tec-memR: Memristor Research Project

Advanced Memristor Computing & Neural Networks

Lissajous Phase-Based Hardware Implementation

DIY Construction & Z80 Integration

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What is a Memristor?

- Passive two-terminal electronic component
- Resistance changes based on voltage/current history
- Acts as non-volatile memory element
- Ideal for neuromorphic computing
- Enables in-memory processing

Key Property: 'Remembers' its last state without power

Project Components

1. DIY Memristor Construction

- Copper-sulfide method

- Simple fabrication process

2. Lissajous Phase Neural Networks

- Novel computing architecture

- Wave-based computation

3. Hardware Integration

- Z80 microprocessor interface

- Crossbar array implementation

DIY Memristor: Copper-Sulfide Method

Materials (Under $20):

- Copper PCB or sheet
- Sulfur powder
- Isopropyl alcohol
- Basic soldering tools

Process:

1. Clean copper surface
2. Apply sulfur slurry (12-24 hours)
3. Form black copper sulfide layer
4. Attach electrodes
5. Test with pinched hysteresis loop

Lissajous Phase Neural Network

Revolutionary Approach:

- Uses phase relationships for computation
- Frequency-division multiplexing (FDM)
- Massive parallelism via wave superposition

Key Advantage:

Each wire can carry MANY parallel computations simultaneously at different frequencies

Implemented logic gates: AND, OR, XOR, NAND

Scaling Analysis: Frequency Multiplexing

Technology	Bandwidth	Neurons Possible
Analog (audio)	100 kHz	1,000
RF (wireless)	10 GHz	100,000,000
Optical (fiber)	100 THz	1,000,000,000,000

MASSIVE parallelism through wave superposition!

Current implementation: 4 neurons @ 1-4 kHz

Hardware Implementation Options

1. FPGA (Fastest to prototype)
- ~1000 neurons @ 100 MHz
- Cost: ~$100 dev board

2. Analog ASIC (Ultimate efficiency)
- 10,000 neurons in 5mm × 5mm chip
- 10 TOPS, only 10mW power

3. Memristor Crossbar (Current focus!)
- Physical wave computation
- Natural phase interference

4. Photonic (Future work)
- Speed of light computation
- 100 THz bandwidth

Memristor Crossbar Architecture

KEY INSIGHT: Memristor state = Phase shift

Architecture:

• N×M crossbar array

• AC voltage on rows (inputs)

• Current summing on columns (outputs)

• Each junction: learnable phase element

Advantages:

✓ Natural phase computation

✓ No external phase shifters needed

✓ Non-volatile (retains state)

✓ Training via simple voltage pulses

Z80 Microprocessor Integration

Hybrid Analog-Digital System:

Z80 Role:

- Controls DC programming pulses
- Sets memristor states
- Reads ADC outputs
- Orchestrates computation

Memristor Array:

- Performs analog computation
- Physical wave interference
- Natural parallel processing

Interface: Custom I/O module with ADC/DAC

Current Achievements

✓ Software simulation in Octave/MATLAB

✓ Logic gates implementation (AND, OR, XOR, NAND)

✓ Frequency multiplexing demonstration

✓ Lissajous curve visualization

✓ Hardware design documentation

✓ Z80 assembly interface code

Generated Visualizations:

- Logic gate phase patterns
- Frequency multiplexing spectrum
- Hardware design diagrams

Implementation Roadmap

Phase 1: Software Validation ✓

- Logic gates working in Octave

Phase 2: Arduino Prototype

- Build 4-input neuron

- Physical XOR gate test

Phase 3: Memristor Integration

- 2×2 crossbar array

- Z80 interface

- Learning demonstration

Phase 4: FPGA Accelerator

- 100+ neuron scaling

- GPU benchmarking

Phase 5: Publication & Open Source

Technical Innovations

Novel Contributions:

1. Phase-coded memristor computing

- Using AC impedance for computation

2. Frequency-division neural multiplexing

- Massive parallelism in single wire

3. DIY memristor fabrication

- Accessible, low-cost method

4. Retro-computing integration

- Z80 + modern memristor tech

Applications

Neuromorphic Computing:

• Pattern recognition

• Analog neural networks

• In-memory computation

Research & Education:

• Physics demonstrations

• DIY electronics projects

• Academic publications

Future Possibilities:

• Edge AI acceleration

• Ultra-low-power computing

• Hybrid analog-digital systems

Key Results & Visualizations

Generated Artifacts:

• lissajous_logic_gates.png

- Phase patterns for logic operations

• lissajous_hardware_design_..._demo.png

- Frequency multiplexing demonstration

• Octave/MATLAB simulation code

- Complete working implementation

• Z80 assembly interface

- Memristor control routines

Challenges & Solutions

Challenges:

- Memristor stability & degradation
- Device variability
- Sneak path currents in large arrays
- Precise phase control

Solutions:

- Improved fabrication techniques
- Error correction algorithms
- Diode integration per cell
- Digital calibration via Z80

Next Steps

Immediate Goals:

1. Build Arduino prototype (4-neuron demo)

2. Fabricate 2×2 memristor crossbar

3. Implement Z80 control interface

4. Demonstrate XOR learning

5. Document results for publication

Long-term: Scale to FPGA (100+ neurons)

Resources & Documentation

Project Repository:

- Complete source code (Octave, Assembly)
- Hardware schematics
- Detailed construction guides
- Simulation results

Key References:

- Frontiers in Nanotechnology
- Nyle Steiner's memristor work
- DIY electronics forums

Questions & Discussion

Thank you!

Project: tec-memR

Memristor Research & Neural Computing

Open for questions and collaboration