, as a means of providing a more sophisticated artificial neural interface. Current research on neural prosthesis applications including cochlear nucleus stimulation for an auditory prosthesis, cortical stimulation for a visual prosthesis, and cortical recording for brain-machine interfaces all require using arrays of electrodes maintained in a stable mechanical position relative to the associated neuronal structures.

We have developed, tested, and are now offering the *floating-planar-array* ***(*****FPA)** whose design permits the mixing of electrode types, impedance values, irregular electrode spacing, arbitrary electrode lengths, and electrode materials such as platinum-iridium and activated-iridium-oxide, within the same microelectrode array. There are many investigative paradigms that require electrodes contained within a single array to have a range of tips exposures, as often characterized by their impedance, or a variety of electrode shaft lengths. Sometimes recordings are done in a differential mode requiring a reference electrode, which typically has an impedance value that is required to be an order of magnitude less than the recording electrodes. "Ground" or "common" electrodes are also required to be within arrays of both recording and stimulation multi-electrode arrays. Often it is desirable to implant an array along a sulcus, where some of the electrodes need to be much longer along the sulcus and shorter away from the sulcus.

Our arrays are fabricated from biocompatible materials: alumina ceramic, Parylene-C, noble metals (gold, and platinum/iridium 70/30% or pure iridium), and medical implant grade silicone elastomers. Rigid microelectrode designs using the same materials also offered by Plexon have been implanted in several studies for periods of up to 3 years and exhibited single unit activity. Our FPA design is based on using solid core conductors instead of silicone technology for several reasons. First as a result of our initial work with the Visual Prosthesis Program at the Illinois Institute of Technology, directed by Dr. Phil Troyk, an electrode design was required that would stand up to indefinite stimulation without compromising either the metal conductor or the integrity of the insulation interface. To date metalized silicone probes have not demonstrated sufficiently robust behavior to warrant long-term stimulation. Secondly our work with Dr. Richard Andersen's laboratory at Cal Tech required floating microelectrode array designs that would accommodate electrode lengths up to 8 mm. They also expressed the desire to have electrodes with different lengths within the same array. We have worked with these groups and others to develop a very flexible array design that is also very affordable for most laboratories.

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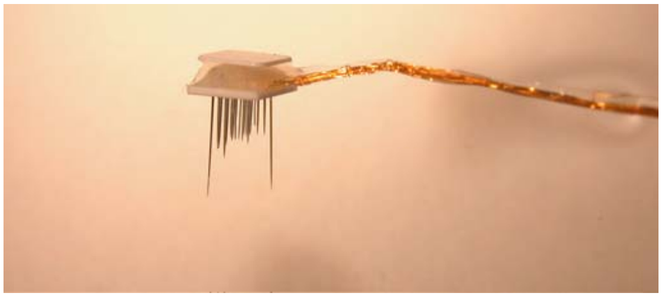
FLOATING PLANAR ARRAYS - FPAs

The concept behind the development of the Floating Planar Arrays, FPA, is based on the incorporation of a light-weight platform populated with rigid microelectrodes and tethered to a nano connector by a thin, flexible and light weight cable. The platform, which houses the individual electrodes, is fabricated from 125-micron thick alumina ceramic. It has been fabricated to have 18 holes evenly distributed with 400-micron separations. The overall dimension of the FPA is 1.95 x 2.45 x 0.5 millimeters. The holes are laser drilled to have a diameter of 105 microns. Because of the flexibility in the way in which these arrays are designed, FPAs can be fabricated with varying electrode depths not typically achieved using planar silicon technology. Current fabrication techniques allow individual electrodes to have depths between 0.5 to 10 mm. Impedance values for individual electrodes within the array may be individually specified between 10 kilohm to 2.5 megohm. The cable is fabricated from Parylene-C insulated 25-micron diameter gold wires, which are wound in a helix and over-coated with MDX4-4210 silicone elastomer for flexibility and strength.



The array shown above has microelectrodes that are 1.25 to 1.75 mm long with 2 stabilizing electrodes used for the ground and reference electrodes that are 2.5 mm long

Chronic FPA Assemblies

The array shown above is tethered by eighteen fine gold wires, 0.001" (25-micron) in diameter, about 1/3 the size of a human hair. The gold wires are micro-welded to the shaft of the microelectrodes at the specified distance from the tip in order to establish the proper length below the ceramic substrate that needs to penetrate into the brain. The other end of the gold wire is sonically bonded to a custom Omnetics connector designed to be compatible with Omnetics' A8141-001 model, which is used by several companies including Plexon, Inc. for their headstages. These connectors have worked very well for other chronic electrode designs and are small enough to be used in mouse experiments as well. Plexon currently offers titanium pedestals that will house a single Omnetics connector but is also working on developing pedestals that will house up to 6 connectors.

Acute FPA Assemblies

The acute FPAs are fabricated exactly the same as the chronic FPA designs. Connecting cables to the Omnetics FPA connectors can be purchased that will interface to headstage connectors that are not compatible with the model A8141-001. The investigators must provide a suitable method to support the FPA connector over the implant site.

Key Design Specifications

- Up to 18 penetrating microelectrodes per array (Plexon is currently working on a 36 electrode array).
- Spacing between electrodes is 400 microns.
- Microelectrode impedance is specified by the user to be anywhere from 10 kilohm to 2.5 megohm
- Un-insulated electrodes may also be specified to act as the ground or common electrode
- Microelectrodes may be specified at any length between 0.5 to 10 mm including different lengths within an array.
- Platinum/iridium 70/30% or pure iridium may be specified as the core conductor for the arrays.
- Pure iridium is suggested for chronic stimulation studies.
- Electrode tip diameter is typically 2-3 microns but maybe different depending on the application of the user.
- The base diameter of the microelectrodes is typically 50 to 80 microns depending on length.
- Array size is 1.95 x 2.45 x 0.5 mm.
- The cable length can be specified anywhere between 1.5 to 20 cm.
- Applications in cortex, spinal cord, association areas, and peripheral nerve bundles.
- Primates, rats, felines and other animal models.
- Excellent long term recording stability as well as rigorous stimulation studies with activated pure iridium electrodes

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Frequently Asked Questions

ARRAYS

Can you make the microelectrodes to have different lengths within an individual array
Yes, electrodes can be made to be any length between 0.5 mm to 10 mm long within an array. Use wiring nomenclature to specify individual lengths by position in the array.

What metals can I select for the electrodes?
At this time we are offering either platinum/iridium 70/30% or pure iridium as the electrode's solid core conductors. Although tungsten is slightly stiffer it is not considered by most investigators to be as inert or biocompatible.

What are the impedance values of the electrodes?
The impedance values may selected anywhere between 10 kilohm to 2.5 megohm depending on your application. Impedance values may also be different for different electrodes within an array. You may also choose to include an electrode with virtually zero impedance for ground or common, which is an uninsulated electrode.

How large are the electrode tips?
Typically the microelectrode tips are between 2 to 3 microns for most Pt/Ir electrodes. However, this value can be specified for special applications. As an example, we are currently supplying pure iridium electrodes for a visual prosthesis study that has diameter on the order of 5 to 6 microns.

What is the insulation over the electrodes?
The microelectrodes are insulated with Parylene-C, a biocompatible polymer that has been successfully used for many years as the primary insulator for many implantable devices and electrodes.

Why do you show 2 electrodes with much longer lengths?
For FPAs requiring microelectrode lengths less than 2 mm we recommend that at least 2 electrodes have lengths of 2.5 mm to act as anchoring pins. The anchoring pins provide needed support to insure that the array remains securely anchored in the brain or spinal cord. These electrodes are typically chosen to be the reference and/or ground electrodes.

Can I use these arrays for either acute or chronic studies?
Yes, although the FPAs were primarily designed for long-term chronic studies, they may also be used for acute studies where one needs to insure that the array will float with the brain during recording or stimulation protocols. If brain movement is not an issue, investigators typically use Plexon's Multi-Electrode Arrays.

Can I select to have less than 18 electrodes?
Yes, 4 is the minimum number of electrodes that may be ordered within a single FPA.

What is the tolerance of the specified electrode length?
At this time we can guarantee the specified electrode length to be within 200 microns.

Can I reuse the arrays?
You can reuse an array used for acute studies. It is recommended you clean the array in 50% bleach and distilled water. Chronically used FPAs may typically not be reused because of tightly bound connective tissue around the FPA and cable.

Can I specify an array with less or more electrodes having a substrate geometry different from the 1.95 x 2.45 mm size that is offered?
Yes, you can specify different layout geometries that also require a different number of electrodes. We have provided custom designed ceramic substrates for other users. There is a one-time non-reoccurring-engineering, NRE, charge of $3800 to $7500 (typical) to have your own layout and implant geometry designed for your particular application. Inner electrode spacing must be within 250 to 1000 microns constraints. Please allow two to three months for delivery of FPAs with custom designed ceramic substrates.

CONNECTORS

Can you make the FPAs with different connectors?
No, at this time Plexon uses custom nano connectors made by Omnetics Corp., designed for sonic bonding techniques needed to attach the fine gold wires from the FPA. Plexon may provide interface cables that can be attached between the Omnetics A8141-001 type design of the FPA and your headstage amplifier connector.

What are the available cable lengths? The cable lengths can be specified from 1.5 cm to 12 cm.

How can I minimize the cable tethering forces?
Putting a slight kink in the cable between where the cable exits the bone edge and the implanted array will help provide necessary slack during potential brain to skull movements. Also many investigators have found that by applying a very small amount of highly viscous biocompatible cyanoacrylate glue over the cable about 2 to 3 mm from the implanted array and securing the cable to the pial surface, is very effective in eliminating potential movement. Keeping the animal relatively immobile during the first few days after implant is also recommended. This assists in the natural encapsulation of the array at the surface of the brain due to normal tissue adhesions that occur around any foreign body implant.

What type of wire is used from the array to the connector?
We used 0.001" (25 micron) gold wire from the ceramic substrate array to the connector. The cable is over-coated with MDX4-4210 silicone elastomer for flexibility and strength.

IMPLANTATION

What is the best way to implant the array?
The primary concern when handling the FPA prior and during implantation is to insure that the microelectrodes do not touch anything other than soft tissue. The microelectrode tips are very fragile and may bend if the electrode tips are allowed to come in contact with bone or any other hard surface. It is imperative that the microelectrodes be implanted perpendicular to the surface of the brain to insure minimal tissue disruption during insertion. Plexon offers a vacuum inserter system that is described in the User Instructions, which is the preferred method of inserting the arrays.

How fast should I insert the array into the brain?
It is recommended that the FPAs be inserted very slowly. The FPA should be lowered until there is only a small amount of dimpling of the brain. Allow the electrodes to penetrate the pial membrane before advancing the FPA further. Slowly lower the FPA into the brain stopping the advancement every few hundred microns to allow the pial membrane to relax after insertion. The concept of this procedure is to advance the FPA at a slow enough speed so as not to depress the pial membrane, which will compress the brain, during insertion of the electrodes.

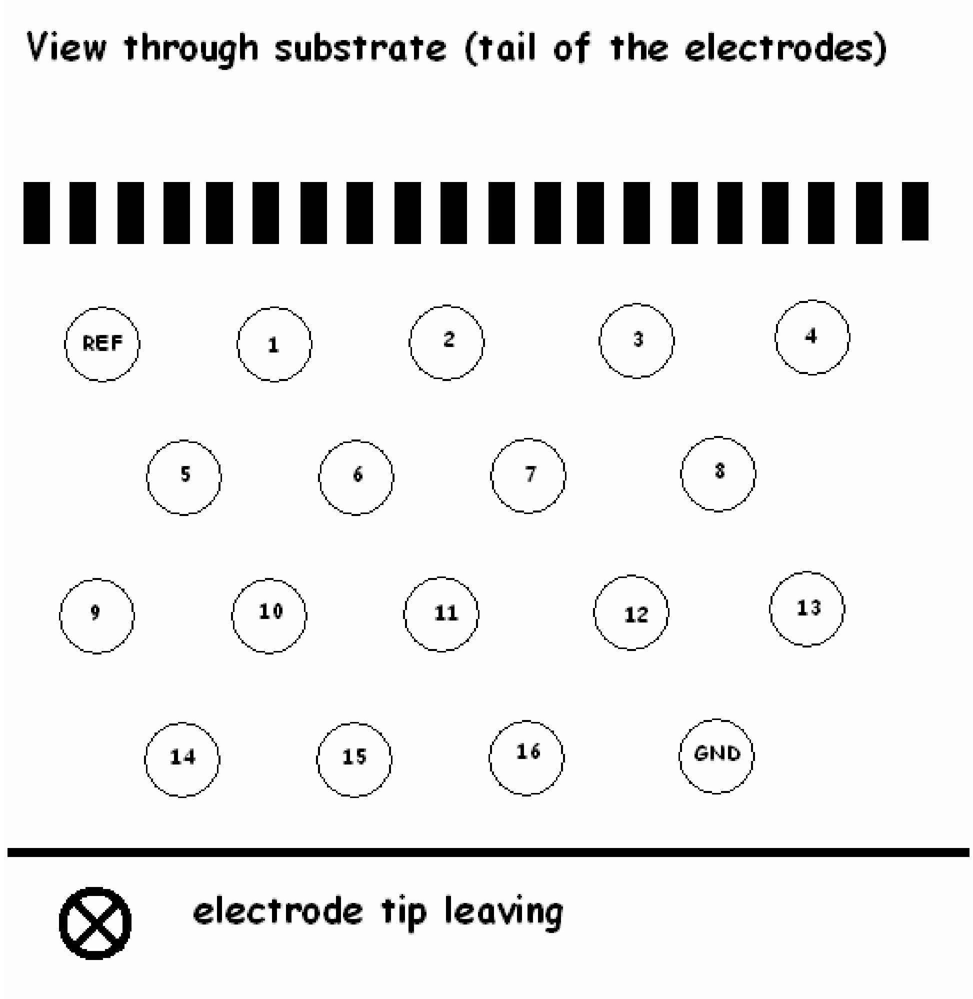
Is their tissue damage resulting from the insertion?
Any tissue damage can be almost completely avoided by insuring the following precautions. First, try to avoid placing the electrodes over any blood vessels when initially positioning the array for implantation. It is important to insure that the electrodes are as close to perpendicular to the brain's surface as possible before lowering the array into the brain. And lastly lower the array as slow as possible into the brain.

What parts of the inserter tool can be sterilized?
The tubing including the inserter wand can all be sterilized although in most instances it usually is only necessary to sterilize the tubing and cannula leading from the wand.

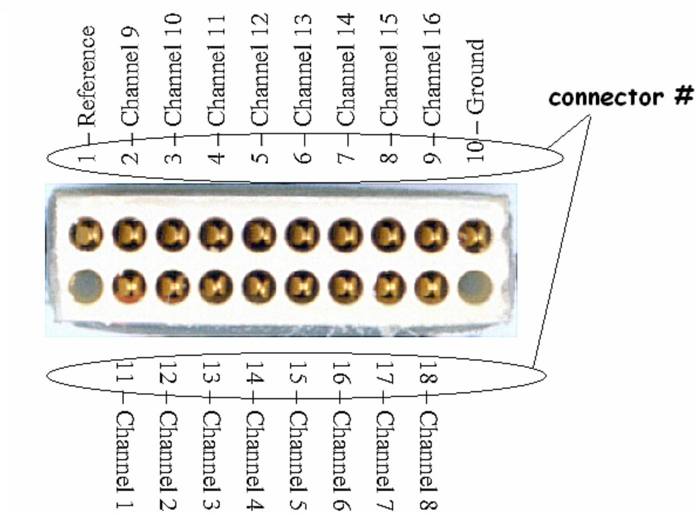
Can I implant the array through dura?
It is possible to implant the array through dura for smaller animals, although this is not advised for chronic studies. One reason for this is that there maybe lateral relative movement between the pial and dura membranes, which may cause the electrodes tips to move causing local adhesions near the tip.

FPA Layout Designations and Specifications

This view demonstrates typical reference and ground locations for several headstage amplifier systems such as the Plexon headstage units.



Male connectors showing for the Omnetics #A8141-001 0.025" pitch nano connector used for the FPAs



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FPA connection table showing typical ground and reference placement for Plexon headstages

Connector #	FPA #	Impedance	Electrode Length (mm)
1	REF (if needed)	10K (typical)	
2	9		
3	10		
4	11		
5	12		
6	13		
7	14		
8	15		
9	16		
10	GND (if needed)	GND uninsulated electrode	
11	1		
12	2		
13	3		
14	4		
15	5		
16	6		
17	7		
18	8		

Cable Length: _______ cm

Special Instructions:

FPA Pricing:

The pricing for the FPAs are based on two criteria; the number of electrodes and the metal electrode core conductors chosen. Discounts can also be provided for quantities of five or more.

When ordering please provide a copy of the "FPA Layout Designations and Specifications" sheet filled out with the desired impedance values for each electrode and electrode lengths. Also, you must specify a cable length as well. Please allow about 15 percent additional length necessary for providing a slight "kink" in the cable for strain relief. Most users will want all the electrodes to be the same impedance (typically 0.5 to 1.0 megohm for recording) except for the reference (typically 10K) and ground or common electrode. For lengths less than two mm it is recommended to have the reference and ground electrode to be 2.5 mm long to act as anchoring pins in order to stabilize the array after it has been implanted. Naturally occurring adhesions will begin to form over the array within the first few hours completely securing the array after about 24 to 36 hours.

The FPA part numbers specify:

1. **Metal Type** -**PI** for platinum/iridium 70/30% and **IR** for pure iridium
2. **Number Of Electrodes** -**N**
3. **Electrode Length** -**L** in mm
4. **Impedance Values** -**X.X** in megohms
5. **Reference Electrode** -**R** for a reference **0** for no reference electrode (25K unless specified)
6. **Ground Electrode** -**G** for a ground **0** for no ground electrode (bare electrode unless specified)

Example: **FPA-PI-16-2.5-0.5-R-G** specifies a FPA with 16 platinum/iridium microelectrodes, all electrodes will be 2.5 mm long, the impedance will be 0.5 megohm except for the reference and ground electrodes, which will be included in the array.

Call for Pricing: 214.369.4957

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Eighteen-Channel Impedance Tester

- **4 Ranges - Accurate From 1k To 5 Megohms**
- **Standard 1 Khz Testing Frequency**
- **Safe To Use In Preparation: Nanoamp Test Current**
- **Easily Portable - Battery Operated**

Description:

An eighteen channel impedance tester is also being offered that will greatly speed impedance checking of pre and post implanted FPA electrode arrays. The impedance tester has been designed with the flexibility of Plexon offering extension cables for other connector styles such as those used in Plexon's other multi-electrode and micro-wire array designs. It can measure impedance values between 1 kilohms and 5 megohms and display the value on an easy to read quality analog meter. A switch is provided, which in one position will test the electrode's impedance or in the other position will allow an externally provided current or voltage source to be applied to the electrode. This is for the purpose of breaking down an oxide layer, bubble testing, or lowering the tip impedance.

Specifications:

Sine Wave Frequency:	1 kilohertz
Testing Current:	Less than 30 nanoapms
Impedance Testing Range:	Zero to 5 megohms
Accuracy:	Less than 10% error
Power Requirements:	Two 9 volt alkaline transistor batteries
Battery Life:	Greater than 50 hours
Size:	5.5"w x 2.5"h x 6.5"d
Weight:	1.5 lbs.

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