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# Orthotic (Pressure Sensing Insole) Using FSR Sensor for People Suffering From Foot Pronation

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***Abstract: Technological advancements have led to the development of numerous orthotics for the physical assistance and restoration of human locomotion. While many challenges remain with respect to the mechanical design of devices it is at least equally challenging and important develop strategies to control them in concert with the intentions of the user. Custom fit orthotics, while helpful, fails to completely alleviate pain caused by this illness. A major weakness of this orthotics is their inability to adapt to changing conditions, either in the patient or the ground. There are many avenues of improvement like an orthotic device which detects the ulcer occurrence symptoms in the patient. The aim of this paper is to develop an orthotic device that can be used with the patient suffering from foot pronation. Our objective is to make a Pressure sensing insole which can be adjusted in the shoe to recognize the foot strike pattern, to adapt changes in foot pattern and pressure during walking, standing and to provide pneumatic stiffness control to correct the foot posture. The system is composed of an insole integrated with FSR Sensor that can be fit in the shoe, a Pneumatic control for stiffness variation. This paper presents initial design considerations and the evaluation of a proof of concept system for foot pronation.***

***Keywords: Pronation, Sensor, Orthotic, FSR (Force Sensing Resistors).***

## 1. INTRODUCTION

Impact forces during running or walking propose that impact forces are input signals that produce muscle tuning shortly before the next contact with the ground to minimize soft tissue vibration and reduce joint & tendon loading. During stance phase, the forces act as an input signal processing a muscle reaction. Orthotics reduce muscle activity.

Muscle tuning can affect fatigue, comfort, work, and performance. In the United States, approximately 37% of all adults 60 years or older suffer from knee osteoarthritis. Approximately 42% of females and 31% of males over 60 years old have some form of knee arthritis. This manifests as sharp pains in the knee upon moving and is ranked as one of the top 5 leading causes of disability among non-institutionalized adults. The recommended treatment options for this condition include surgery, cortisone injections, and foot orthotics. Foot orthotics usually consist of a “custom fit” insole designed to place the foot in and ideal position for running or walking. While effective, high variations between different orthotics could necessitate multiple orthotics per patient.

Orthotics produces only small not systemic and subject-specific changes of foot & leg movement. The major function of orthotics consists in aligning the skeleton. To reduce the frequency of movement related injuries.To align the skeleton properly, To provide improved cushioning, To improve comfort and sensory feedback. Custom foot orthosis or orthopedic footwear or modifications can be really helpful.

There are four common conditions that orthotics have the most potential to help: Plantar fasciitis, Diabetes, Foot Pronation, Metatarsalgia. An exciting revolution is underway in the fields of rehabilitation and assistive devices, where technologies are being developed to actively aid or restore legged locomotion to individuals suffering from muscular impairments or weakness, dorsiflexion, inversion, eversion, plantar fasciitis and foot flat.

Examples of orthotic devices date back thousands of years and have been used with varying levels of success. While many engineering challenges remain with regard to the mechanical design of orthosis. Additional questions remain with respect to how the physical interaction between the user and orthotic device can be improved through various control strategies.

### 1.1 Related Work

The term orthosis is used to describe a device used to assist a person with an impairment of the limbs. Several related papers have been published in recent years that comprehensively establish the state of art in orthotics design and hardware realization. Based on the review of Marchal – Crespo, and Reinkensmeyer, most training paradigms for gait rehabilitation can be classified into two groups.

- An assistive controller directly helps the user in moving their affected limbs in accordance with the desired movement
- A challenge based controller could be used to provoke motor plasticity within the user by making movements more difficult through. For example error amplification.

**Ankle Foot Orthosis** at the University Of Delaware (ALOUD) with 2 DOF. The two motions incorporated are dorsiflexion/ plantarflexion and inversion/ eversion motion.

**Active foot orthosis** on the contrary to stationary systems, active foot orthosis are actuated exoskeleton that the user wears while walking over the ground or on a treadmill. They are intended to control position and motion of the ankle, compensate for weakness or correct deformities. Two early attempts to develop such system were the **Powered Gait Orthosis** (PGO) & the **Pneumatic Active Gait Orthosis** (PAGO). Both devices underwent testing on human participants, but they were not commercialized.

Currently, the only commercialized system for rehabilitation is the Ankle **Boot**, an ankle robot developed at the Massachusetts Institute of Technology (MIT) to rehabilitate the ankle after stroke. It allows a normal range of motion in all 3 DOF of the foot relative to the shank while walking over the ground or on a treadmill.

The MIT also developed an **Active Ankle-Foot Orthosis** (AAFO) where the impedance of the orthotic joint is modulated throughout the walking cycle to treat drop – foot gait.

The Robotic Gait Trainer (RGT) developed in the Human Machine Laboratory at the Arizona State University is a walking device meant to be used on a treadmill. It is naturally complaint due to the spring in muscle actuator and has the ability to achieve a more natural gait by allowing the patient’s ankle joint to move in eversion-inversion, plantar flexion, and dorsiflexion.

Donatelli & Cowerkers assessed, through a post – treatment survey, selected effects of a semi-rigid plastic or fiberglass orthotic to treat knee pain, ankle pain, shin splints or chondromalacia.

Most (96 %) patients experienced relief from pain plantar fasciitis (20.7 %), Achilles tendinitis (18.5 %).The Yonsei University has developed an Active Ankle Foot Orthosis (Yonsei - AAFO) that can control dorsiflexion/ plantarflexion of the ankle joint to prevent foot drop & toe drag during walking.

**Cushioned (Sach) Heel:** This cushion is a wedge of compressible rubber that is inserted into the heel to absorb impact during the heel strike. The cushion is also used to reduce unnecessary knee movement by allowing more rapid ankle plantar flexion (when in motion, this is the point when the heel is off the ground and you are moving forward).

**Figure 1.1.1: Cushioned Heel**

**Heel Wedges:** Depending on their design, these are used to promote inversion (turning inward) or eversion (turning outward), and prevent the hind foot (the ankle region) from sliding down the incline created by the wedge.

**Figure 1.1.2: Heel Wedges**

**Heel flares**: These are used to resist inversion or eversion and to provide stability.

**Extended heel**: Also known as a Thomas heel, it runs up the front of the medial side to provide support to the medial longitudinal arch (the highest and strongest of the three arches located on each foot). This can also be reversed to support the front side of the lateral side to provide stability to the lateral longitudinal arch.

**Sole wedges**: These medial wedges are used to promote supination or pronation, based on their medial or lateral design.
**Sole flare** promotes stability and can be used to resist either inversion or eversion, depending on their design.

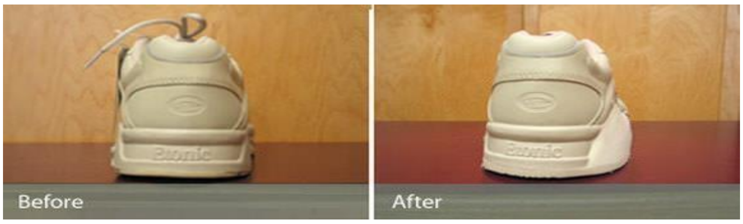



**Figure 1.1.3: Sole Flare**

**Fantastic Phantom slipper:** The "Fantastic Phantom Slipper" was an installation that used a pressure sensing shoe with an active IR optical system that tracked translational position across a small area, enabling users to step on animated insects that were projected onto the floor. Retrofits to jogging sneakers are now being brought to market that uses inertial sensors for quantifying footfalls and estimating elapsed distance.

## 11. PRINCIPLE

The design of pressure-sensing insole using FSR (Force Sensitive Resistor) sensor is to help the people suffering from foot pronation. The final design of the pressure-sensing insole can be broken down into two main components:

1. The data collection and processing system.
2. The control of the shoe variable stiffness.

The force distribution of a user's foot will be measured using force-sensing resistor (FSR) sensors, while ATMega 16 and a custom printed circuit board (PCB) collect and process the force data. Two FSR sensors are distributed along the insole and communicate with ATmega 16 microcontroller.

When certain force thresholds are exceeded, the software attempts to vary the stiffness of the insole in order to adjust the forces to an acceptable level. The software does this by triggering solenoid valves and an air compressor to control air-flow inside the shoe that will modify its stiffness.

## 111. WHAT IS FSR (Force Sensitive Resistor) SENSOR

FSRs are sensors that allow you to detect physical pressure, squeezing and weight. They are simple to use and low cost. This sensor is an Interlink model 402 FSR with 1/2 diameter sensing region. FSR's are basically a resistor that changes its resistive value (in ohms Ω) depending on how much it's pressed. These sensors are fairly low cost, and easy to use. They also vary some from the sensor to sensor perhaps 10%. So basically when you use FSR's you should only expect to get ranges of response. FSRs are made of plastic and the connection tab is crimped on the delicate material.

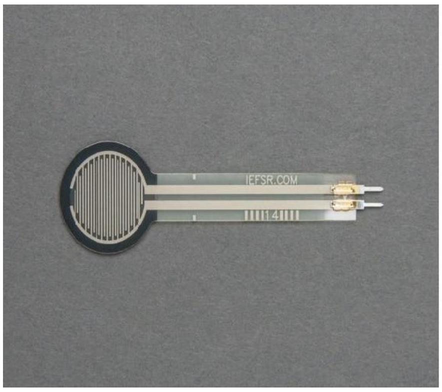


**FIG (a) – FSR Sensor**

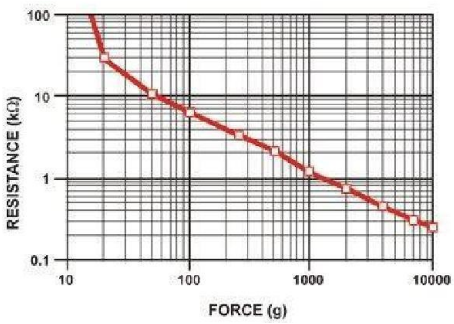



**FIG (b) – Resistance vs force**

**[FSR Homepage:https://www.adafruit.com/product/166]**

### 3.1 Working Principle of FSR Sensor

Force-sensing resistors consist of a conductive polymer, which changes resistance in a predictable manner following application of force to its surface. They are normally supplied as a polymer sheet or ink that can be applied by screen printing. The sensing film consists of both electrically conducting and non-conducting particles suspended in a matrix. The particles are sub-micrometer sizes and are formulated to reduce the temperature dependence, improve mechanical properties and increase surface durability. Applying a force to the surface of the sensing film causes particles to touch the conducting electrodes, changing the resistance of the film. As with all resistive based sensors, force-sensing resistors require a relatively simple interface and can operate satisfactorily in moderately hostile environments.

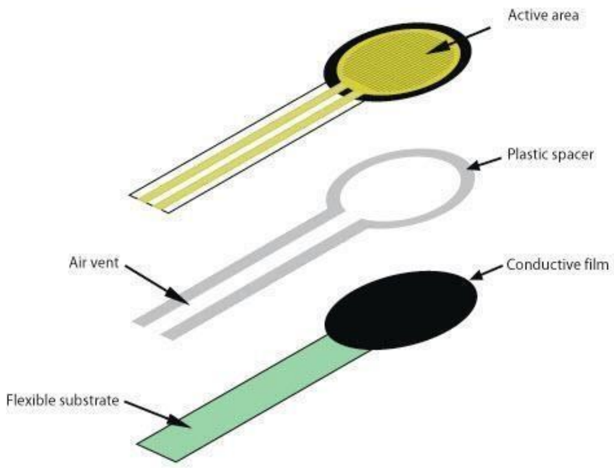
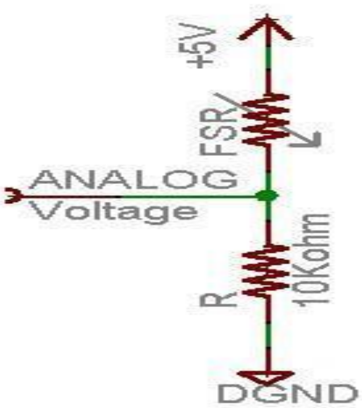



**FIG (c) – FSR Sensor module**

Flexi force sensors are ultra-thin and flexible printed circuits, which can be easy, integrated into force measurement applications. One of the most common circuits implemented to utilize an FSR's output is the voltage divider. A voltage (usually +5 V) is applied to one of the leads, while the other is grounded.

FSRs are not polar, meaning it does not matter which side receives the voltage.




One lead from a second resistor (with fixed value) is then connected to the voltage side, while the other lead of the second resistor is also connected to ground. In this way, the FSR is able to measure the "voltage drop across a resistor". The resistance value of the second resistor determines the output range of the sensor.

### 1V. System Implementation

The process begins when the user's foot strikes. 2 FSR Sensors placed around the sole of the shoe, pick up the difference in resistance felt. This is then translated and interpreted through an ATMega 16 microcontroller.

The microcontroller then suggests an action in order to correct the pronation or supination involved. This involves signaling the compressor and solenoid valves.

### 4.1 FLOW CHART

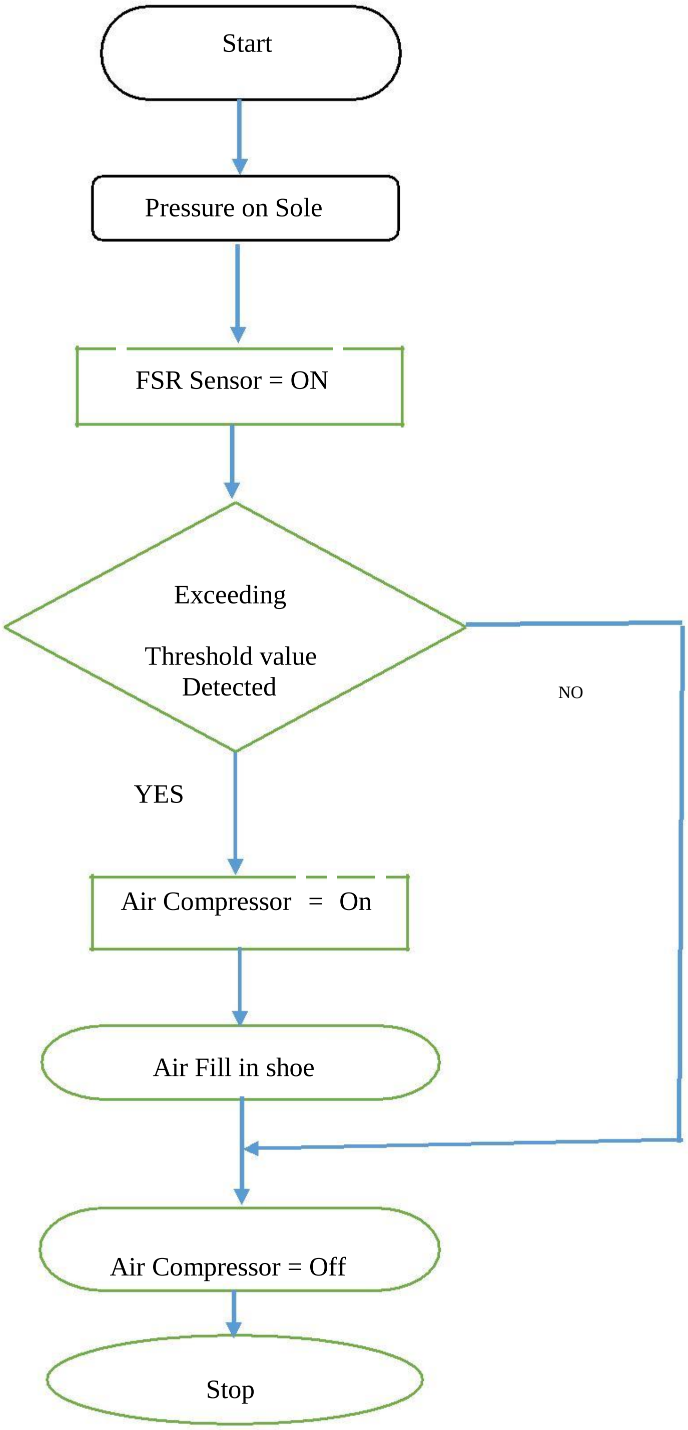



**FIG 4.1.1– OPERATING FLOW CHART**

When foot pressure exerts on sole weight is detected by the pressure sensor. If the pressure value exceeding threshold value then ATMega 16 microcontroller give the command to the compressor. The compressor gets on and provides the air support to the sole. After filling the air insole compressor automatically get off. Again when the sensor detects pressure then the process repeats itself.

The figure shows complete path of the program & along with complete working of the orthotic. When user's foot strike on sole the pressure sensor detects the pressure exerted on the sole. If the pressure exerts on sole exceed more than the threshold value, the processor starts the compressor. Compressor fills the air insole through a solenoid valve.

### 4.2 HARDWARE DESIGN

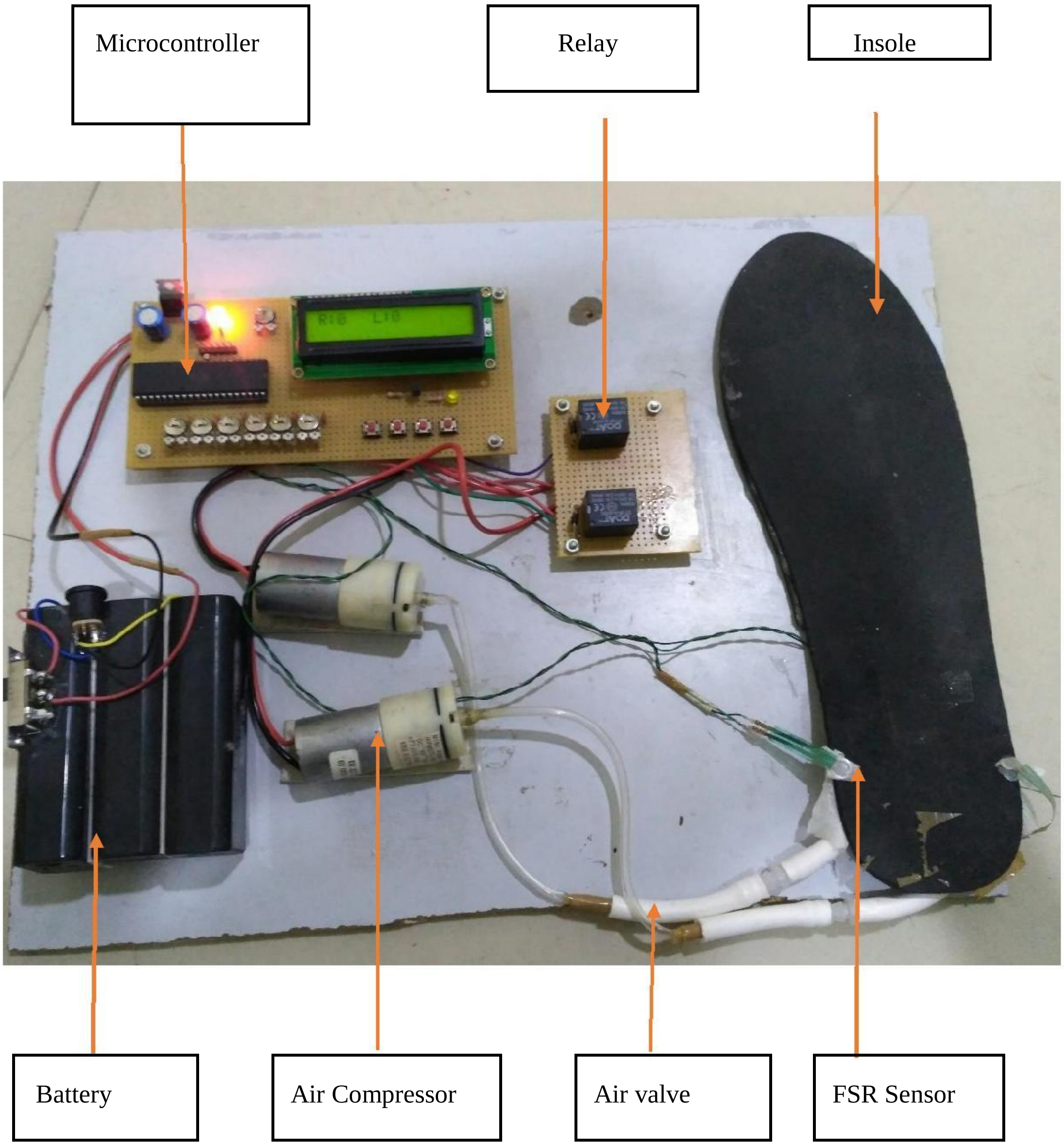



**Figure 4.2.1 - Hardware Design of Orthotic (Pressure Sensing Insole)**

**RESULTS**

The process begins when the user's foot strikes. Sensors placed around the sole of the shoe, pick up the difference in resistance felt in. This is then translated and interpreted through ATMega 16 microcontroller. In microcontroller, a pressure threshold value is set. If the pressure exceeds the threshold value then the microcontroller suggests an action in order to correct the pronation or supination involved. Microcontroller gives the command to the air compressor to fill the air in the shoe through valves. It provides the air support in a shoe in area 6×11 cm. After providing air support to feet the compressor gets off when again pressure exceeds the threshold value then process repeat again.

**Table 6.1: FSR Resistance vs Voltage**

| Force (lb) | Force (N) | FSR Resistance | (FSR + R) Ω | Current thru FSR+R | Voltage across R |
|---|---|---|---|---|---|
| None | None | Infinite | Infinite! | 0 mA | 0V |
| 0.04 lb | 0.2 N | 30KΩ | 40 KΩ | 0.13 mA | 1.3 V |
| 0.22 lb | 1 N | 6 KΩ | 16 KΩ | 0.31 mA | 3.1 V |
| 2.2 lb | 10 N | 1 KΩ | 11 KΩ | 0.45 mA | 4.5 V |
| 22 lb | 100 N | 250 Ω | 10.25 KΩ | 0.49 mA | 4.9 V |

This table indicates the approximate analog voltage based on the sensor force/resistance w/a 5V supply and 10K pull-down resistor. That is, the voltage is proportional to the **inverse** of the FSR resistance.

Note that our method takes the somewhat linear resistivity but does not provide linear voltage! That's because the voltage equation is:

$$\mathbf{VO = Vcc\ (R / (R + FSR))}$$

Where**,**

VO = Voltage Output

Vcc = Collector Supply Voltage

FSR = Force Sensing Resistor

R = Resistance

The analysis of patient facing foot problems like pain in the **knee, metatarsal pain, problems with Achilles tendon caused by incorrect foot posture,** was done on 6 patient, (4 female, 2 male) having different age and body weight in AIIMS New Delhi.

**Table 6.2: The Data Analysis of Person**

| Patient Name | Age (Year) | Weight (Kg) | Force (Ib) | Problem |
|---|---|---|---|---|
| Chanda Tiwari | 60 | 58 | 127 | Over Pronation |
| Shakuntla | 73 | 62 | 136 | Over Pronation |
| Vibha Gupta | 37 | 52 | 114 | Under Pronation |
| Raghuveer | 72 | 75 | 165 | Under Pronation |
| Sushma Sisodiya | 42 | 56 | 123 | Over Pronation |
| Dr. Ramesh Aggarwal | 45 | 65 | 143 | Under Pronation |

**Relationship between participant characteristics and change in foot posture**

There was no relationship between the changes in FSR Sensor pressure on the participants' age, gender, BMI.

## CONCLUSION AND APPLICATION

Good orthotics is a reasonably good way of trying to "tinker" with any gait or postural dysfunction that may have contributed to your pain in the first place. For instance, unusually high arches are a plausible factor in runner's knee. Custom fit orthotics, while helpful, fails to completely alleviate pain caused by this illness. A major weakness of this orthotics is their inability to adapt to changing conditions, either in the patient or the ground.

The objective of this work is to make an orthotic to avoid the foot problems like pain in the knee, metatarsal pain, problems with Achilles tendon caused by incorrect foot posture. This orthotic device is designed to adapt the changing condition of foot strike and automatically take an action to correct the posture of the foot. When foot pronation detected compressor automatically start and provide the air support in the sole. After providing air support the compressor automatically gets off. When exceeding pressure detected again compressor get on and provide air support again in the sole.

### Application

- To correct the foot pattern during walking, running.
- To increase the body's natural shock absorbing capability.
- Can be used with a patient suffering from knee pain, metatarsal pain and other disorder caused by over pronation, and under pronation.

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