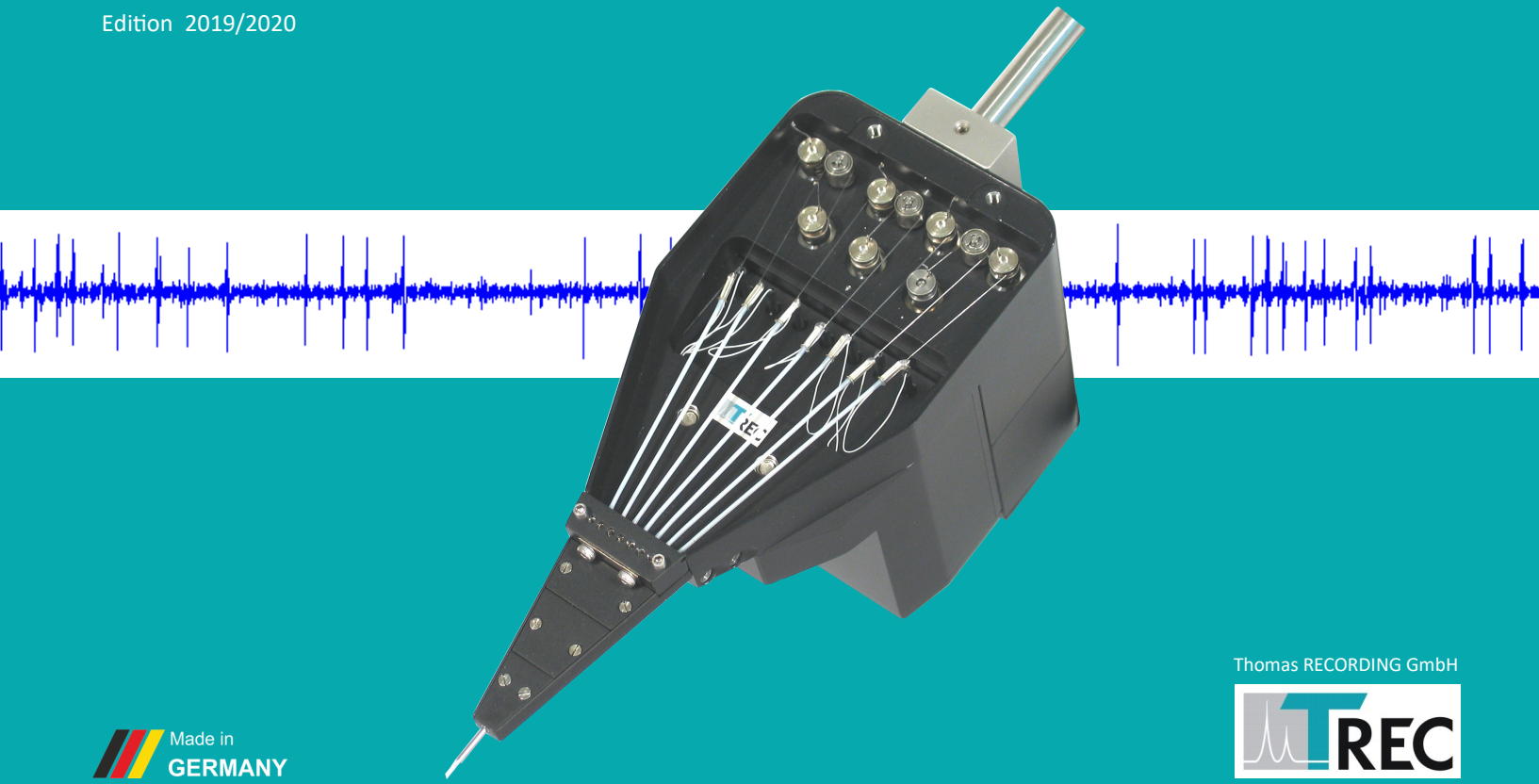
Neuroscience Solutions

Hightech Products for Neurophysiological Research

Edition 2019/2020



Made in GERMANY

Thomas RECORDING GmbH

MTREC

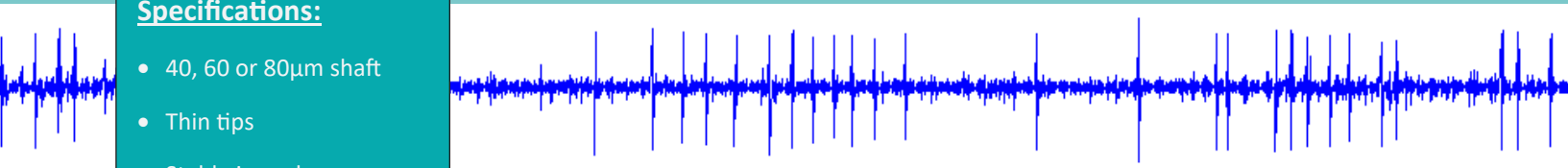
Micro Probes

Thomas RECORDING ***microelectrodes*** are quartz glass insulated platinum-tungsten electrodes with shaft diameters from 40 to 80µm. Based on the fact that we use an alloy of 95% platinum and just 5% tungsten our electrodes have a high impedance stability over time. Besides this we have a high reproducibility of the tip geometry due to our manufacturing process. As a result, TREC electrode users can expect consistent recording results while using our microelectrodes.

[1] ***Fiber microelectrodes for electrophysiological recordings***; Reitboeck, H.J.; Journal of Neuroscience Methods 1983; 8:249-262

Specifications:

- 40, 60 or 80µm shaft
- Thin tips
- Stable impedance
- Dura penetration
- Minimal tissue damage
- Field potential, multi-unit and single-unit activity recordings
- Low noise



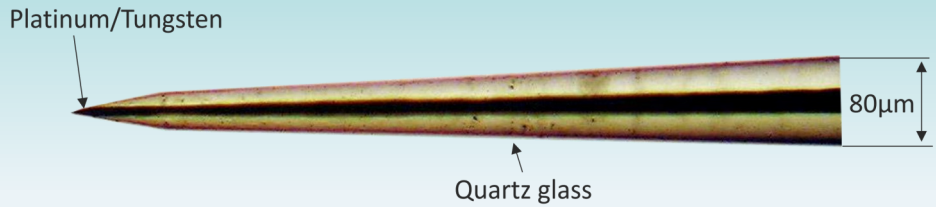
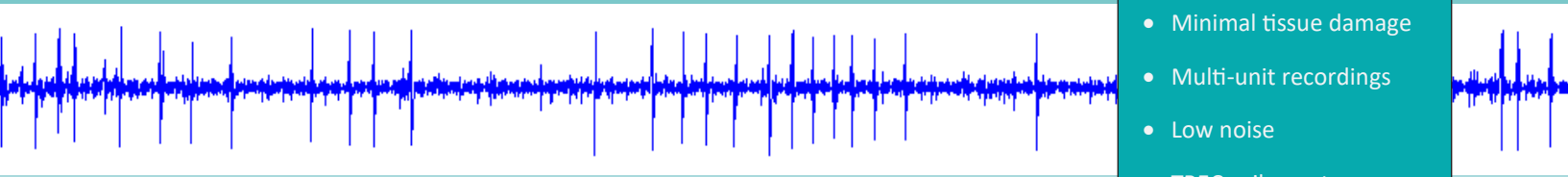


Figure 1: Tip of a quartz glass insulated platinum-tungsten electrode with pulled & ground tip (tip shape A), impedance 1-2MΩ, well suited for single-unit isolation

Thomas RECORDING ***tetrodes*** were introduced 1987, have a shaft diameter of app. 100µm and 4 individual metal cores insulated from each other by quartz glass. In contrast to twisted wire tetrodes the Thomas tetrodes have a highly reproducible tip geometry and no sharp cutting edges. The metal contacts have low impedance values caused by the manufacturing process which does not require tip plating. The signal-to-noise ratio of the recorded signal is outstanding. The tip shape of Thomas tetrodes can be adapted to brain areas with different cell densities, which is not possible with twisted wire tetrodes.



[2] ***Tetrode recordings in the cerebellar cortex***; Gao, H.Y. et al., Journal of Physiology; 2012, 106: 128-136

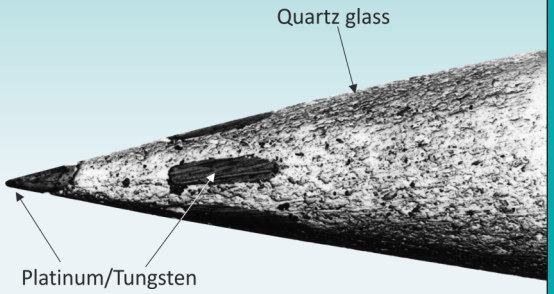
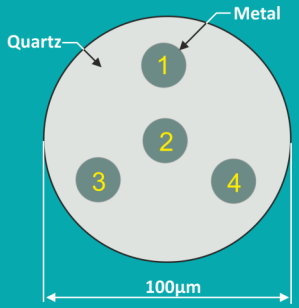


Figure 2: Tip of a quartz glass insulated platinum-tungsten tetrode with ground tip (tip shape D), impedance 0.5-0.8MΩ, well suited for multi-unit recording in brain areas with normal cell density

Tetrodes

Specifications:

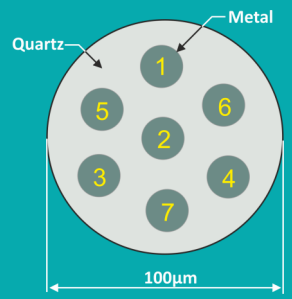
- 100µm shaft
- Thin tips
- Stable impedance
- Reproducible tip geometry
- Minimal tissue damage
- Multi-unit recordings
- Low noise
- TREC spike sorter available



Heptodes

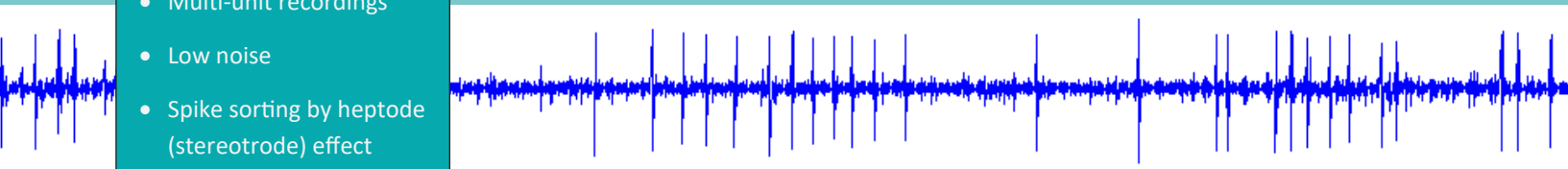
Specifications:

- 7 recording channels
- Shaft diameter 100µm
- Stable impedance
- Minimal tissue damage
- Multi-unit recordings
- Low noise
- Spike sorting by heptode (stereotrode) effect
- TREC spike sorter



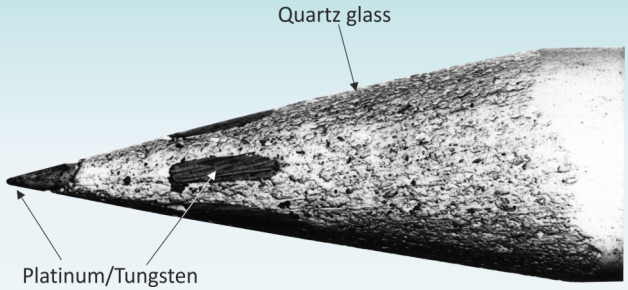
Thomas RECORDING ***heptodes*** have a shaft diameter of 100µm and 7 individual metal cores insulated from each other by quartz glass. In contrast to twisted wire or multielectrodes the Thomas heptodes have a highly reproducible tip geometry and no sharp cutting edges. The metal contacts have low impedance values caused by the manufacturing process, which does not require tip plating. The signal-to-noise ratio of the recorded signal is outstanding. The multi-unit activity recorded with Thomas heptodes allows improved spike sorting based on the heptode effect.

[3] ***Efficient Signal Processing of multineuronal Activities for neural Interface and Prosthesis***; Kaneko, H. et al.; Methods of Information in Medicine, 2007, 46:147-150



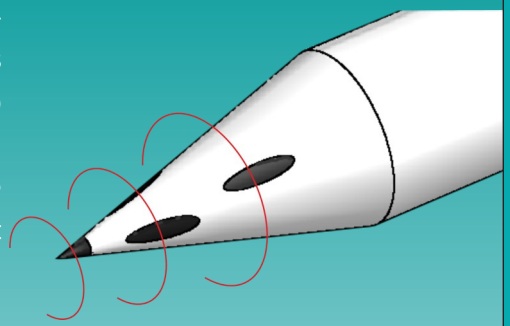
[4] ***Quantitative Analysis of functional clustering of neurons in the macaque inferior temporal cortex***; Tamura, H. et al.; Neuroscience Research, 52, 2005:311-322

Figure 3: Tip of a quartz glass insulated platinum-tungsten heptode with ground tip (tip shape D), impedance app. 1MΩ.

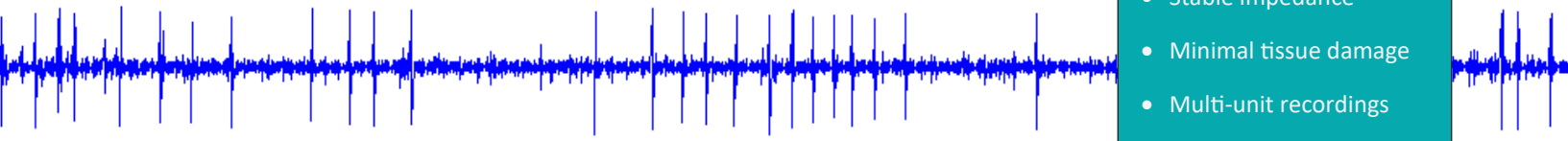


3D Heptodes

Thomas RECORDING´s latest electrode development are ***3D-heptodes***. These heptodes have 7 individual metal cores. In contrast to our standard heptodes these contacts are arranged in three different heights from the tip. This allows recording from three different layers of a neural structure.

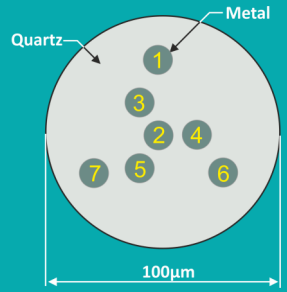


[5] ***Are Heptodes better than Tetrodes for Spike Sorting***; Doerr,Ch.; Schanze T.; IFAC-PapersOnline; 48-20; 2015: 094-099



Specifications:

- 7 recording channels
- 3 different contact planes
- Shaft diameter 100µm
- Stable impedance
- Minimal tissue damage
- Multi-unit recordings
- Low noise
- Improved spike sorting by heptode effect



NEW

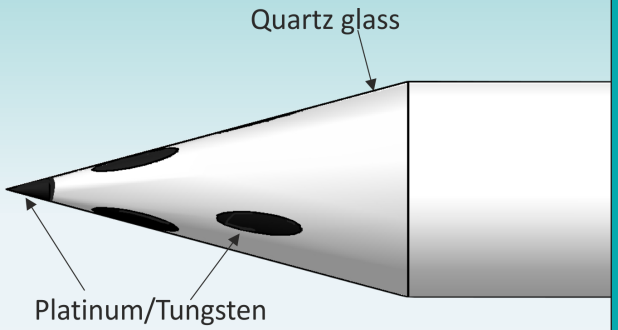
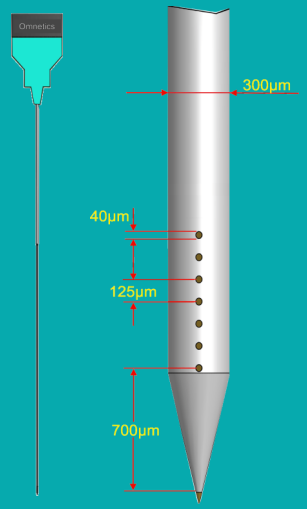


Figure 4: Tip of a quartz glass insulated platinum-tungsten 3D-heptode with ground tip (tip shape D), impedance 1-2MΩ.

Multitrodes

8 Channels



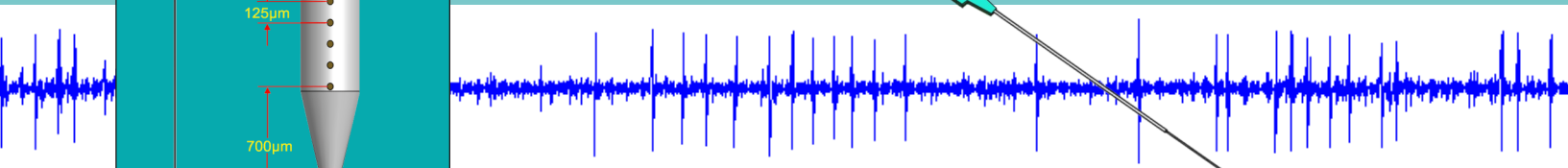
Specifications:

- 8 recording channels
- Shaft diameter 300µm
- Contact diameter 40µm
- Tip contact
- Spacing between 100-250µm
- High stability

Thomas RECORDING ***multitrodes*** are 8-channel linear electrodes for acute extracellular recordings in medium to large animals. The electrode contact diameter is 40µm, the contact spacing can be customized between 100-250µm, the shaft is made of stainless steel and is available in different lengths. An implantable multitrode version is also available.

[6] ***Neuronal Functional Connection Graphs among Multiple Areas of the Rat Somatosensory System during Spontaneous and Evoked Activities***; Zippo, A.G. et al.; PLOS Computational Biol.; June 2013; volume 9; issue 6

[7] ***Efficient generation of reciprocal signals by inhibition***; Park, S.; Tara, E.; Khodakhah, K.; *J. Neurophysiol* 107: 2453–2462, 2012



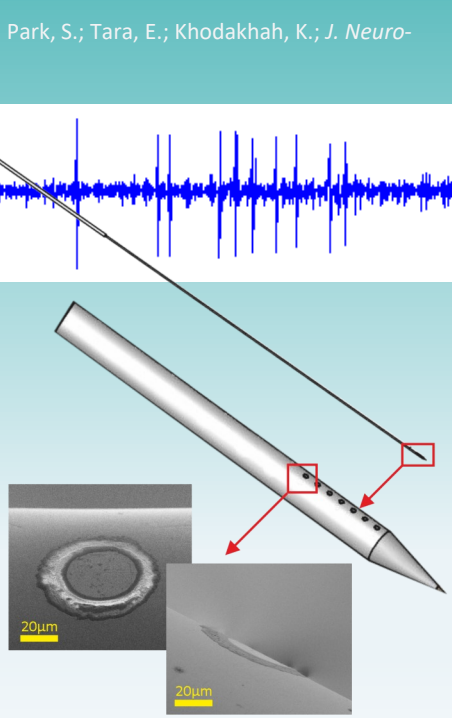


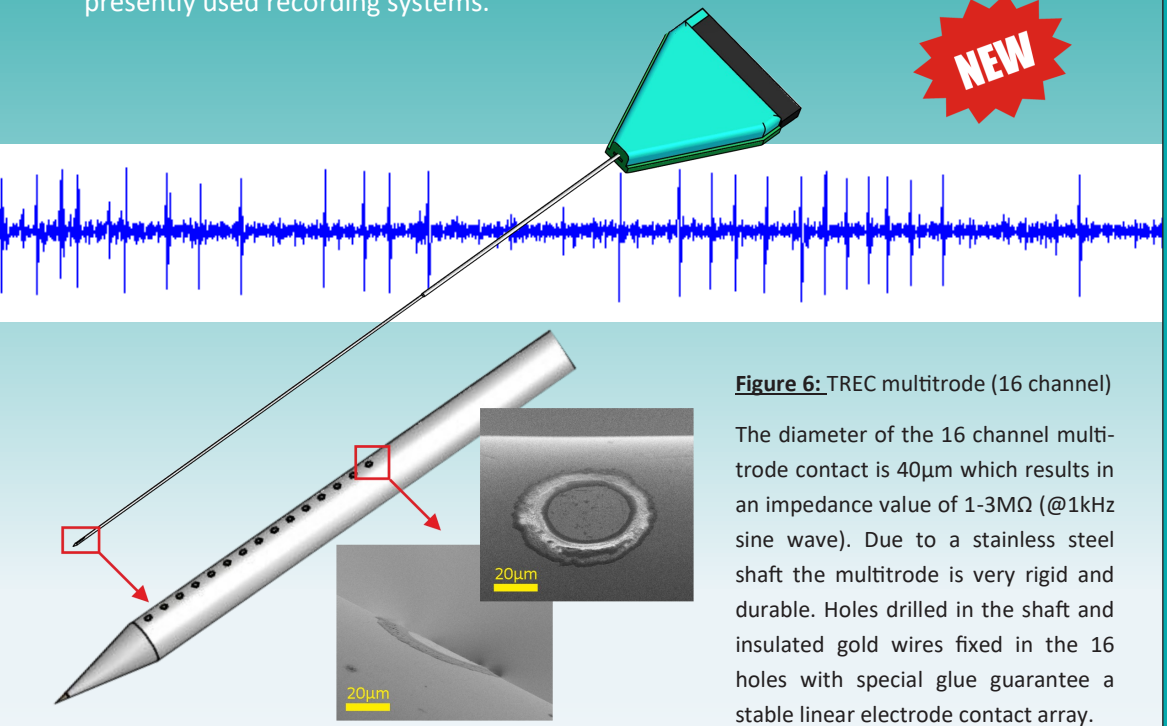
Figure 5: (left side) Two Thomas MEM microdrives (see page 14-15) loaded with Thomas multitrodes.

(right side) Multitrode with 8 channels, SEM photo of one gold contact from top and side, contact spacing 125µm (others on request), Impedance 1-3MΩ

Multitrodes

16 Channels

Thomas RECORDING ***multitrodes*** are also available in a 16-channel linear version for acute extracellular recordings in medium to large animals. The electrode contact diameter is 40µm, the contact spacing can be customized between 100-250µm (standard is 125µm). The shaft is made of stainless steel and is available in different lengths. The connector of the multitrode is customizable and can be adapted to all presently used recording systems.



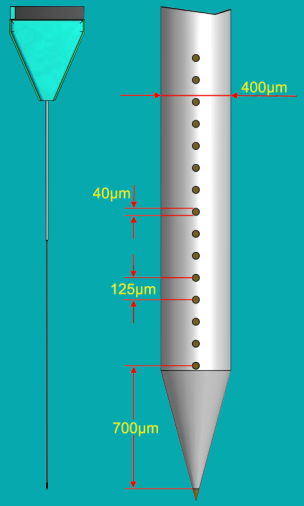


Figure 6: TREC multitrode (16 channel)

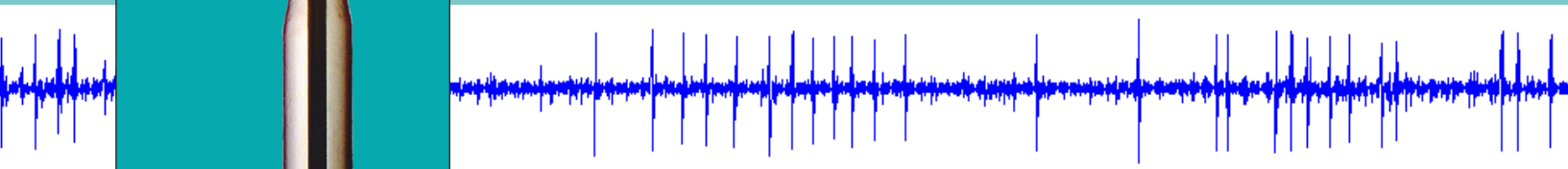
The diameter of the 16 channel multitrode contact is 40µm which results in an impedance value of 1-3MΩ (@1kHz sine wave). Due to a stainless steel shaft the multitrode is very rigid and durable. Holes drilled in the shaft and insulated gold wires fixed in the 16 holes with special glue guarantee a stable linear electrode contact array.

Specifications:

- 16 recording channels
- Shaft diameter 400µm
- Contact diameter 40µm
- Tip contact
- Spacing between 100-250µm
- High stability

Stimulation Electrodes

Thomas RECORDING ***stimulation microelectrodes*** are thin shaft microelectrodes with outer diameters of 80-100µm. The electrodes have a metal core (platinum/ tungsten) and a quartz glass insulation. The metal tip of the stimulation electrodes is coated with iridium oxide (IrOx). Although the electrodes have a very small tip size this IrOx-coating increases the effective metal area of the small sized electrode tip and guarantees a large charge transfer capacity. The small size of the electrodes makes them suitable for stimulation of small brain nuclei. The stimulation electrodes are available in mono– and bipolar versions for acute and chronic applications as well as for Thomas rubber tube microdrive systems (Mini and Eckhorn Matrix). We also provide stimulus generators with stimulus isolation units (SIU).



Specifications:

- Impedance below 100kΩ
- Small tip size
- Mono-/bipolar version
- Implantable versions for chronic stimulation
- Customizable to your needs

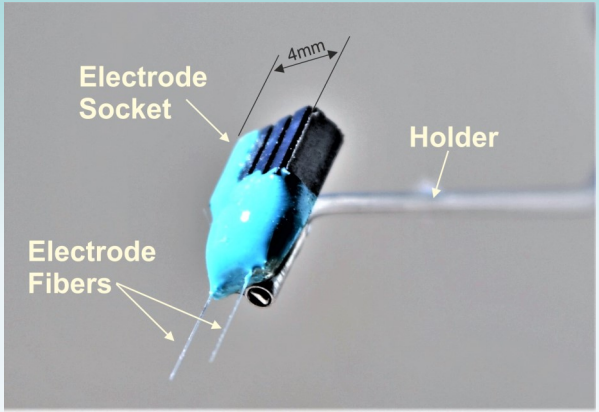
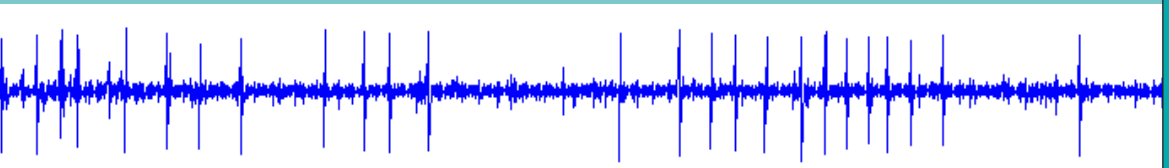


Figure 7: This picture shows an example of an implantable bipolar microelectrode for electrical microstimulation. This electrode consists of two electrode fibers mounted on a pcb with a special holder. This implantation holder allows easy implantation of the electrode. The holder is fixed with TREC water soluble glue! After placing and fixation of the electrode the holder is easily removeable by a drop of water.

Array Electrodes

A Thomas RECORDING handcrafted and customized neural ***electrode array*** consist of two parts, the electrode array and the carrier unit. The electrode array is the interface to the neural tissue and consists of several recording electrodes e.g. single core electrodes, tetrodes (4 cores, shaft diameter 100µm) or heptodes (7 cores, shaft diameter 100µm) and stimulation sites like for example optical stimulation fibers, electrical stimulation electrodes or drug injection cannulas. The carrier unit provides the electrical interface between the electrode array and the preamplifiers and the mechanical interface for mounting the carrier unit to a microdrive system. These arrays are customizable to our customer´s requirements!



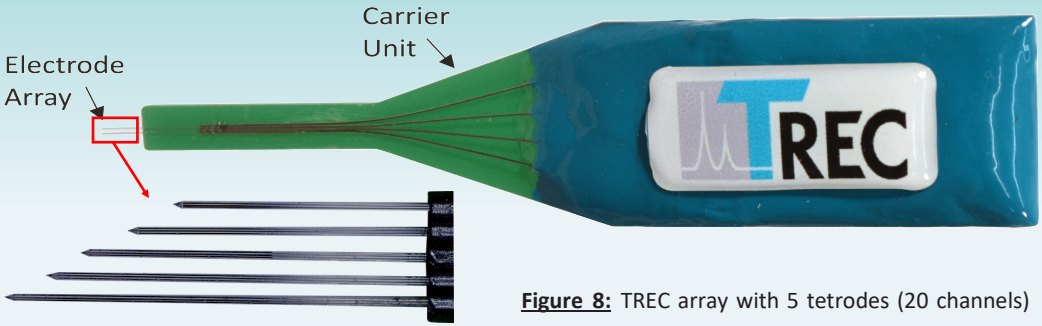
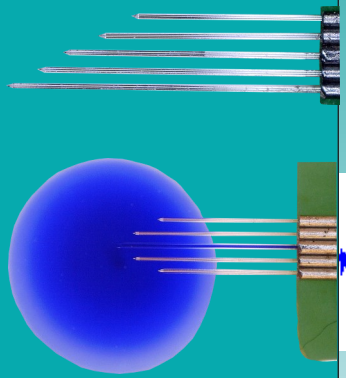
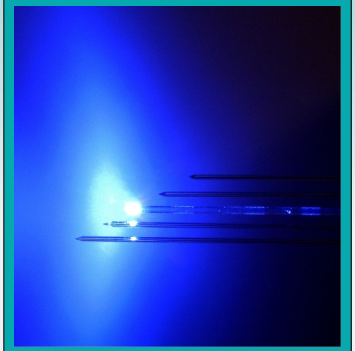
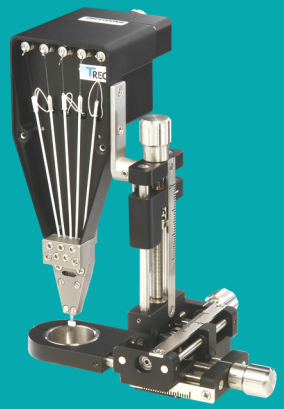


Figure 8: TREC array with 5 tetrodes (20 channels)

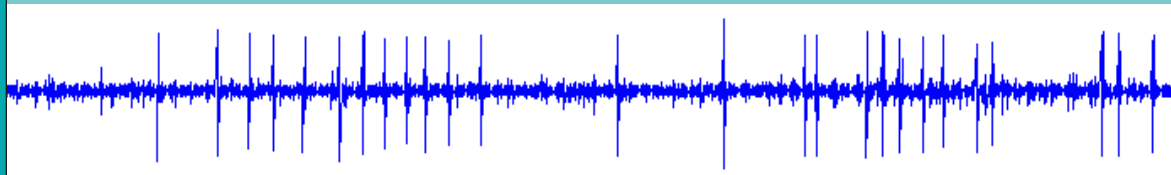




Mini Matrix



The Thomas ***Mini Matrix*** microdrive system drives up to 5 single microelectrodes or tetrodes independently from each other to different depths of the brain. The system is available in a 5 electrode or 5 tetrode version. Each Mini Matrix is equipped with an integrated low-noise preamplifier with 5 or 20 channels. The electrodes are quartz glass insulated platinum-tungsten microelectrodes (see page 2 of this brochure) working with the patented Thomas rubber tube drive (see [8] for details). The rubber tube drive allows a hysteresis free electrode positioning and is working as a damper that reduces movement artifacts. This guarantees neural signal recordings while the electrodes are moving in the brain.



Specifications:

- Electrode version with up to 5 channels
- Tetrode version with up to 20 channels
- Up to 24mm electrode travel
- 1µm resolution
- Complete electrical shielding

[8] Eckhorn R., Thomas U. ***A new method for the insertion of multiple microprobes into neural and muscular tissue, including fiber electrodes, fine wires, needles and microsensors*** Journal of Neuroscience Methods, 49 (1993) 175-179

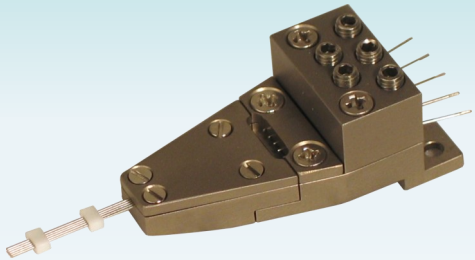
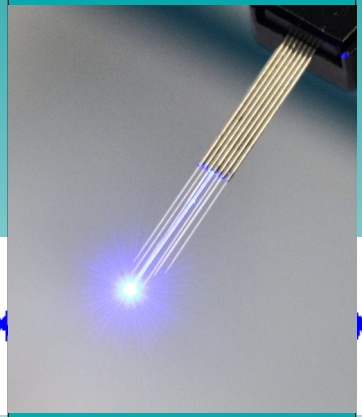
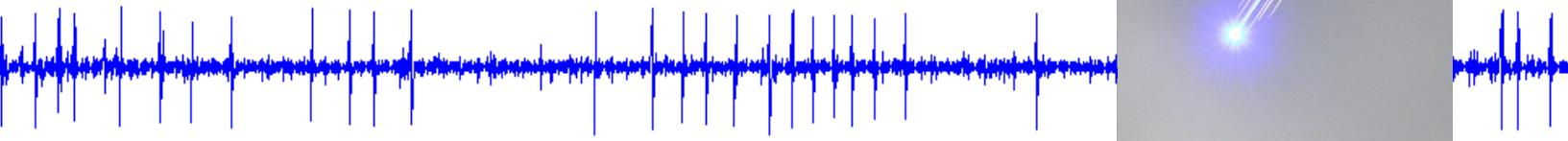


Figure 9: The frontal part of the Mini Matrix (microdrive head) is exchangeable. This picture shows a 5-channel head with linear guide tube arrangement and 305µm guide tube spacing. Other guide tube spacings and arrangements (e.g. concentric) are available on request!

The Thomas microdrive systems ***Eckhorn Matrix*** and ***Mini Matrix*** are able to move fiber microelectrodes with shaft diameters of 80µm-120µm independently from each other to different depths of the brain. Each microdrive is equipped with the patented Thomas rubber tube drive that allows to move the electrode up to 24mm (***Mini Matrix***) or 40mm (***Eckhorn Matrix***). Other electrode travel distances are possible and available on request. The drives can move recording microelectrodes (e.g. single electrodes, tetrodes and heptodes) as well as injection cannulas, optical fibers and microstimulation electrodes with an axial resolution of 1µm and a max. speed of 250µm/s.

Matrix Applications





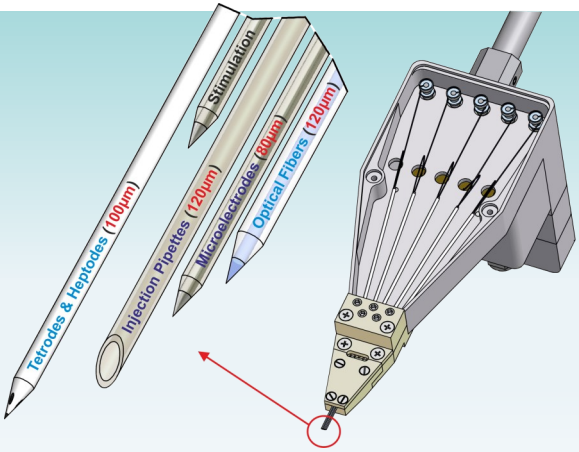
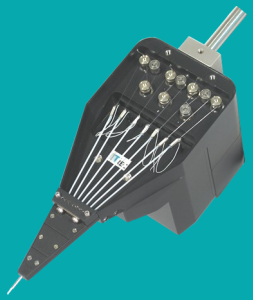


Figure 10: The Thomas microdrives (Mini & Eckhorn Matrix) combine popular neurophysiological techniques (e.g. microinjection, recording, electrical and optical stimulation) in one research instrument. The Matrix systems are able to move fiber electrodes, injection pipette, optical fiber, electrical stimulation electrode independently from each other to different depths of the brain.

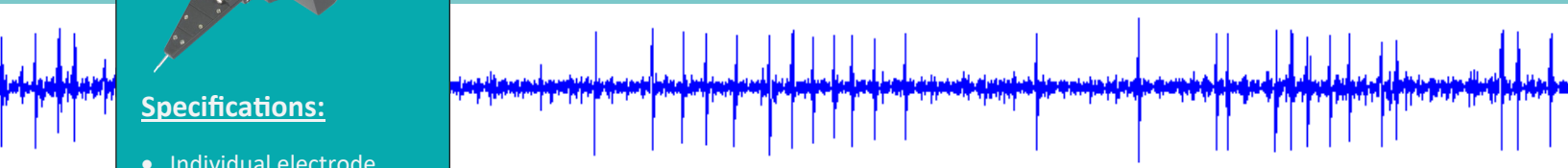
Specifications:

- Extracellular recording with up to 224 recording channels (32 heptodes)
- Optogenetic setup
- Microinjection setup
- Microstimulation setup
- Tetrode (4 Ch) & Heptode (7 Ch) recording

Eckhorn Matrix



Thomas ***Eckhorn Matrix*** systems are using the patented Thomas rubber tube drive (see [8]). These drives are available in a 7-/16-motor version for TREC single electrodes, tetrodes and heptodes with integrated preamplifier (with 7, 16, 28, 49, 64, 112 or 224 signal channels). The rubber tube drive offers a hysteresis free electrode movement. Furthermore, the rubber is working as a damper that minimizes movement artifacts and allows neural signal recording while the electrodes are moving in the brain. The metal chassis of the Eckhorn Matrix works like a Faraday cage that shields electrical interference and increases signal-to-noise ratio of the recorded neural signals.



Specifications:

- Individual electrode positioning via software
- High positioning accuracy (1µm resolution)
- Up to 224 recording channels (32 heptodes)
- No hysteresis!
- Very thin electrodes
- Independently moving

[8] Eckhorn R., Thomas U. ***A new method for the insertion of multiple microprobes into neural and muscular tissue, including fiber electrodes, fine wires, needles and microsensors*** Journal of Neuroscience Methods, 49 (1993) 175-179

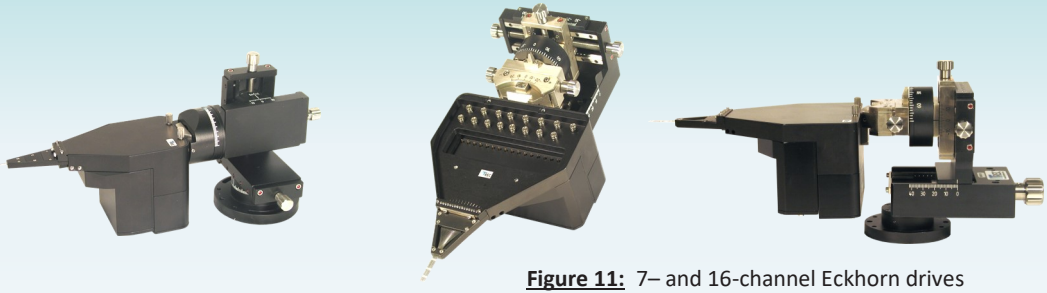
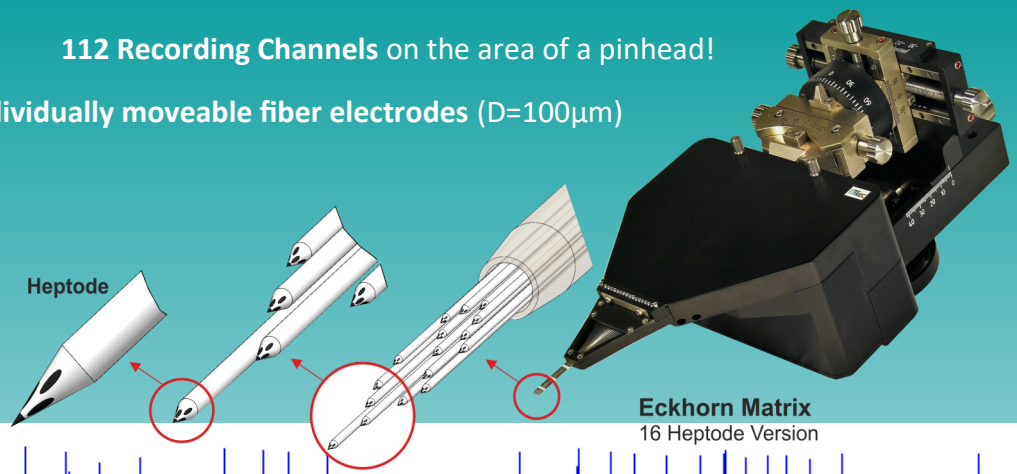


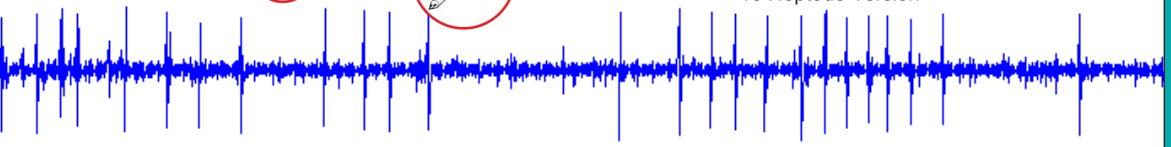
Figure 11: 7– and 16-channel Eckhorn drives

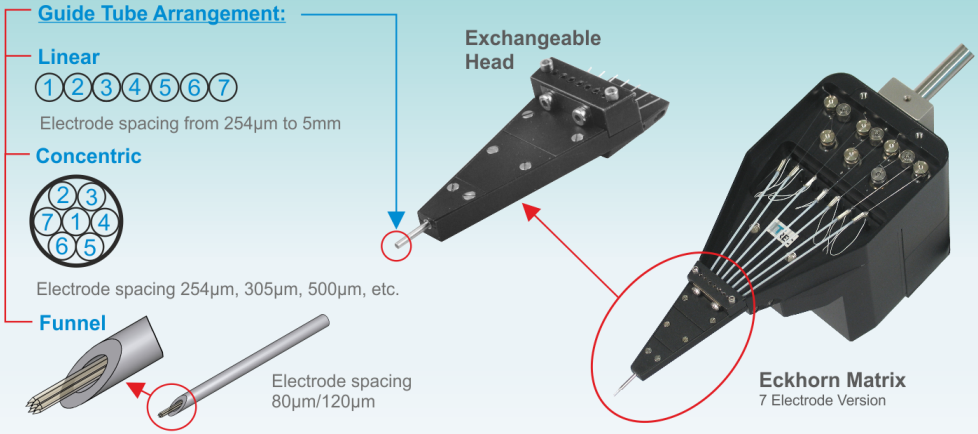
Eckhorn Matrix

112 Recording Channels on the area of a pinhead!

Individually moveable fiber electrodes (D=100µm)



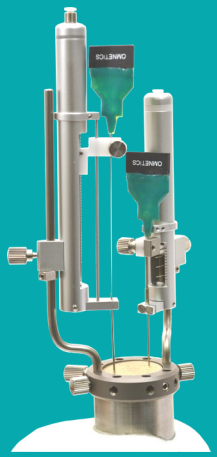




Specifications:

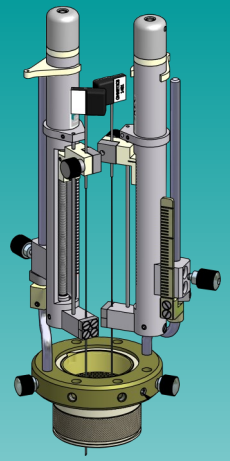
- Up to 32 fiber electrodes
- Individually moveable
- Thin electrode fibers (80 - 100µm)
- Minimal tissue damage
- High precision positioning (no hysteresis)
- Recording while fiber electrode is moving!

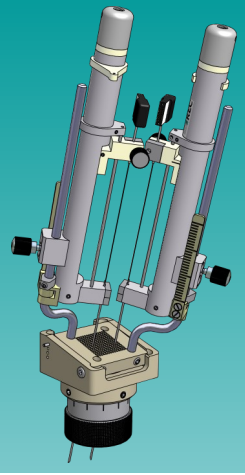
MEM

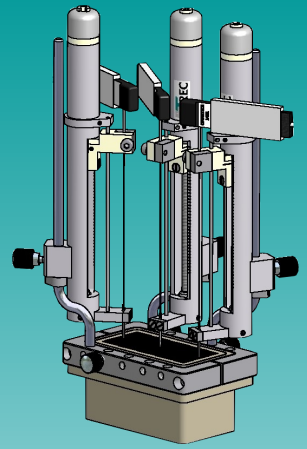


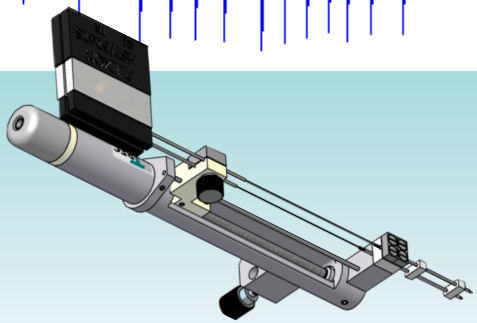
Specifications:

- Useable with many different probes (e.g. Plexon S-, U-, V-probe, TREC Multitrode, etc.)
- Customized to your application
- Networkable motor control unit









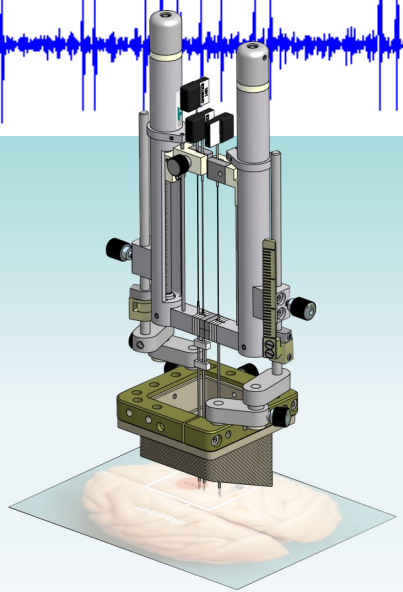
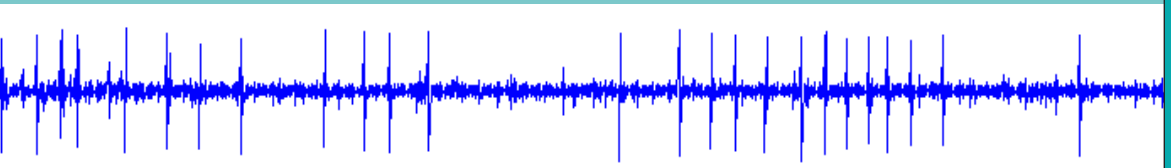


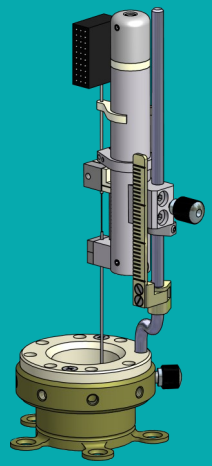
Figure 12: (above) Dual probe MEM; (right side) Two MEM with optional joint chamber holders mounted to a squared recording chamber. The left MEM is able to move two probes simultaneously while the right MEM is a single probe drive

MEM

The Thomas **M**otorized **E**lectrode **M**anipulator (MEM) was developed to drive linear electrodes like the Thomas multitrode or the Plexon S-, U- or V-probe. This system is available with two different electrode travel distances of 10mm for cortical and 40mm for cortical and deep brain recordings. Adapters for mounting the devices on primate recording chambers or small animal stereotaxic instruments are available.

„...The MEM works wonderfully to advance the U-probe and secures the probe in place very nicely. It is easy to load and convenient to attach to the rig on a daily basis...Overall, we are extremely satisfied with the MEM for use with the U-probe…“ Prof. Dr. Farran Briggs, Department of Physiology and Neurobiology, Geisel School of Medicine at Dartmouth





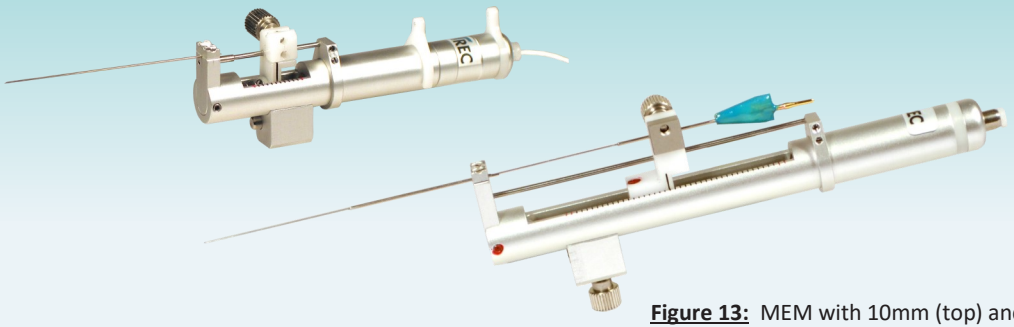


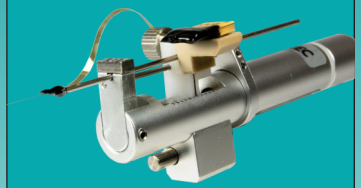
Figure 13: MEM with 10mm (top) and 40mm (bottom) electrode travel

Specifications:

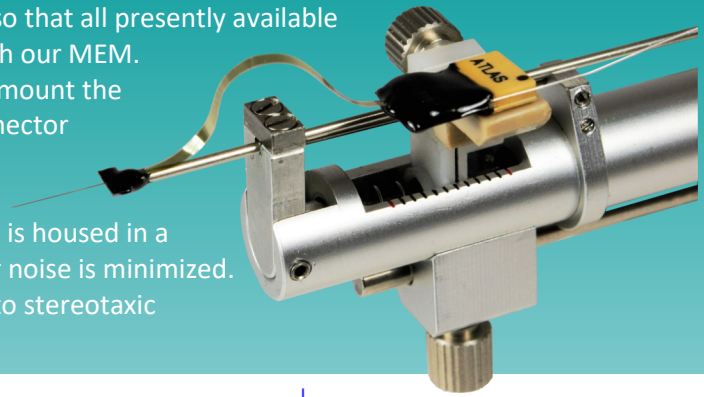
- 10 or 40mm electrode travel
- High precision drive
- Easy to use
- Complete with motor control unit and software

MEM

for silicon probes

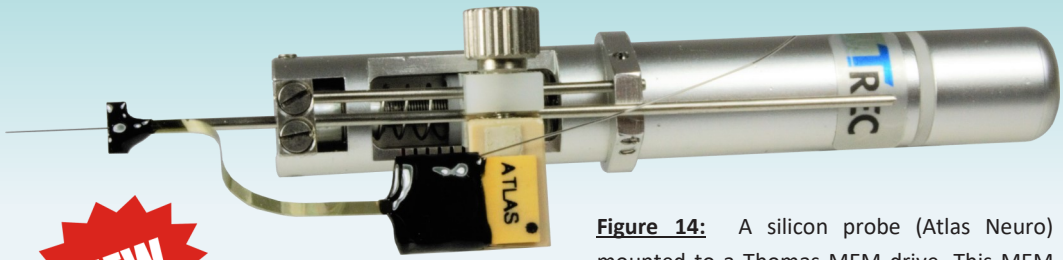


Thomas ***MEM*** drives are able to move silicon probes with high positioning accuracy. We can customize our drives so that all presently available silicon probes can be used with our MEM. Beside the probe we can also mount the headstage and the probe connector to the MEM so that both are moved together with the probe. As the MEM motor is housed in a metal cabinet electrical motor noise is minimized. Adapters to mount the MEM to stereotaxic instruments are available.



Specifications:

- Useable with all kinds of silicon probes
- Customizable
- Moves silicon probes with high precision
- Adapters for silicon probe headstages
- 10mm electrode travel distance (other travel distances are available)
- Adapters available to mount the MEM to stereotaxic instruments

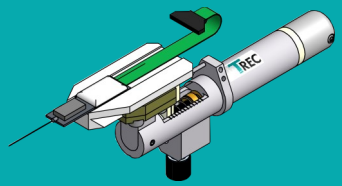


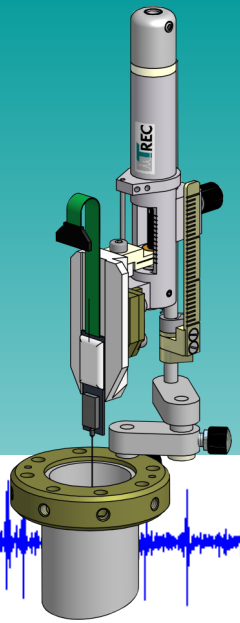
NEW

Figure 14: A silicon probe (Atlas Neuro) mounted to a Thomas MEM drive. This MEM has an electrode travel distance of 10mm.

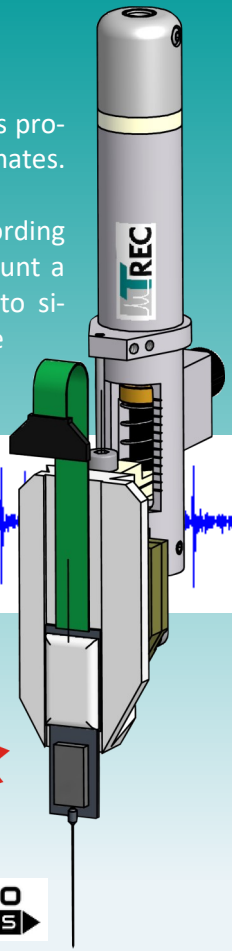
MEM

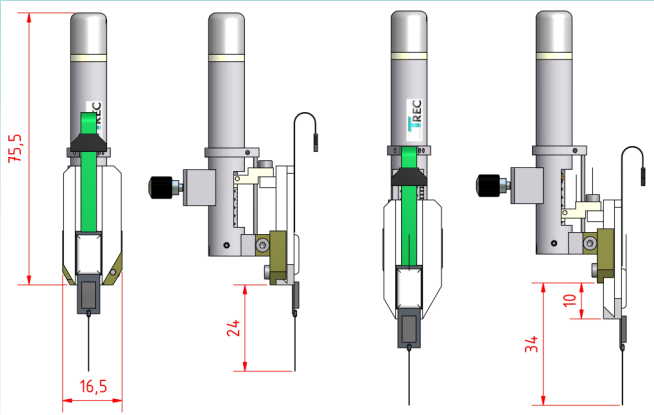
for Neuropixels probes





Thomas ***MEM*** drives are adapted to move the ***Neuropixels*** microelectrodes with high accurary. The MEM can be adapted to use the Neuropixels probes in small animals as well as non-human primates. The picture on the left side shows a MEM with a ***Neuropixels*** probe mounted to a primate recording chamber. Beside the probe it is possible to mount a multichannel headstage to the MEM allowing to simultaneously move the probe and the headstage (no relative movements between headstage and probe).





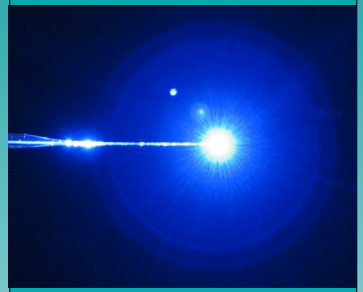
NEW

Figure 15: Neuropixels probe loaded to TREC MEM with 10mm electrode travel

Specifications:

- Adapted to Neuropixels probes
- 10 mm electrode travel (others on request)
- High precision drive
- Easy to use
- Complete with motor control unit and software
- Adapter for headstage available

Optogenetics

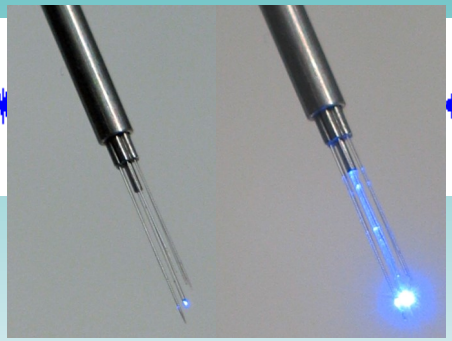


Thomas RECORDING offers complete **equipment for optogenetic experiments** like optical fibers, optrodes, optetrodes, opheptodes, LED light sources, light source controllers and stimulation-software as well as integrated solutions for our multielectrode microdrive systems. The microdrive solutions include optical stimulation via thin and movable optical fibers and simultaneous recording of the neural response with individual and independently moveable microelectrodes (see [9]).

[9] Kruse, W; Krause, M; Aarse, J; Mark, MD; Manahan-Vaughan, D; Herlitze S; **Optogenetic modulation and multi-electrode analysis of cerebellar networks in vivo;** PLoS One; 2014 Aug 21; doi: 10.1371/journal.pone.0105589. eCollection 2014.

Specifications:

- Optical fiber OD=120µm
- Optrodes, optetrodes, opheptodes
- LED Light sources
- Light source controllers
- Microdrive solutions
- Customized optrodes



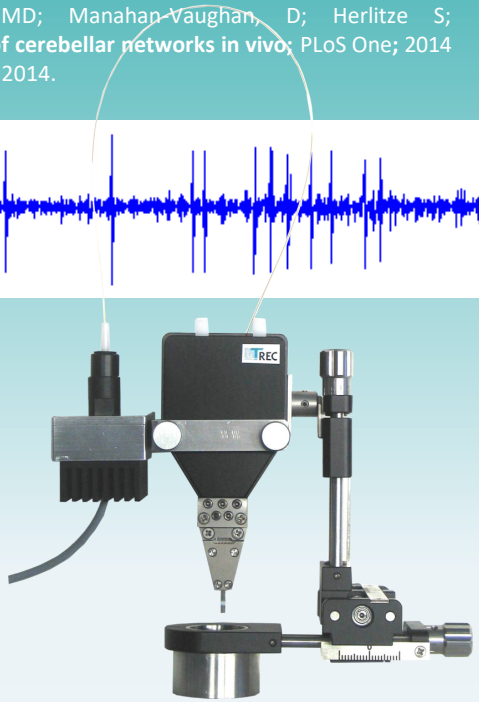


Figure 16: (Top) TREC microdrive guide tubes with one optical fiber in the center and 6 recording micro-electrodes arranged around the center optical fiber. Stimulation with the fiber, recording of the neural response with the electrodes. Electrodes and optical fiber are independently moveable by the microdrive (see right picture and [9]).

Micro-Injection

The Thomas microinjection system MIS-03 is available as a stand-alone device or as an extension of our multielectrode recording systems (Mini or Eckhorn Matrix Systems). In the Mini or Eckhorn Matrix application the system combines an injection pipette with multiple parallel-oriented recording electrodes at defined distances in a customizable arrangement (details see [10]). Electrodes and pipette are independently moveable to different depth of the brain. The injected drug volume is controlled by software.

[10] Vera K. Veith, Cliodhna Quigley and Stefan Treue; ***A Pressure Injection System for Investigating the Neuropharmacology of Information Processing in Awake*** Behaving Macaque Monkey Cortex; J Vis Exp. 2016; (109): 53724; Published online 2016 Mar 14; doi: 10.3791/53724; PMCID: PMC4828981

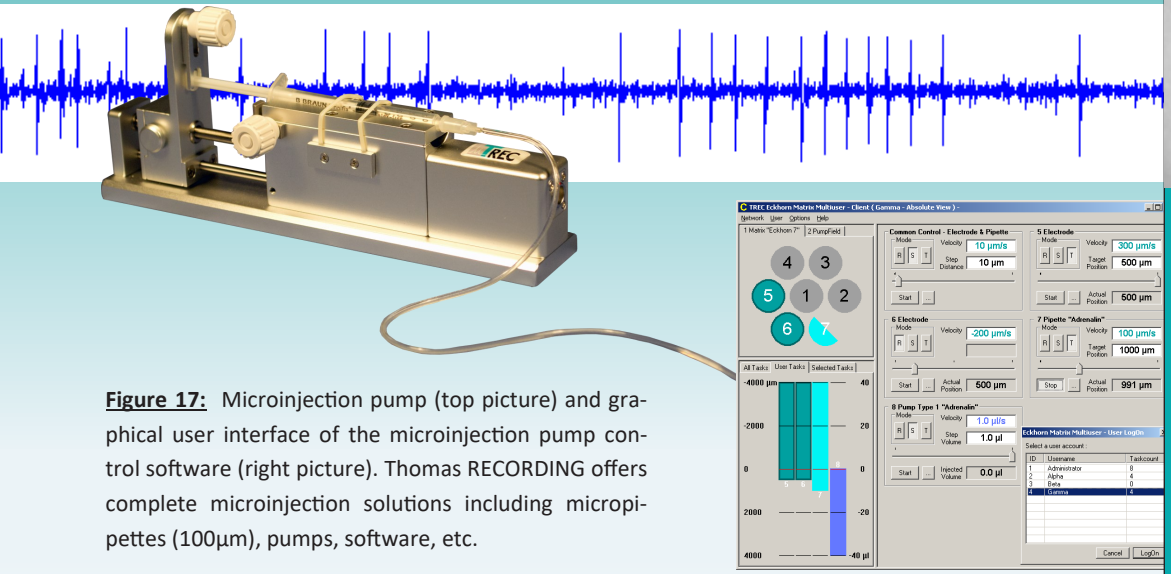
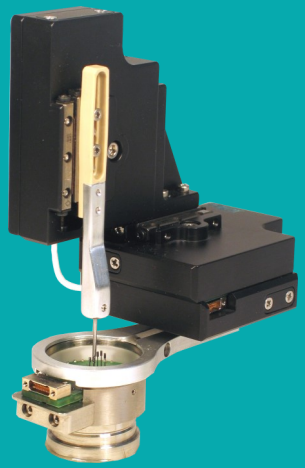


Figure 17: Microinjection pump (top picture) and graphical user interface of the microinjection pump control software (right picture). Thomas RECORDING offers complete microinjection solutions including micropipettes (100µm), pumps, software, etc.

Specifications:

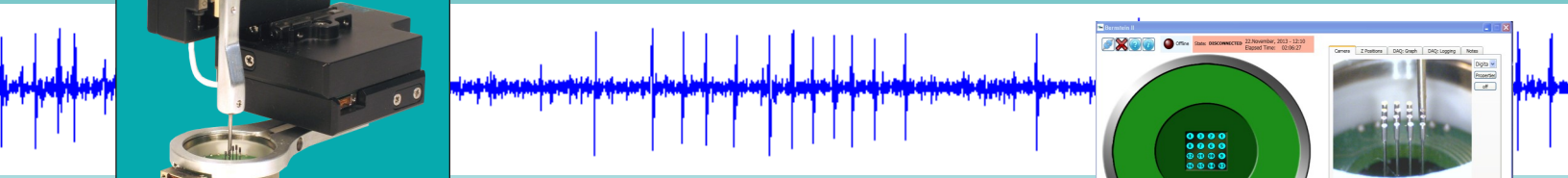
- Software controlled pressure injection
- Complete solution
- Micropipettes
- Pumps

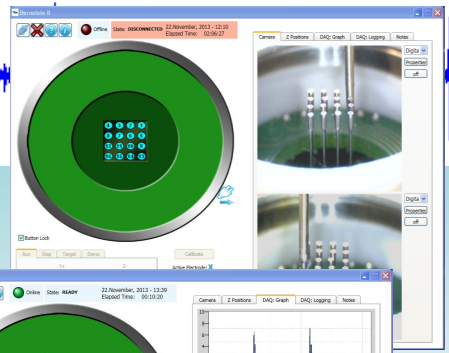
Primate Recording



The Thomas **A**daptive **M**ulti**E**lectrode **P**ositioning (AMEP) System was developed for chronic extracellular recordings with up to 16 individual and bidirectionally moveable microelectrodes in awake behaving non-human primates. The system consists of a special designed implantable recording chamber, a chamber insert loaded with up to 16 microelectrodes, a motorized robot for bidirectional electrode movement, a motor control unit for the robot, a dual camera system, a motor control software, pre– and main-amplifiers and a data acquisition system (details see [11]).

[11] Ferrea E, Suriya-Arunroj L, Hoehl D, Thomas U, Gail A (2018) Implantable *computer-controlled adaptive multi-electrode positioning system (AMEP).* Journal of Neurophysiology 119(4): 1471-1484)





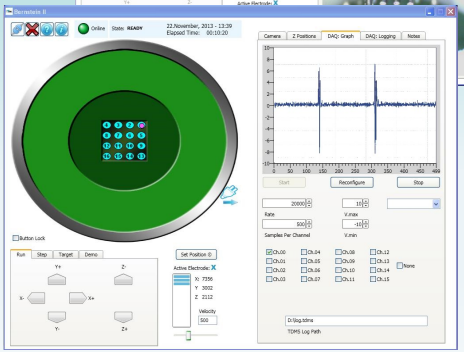


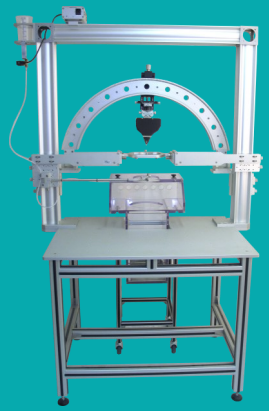
Figure 18: AMEP recording chamber insert (left) with up to 16 electrodes. The electrodes are moveable up and down by using the motorized xyz-manipulator. This manipulator is software controlled (right pictures show the software gui)

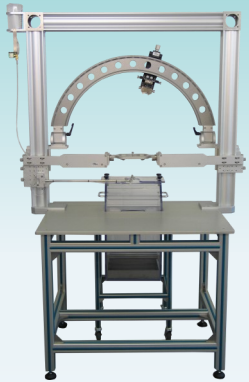
Specifications:

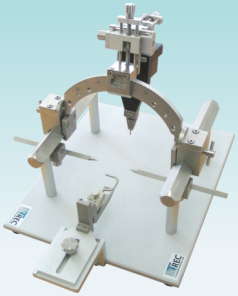
- 16 microelectrodes
- Bidirectionally moveable
- Semi-chronic recording
- Software controlled
- Wireless headstage optional available

Stereotaxy

Thomas RECORDING offers a broad range of stereotaxic instruments for neurophysiological applications. The primate stereotaxic system (PPS) is a complete system consisting of a robust table with a strong frame, a curved guided rail (round arch) for mounting different instruments, a unique three-point head holder, a primate chair with trolley and a computer-controlled reward unit. The system is modular so that it is easily adaptable to the individual customer´s requirements. Our small animal stereotaxic instruments (SASI) offer the Thomas specific unique round arch design that we have originally developed for our primate stereotaxy.







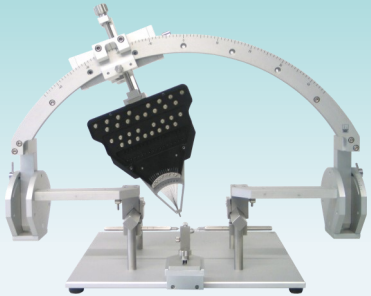


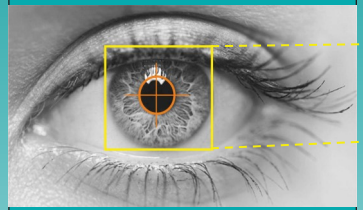
Figure 19: Thomas stereotaxic instruments: primate PPS (left), small animal with Mini Matrix (middle), small animal with Eckhorn Matrix (right)

Specifications:

- Customized design
- Modular systems
- For primates and small animals
- Stable & robust systems

Eye Tracking

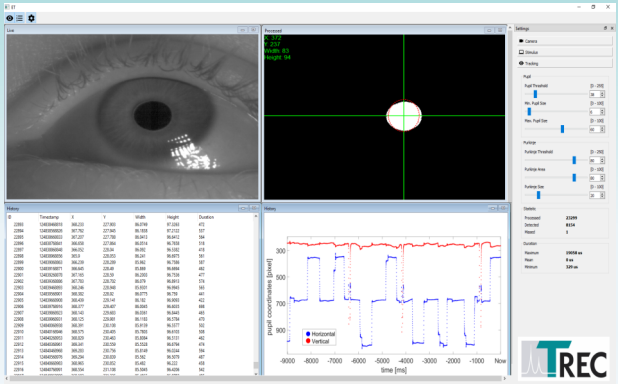
stationary



The video-camera based eye tracking system ***Thomas Oculus Motus (TOM) research stationary*** is available in a 1000Hz (800x400px) and 2000Hz (640x200px) version. The TOM system software is running under MS Windows, Linux and Macintosh operating systems. The TOM research stationary system can be operated plug-and-play via USB on a notebook and is therefore easy to install and mobile between measurements. The TOM ET-series is accurate and reliable, the system utilizes special algorithms for efficient operation and superior results. The zoom lens and the freely adjustable image section provide optimal conditions to detect even the smallest eye movements.

Specifications:

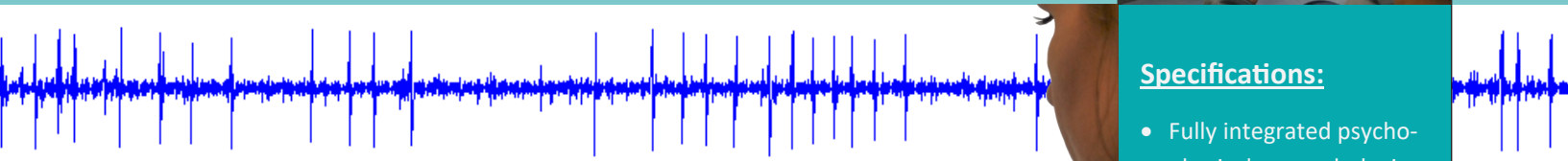
- 1000/2000Hz System
- Spatial resolution <0.01°
- Accuracy app. 0.5°
- Working distance 25-300cm
- XY-range gaze: app. 30°
- IR-Illumination unit
- Software package for Windows, Linux and Mac
- LAN-interface to stimulus computer system
- Analog output



Eye Tracking

mobile

The ***TOM research mobile*** system is the world´s smallest, fully integrated visual stimulation eye-tracking device for psychophysical experiments. The device presents customized stimuli and operates the eye-tracking application simultaneously. Raw data is stored and can be analyzed offline with customized tools (e.g. Mathlab, scipy, etc.). The TOM research mobile system is mobile and records head–unrestrained eye movements in almost any environment. The integrated display and speakers can be used for easy stimulus presentation with just one click. The versatile mounting mechanism of the lightweight system (just 464g) allows for a safe and natural use with low compliance demands.



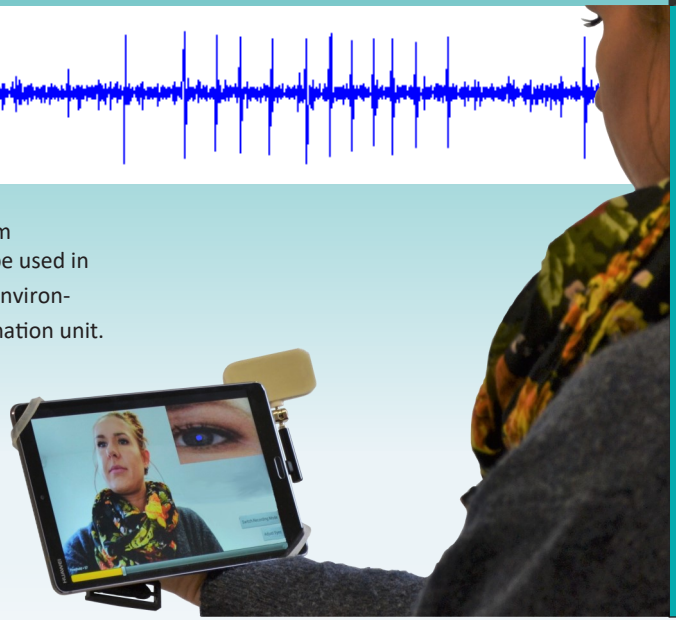


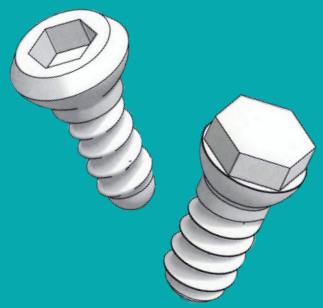
Figure 20: TOM research mobile system
The TOM research mobile system can be used in almost any environment. For dimly lit environments, it is equipped with a USB illumination unit.

NEW

Specifications:

- Fully integrated psychophysical research device
- Time synchronized recording of eye videos and stimulus events
- Fully customizable stimuli
- Easy handling and low compliance
- Versatile mounting mechanism for natural use

Ceramic Screws

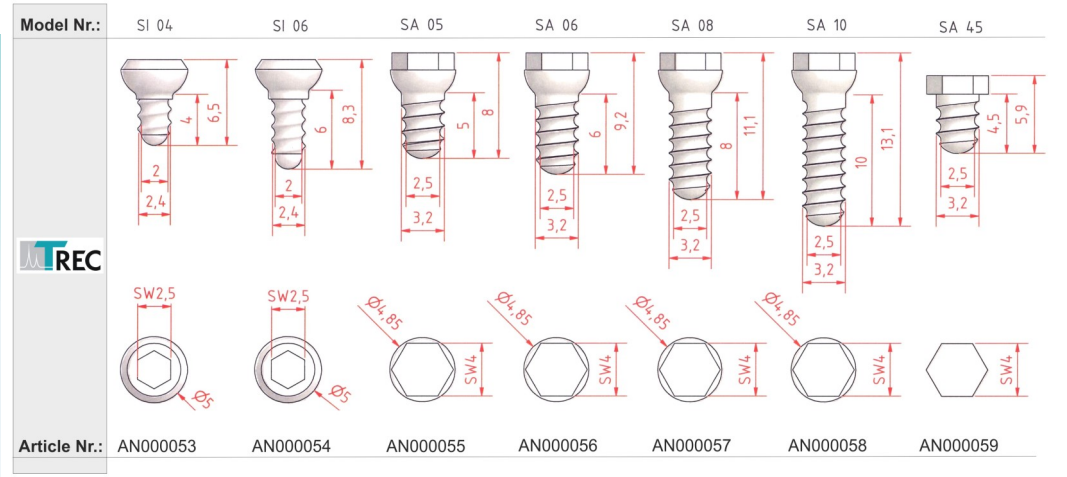


The Thomas RECORDING ***ceramic screws*** were developed and initially used by Prof. Dr. Nikos Logothetis at the Max-Planck-Institute for Biological Cybernetics in Tuebingen, Germany [12]. The ceramic screws were tested on MR quality control phantoms and were found to have no effects on the homogeneity of the B0 field of the magnet [12]. In addition, the material was chosen to be tissue compatible and are surface roughened to optimize the bone and skin implant interface [12]. Thomas RECORDING is proud to be the worldwide sole distributor of these high-quality ceramic screws.

[12] Logothetis N., Guggenberger H., Peled S., Pauls J., ***Functional imaging of the monkey brain.*** nature neuroscience, vol. 2 no. 6, June 1999

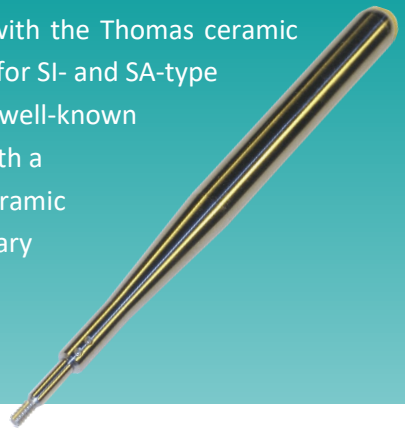
Specifications:

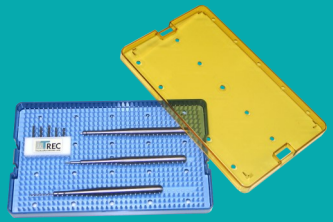
- MRI compatible
- Biocompatible
- Different sizes available
- Tools available



Ceramic Screw Tools

Thomas RECORDING offers all required ***tools*** for use with the Thomas ceramic screws. The tools are available in two different toolsets for SI- and SA-type ceramic screws. These tools are manufactured with the well-known quality „Made in Germany“. Each toolset is delivered with a sterilization tray for easy sterilization before use. The ceramic screws are no self-tapping screws, therefore it is necessary to have a drill and a tap, both adapted to the special thread of the ceramic screws which is different from metal bone screws!





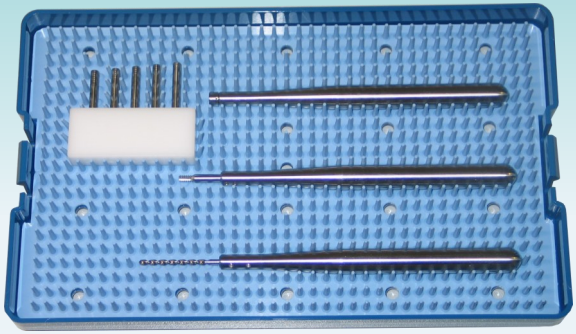


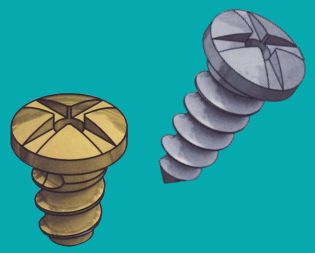
Figure 21: Set of ceramic screw tools

The toolset for SI– or SA– ceramic screws consists of one drill adapted to the core diameter of the ceramic screw, one distant tube set for defined drill depth, one tap because the ceramic screws are no self-tapping screws and a screw driver. The sterilizable tools are delivered in a sterilization tray.

Specifications:

- Toolsets for SI– and SA-type ceramic screws available
- Tools are adapted to the screw thread of the ceramic screws which is different from metal bone screws!
- Tools are sterilizable

Titanium Bone Screws



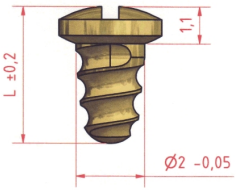
The Thomas RECORDING ***bone screws*** are manufactured from high quality titanium. The titanium screws are self-fitting screws which realizes a faster and easier handling of the screws as the use of an expensive screw driver with a holding device is not necessary. Thomas RECORDING offers a low-cost cross-head screw driver blade with self-fitting features.

Self-fitting

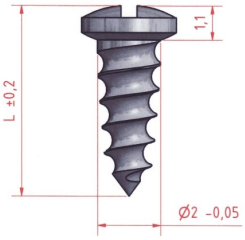
Self-fitting and self-drilling

Specifications:

- Biocompatible
- Different sizes available
- Tools available



Screw dimension (diameter=2mm x length) L=length
2 x 4mm
2 x 5mm
2 x 6mm
2 x 7mm
2 x 8mm
2 x 9mm
2 x 10mm
2 x 11mm
2 x 12mm
2 x 13mm
2 x 14mm
2 x 15mm
2 x 16mm



Screw dimension (diameter=2mm x length) L=length
2 x 4mm
2 x 5mm
2 x 6mm
2 x 7mm
2 x 8mm
2 x 9mm
2 x 10mm
2 x 11mm
2 x 12mm
2 x 13mm
2 x 14mm
2 x 15mm
2 x 16mm

Recording Chambers

Thomas RECORDING has a long tradition in design and manufacture of implantable ***primate recording chambers***. Our standard round recording chambers are angled at "0" degrees. Angled recording chambers can be custom designed to the degree you specify. We offer different materials like **stainless steel** (well suited when strength and durability are required), **titanium** (a strong, hard and lightweight material which is very tissue compatible) or **PEEK** (a strong and hard plastic material which is very biocompatible and well suited if MRI compatibility is required). Beside the standard circular chamber, we offer different customized chamber sizes and shapes. Our experienced team is looking forward to find the optimal solution for you!

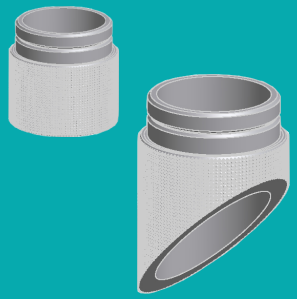


Figure 22: Different recording chamber designs

Specifications:

- Different materials (stainless steel, titanium, PEEK)
- Different chamber sizes
- Different chamber designs
- Customized chambers available

Thomas Cylinder Test System

The Thomas ***cylinder test system*** is a new fully integrated device for the automatic measurement and fast analysis of the classical "Schallert cylinder test", typically used for investigating the exploratory and motor behavior of rodents or marmoset monkeys. Due to its highly sensitive surface, it will recognize and store every interaction of the animal (e.g. rearing, vertical progression, nose pokes, etc.) automatically on the connected PC. A time synchronized observation video will allow for a combination of these quantitative data with the qualitative behavior at any time.

Specifications:

- Automatic Schallert cylinder test
- Simultaneous tracking of 10 surface contacts
- High spatial resolution (300µm)
- High temporal resolution (200Hz)

Figure 23: Thomas cylinder test setup. This system will highly increase the quality of the experimental data and the speed for analyzing them, since experimenters are not required to perform a qualitative frame-by-frame analysis of the video recorded.

Rodent InCage Training System

The ***Rodent InCage Training System (R-ICTS)*** is a new light-weight, flexible and fully integrated cage mountable system for the training of behavioral and cognitive tasks, enrichment or surveillance directly in the rodents' home cage. It can be mounted on every Eurostandard IV cage (other cage sizes on request) with low effort and can be operated for more than 24 hours non-stop. A set of predefined cognitive standard paradigms and the ability to fully customize own stimuli and parameters recorded meets the requirements of all scientists and their individual research questions. After setup the system works independently and without any human supervision until a defined endpoint is reached. During that, the current training status can be viewed via the optional remote access from any permitted computer.

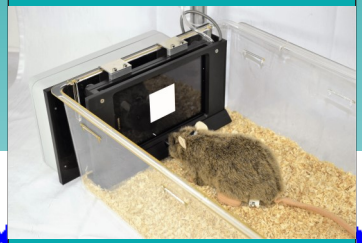


Figure 24: R-ICTS Setup

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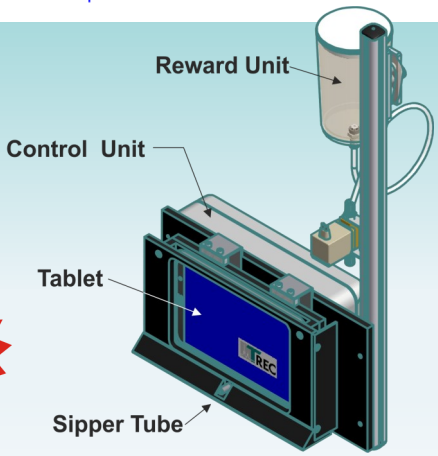
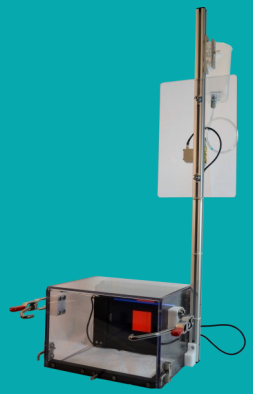


Specifications:

- Rugged tablet computer (IP68 certified)
- Fully integrated liquid reward unit
- Networkable system
- Fully customizable stimuli
- Remote access from any computer via wifi

Primate InCage Training System



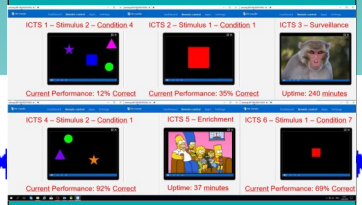
To optimize the training of awake NHPs on cognitive tasks Thomas RECORDING offers an ***InCage Training System (ICTS)***. The ICTS is a flexible, light-weight, fully-automatic device for the training of behavioral and cognitive paradigms and enrichment of NHPs in their home cages instead of the classic primate chair restraint training environment. The new training system provides a comfortable training environment that reduces stress, improves the animal´s well-being, increases the speed of training and the animal´s performance. The ICTS displays predefined training stimuli (e.g. a change detection task or a match-to-sample task) on the touch screen and allows the animal to give feedback in order to receive a liquid reward via the integrated reward unit.

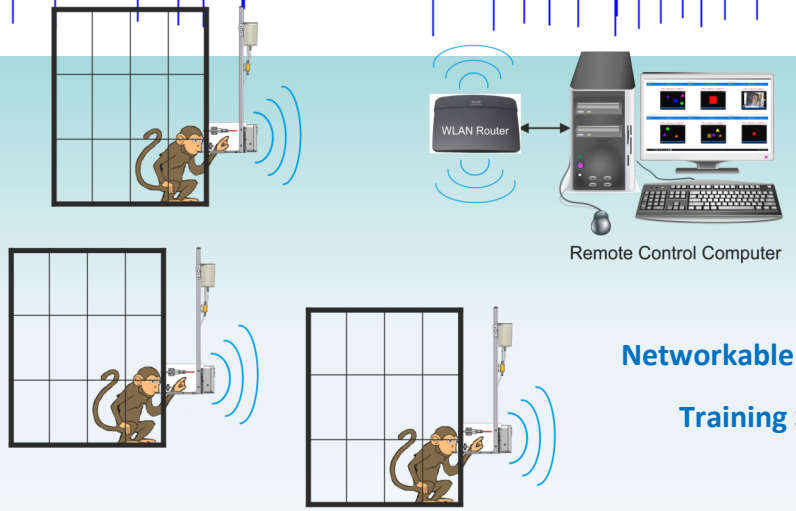
Specifications:

- Cage mountable
- Fully integrated portable system
- Small and lightweight
- No human interference
- No NHP restraining
- Water and dirt protected
- Integrated eye tracking

Networkable Training Systems

Although the Thomas ***InCage Training System (ICTS)*** for non-human primates is designed as a stand-alone system that requires no external cables it is possible to connect the ICTS control unit via LAN or WLAN connection to a remote computer system. This remote computer system normally is located within the research facility but outside of the room housing the NHPs. This concept allows to monitor and control the training of the behavioral paradigm from the local remote-control computer. Furthermore, the tablet sends the NHPs training results back to the remote computer.



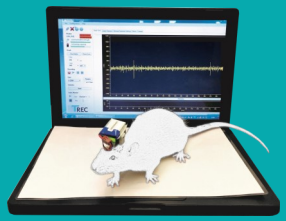


Networkable Training System

Specifications:

- Several ICTS units are operated in a wireless network
- Training results are available on host computer screen
- Training of each primate is monitored and controlled from one computer

Wireless Rec/Stim System



The ***Thomas Wireless System (TWS)*** is the only complete solution for wireless multi-channel recording, stimulation and data analysis for neurophysiological applications with freely moving animals. Beside the wireless device we also offer customized implantable recording microelectrodes and tetrodes as well as stimulation electrodes for different neurophysiological applications. For analyzing the recorded multi-unit activity our Thomas Spike Sorter is available. One important feature of the Thomas Wireless System is the amplification and digitalization of the data on the headstage, so that only digital data is sent to the transceiver, which ensures that your data is not distorted (details see [13]).

Specifications:

- 4 recording channels
- 1 stimulation channel
- Electrodes/Tetrodes included
- Operating distance 5m
- Software controlled recording & stimulation
- Small & lightweight

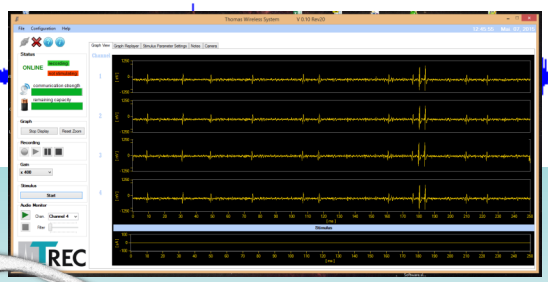


Figure 26: TWS software graphical user interface

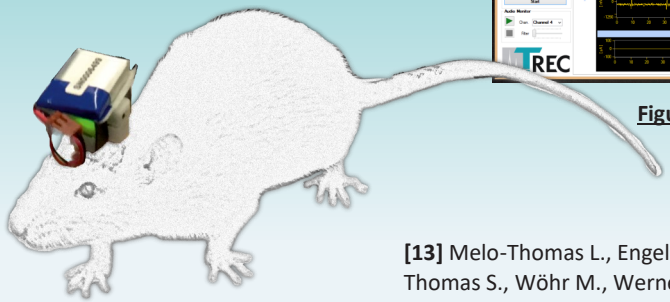
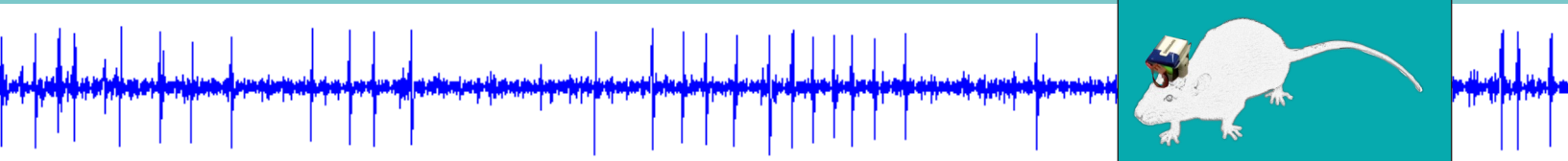


Figure 25: Thomas Wireless System (TWS) mounted on the skull of a rat.

[13] Melo-Thomas L., Engelhardt A., Thomas U., Hoehl D., Thomas S., Wöhr M., Werner B., Bremmer F., Schwarting R. *A Wireless, **Bidirectional Interface for In Vivo Recording and Stimulation of Neural Activity in Freely Behaving Rats*** J. Vis. Exp. (129), 2017, e56299, DOI: 10.3791/56299

Wireless Dual Stimulator

The ***Thomas Dual Stimulator (TDS)*** system allows neuroscientists to generate and upload two separately customizable waveform patterns to an electrical stimulator headstage. The TDS supplies stimulation patterns in real time via wireless digital communication with a transceiver connected to a computer USB port. We also offer customized implantable stimulation microelectrodes with different impedance ranges and charge transfer capacities. Each complete TDS system is comprised of a dual channel stimulator headstage with external battery pack and all necessary accessories, including the TDS control software running under MS Windows operating system.



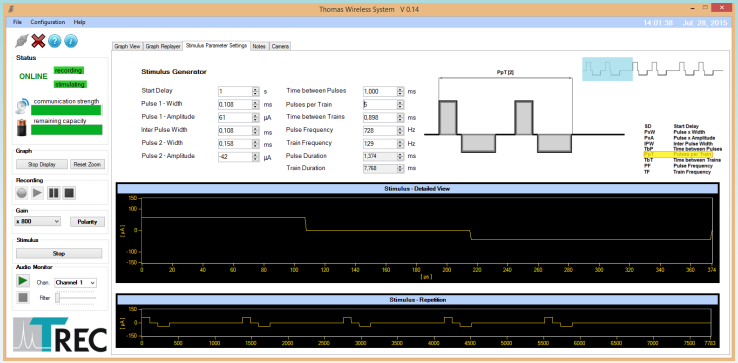


Figure 27: Graphical user interface (gui) of the dual channel Thomas Wireless Stimulator (TDS). This software allows to supply stimulation patterns in real time via wireless digital communication to the freely moving animal

Specifications:

- Two Channels
- Stimulation current up to +/-625µA per channel
- Mono- & biphasic

Data Acquisition System

The ***Thomas Data Acquisition System (DAS)*** is a 16-channel recording system with USB interface (more channels are available on request!). With our USB data acquisition system, you are free to run your experiment on any desktop PC or laptop. The USB Data acquisition system consist of an interface device that is connected to a main amplifier signal output and to a USB socket of a personal computer and a data acquisition software running under MS Windows© operating system. If a Thomas programmable gain main amplifier is used to amplify neural signals, it is possible to set the amplifier gain values per channel via the graphical user interface of the data acquisition software.

Specifications:

- 16 Channels
- USB Interface
- 16bit resolution
- Sampling rate per channel is 31kHz
- Input voltage ±10V

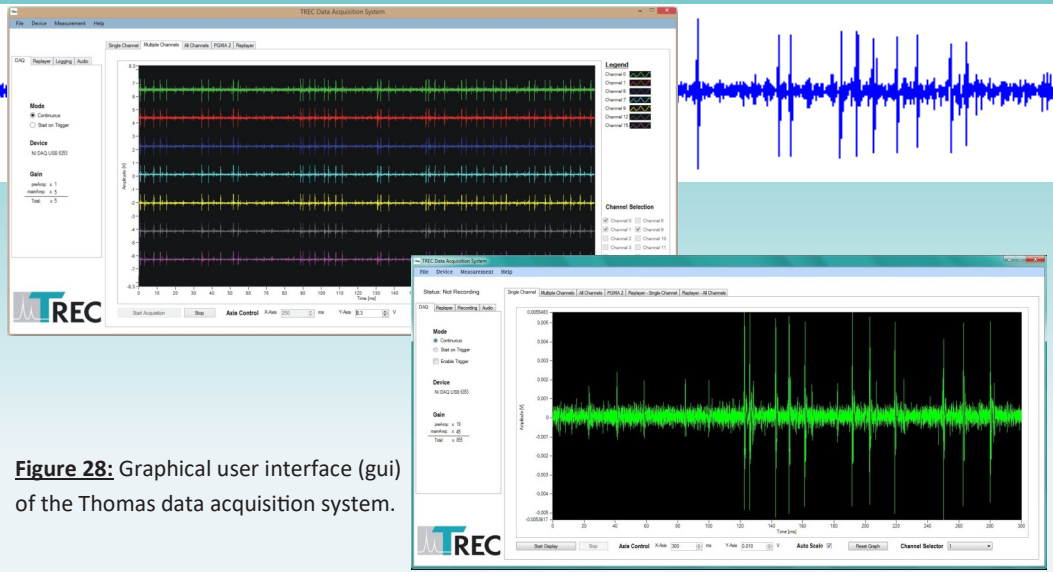


Figure 28: Graphical user interface (gui) of the Thomas data acquisition system.

Audio Monitor

The ***TREC audio monitor*** has an integrated bandpass main amplifier (gain: x50...x5000, bandpass: 500Hz...10kHz). This allows to connect the audio monitor directly to the analog signal output of recording system headstages (preamplifier output). The audio monitor offers advanced audio features like a continuously adjustable noise reduction circuit that allows background noise suppression. The audio monitor is a power amplifier that directly forwards the signal from the electrode to the speaker or headphones without any delay by digital data acquisition systems, thereby allowing signals in the audio frequency range to be heard.

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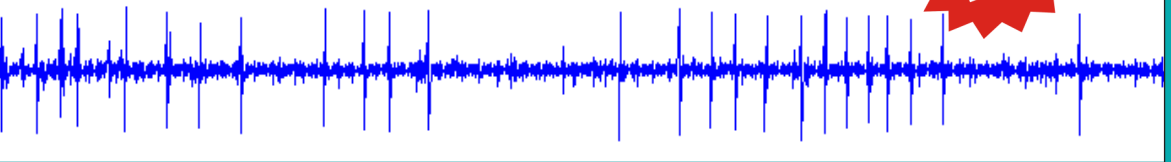

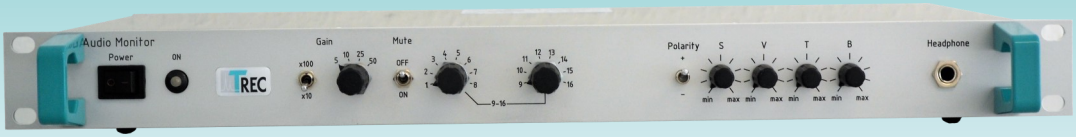

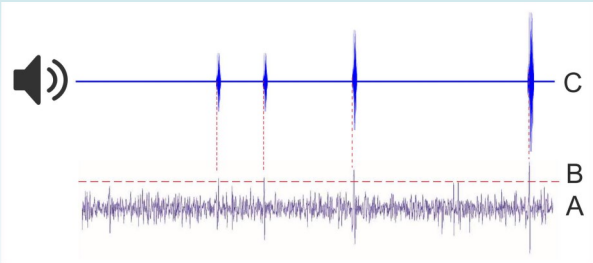

Figure 29: (top) TREC audio monitor with integrated signal amplifier and 1 out of 16 channel selector (right side): A=original neural signal, B=squelch threshold level, C=monitored spike signal (without neural background noise)

Specifications:

- Listen to non-digitized neural signal
- No delay of neural signal by digital data acquisition
- Loudspeaker and headphones included
- Integrated analog main amplifier
- Adjustable squelch circuit for background noise attenuation

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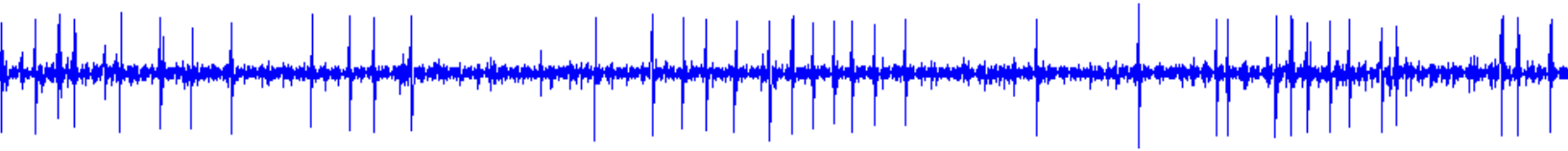

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