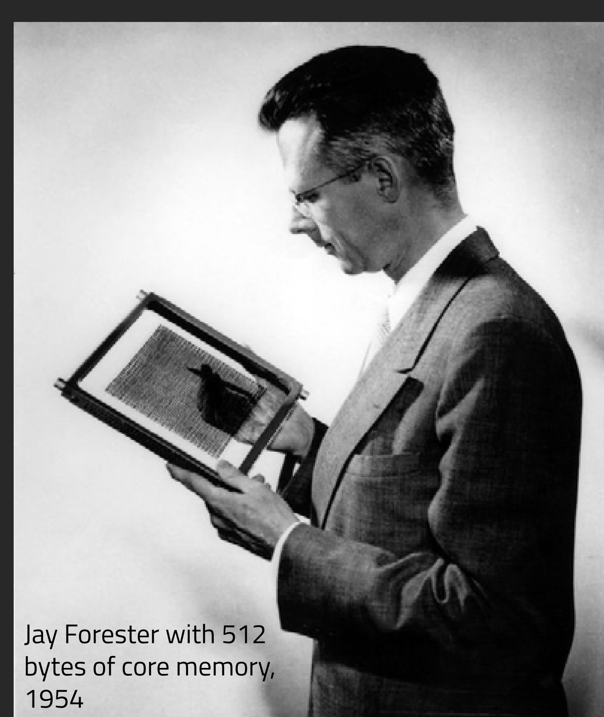
History

- Magnetic Tape 1928
- Magnetic Drum 1932
- CRT Memory 1946
- Delay Line 1949
- Magnetic Core 1949
- Cassete Tape 1963
- Semiconductor RAM 1965
- 8-Inch Floppy Disk 1971
- CD 1980
- Assorted Optical Media
- Flash Memory 1994

Jay Forrester invented 3D core memory at MIT in 1949 for the Whirlwind computer, completed in 1953. An Wang invented 2D core memory for the Harvard Mark IV computer, completed in 1952.


Whirlwind computer, 1951


Jay Forester with 512 bytes of core memory, 1954

Core Memory in Perspective

	Core Memory	Modern Micro-SD
Typical Storage	4 KB	1 TB (1 billion KB)
Typical Volume	149 mL	0.165 mL
Typical Data Density	27 KB/L	6 trillion KB/L
Cost per GB	$80,000,000	$0.13

A 8 GB micro-SD card on top of 8 bytes of core memory, a billion times less then the micro-SD card

1 TB = 50 copies of *The Bee Movie* (4K resolution).
4 KB = this image of a bee.

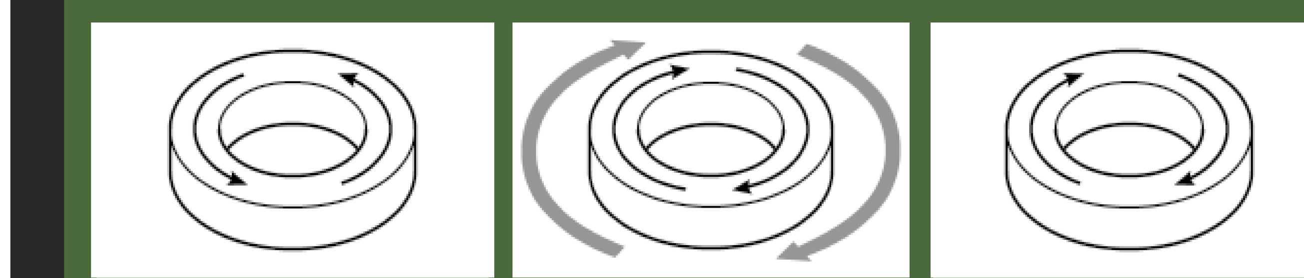
1 TB of core memory would occupy the school's gravel field up to the third floor.

How Does Core Memory Work?

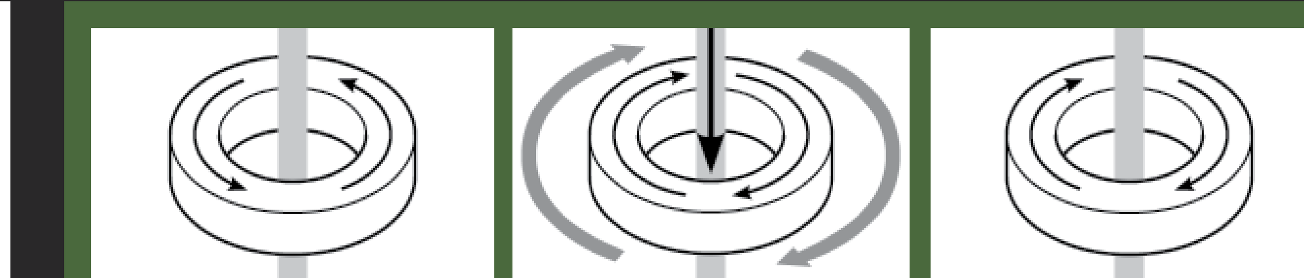
Write a Bit

Running electricity through a wire induces a **magnetic field** based on the **direction** of the current. More current means a **stronger** magnetic field.

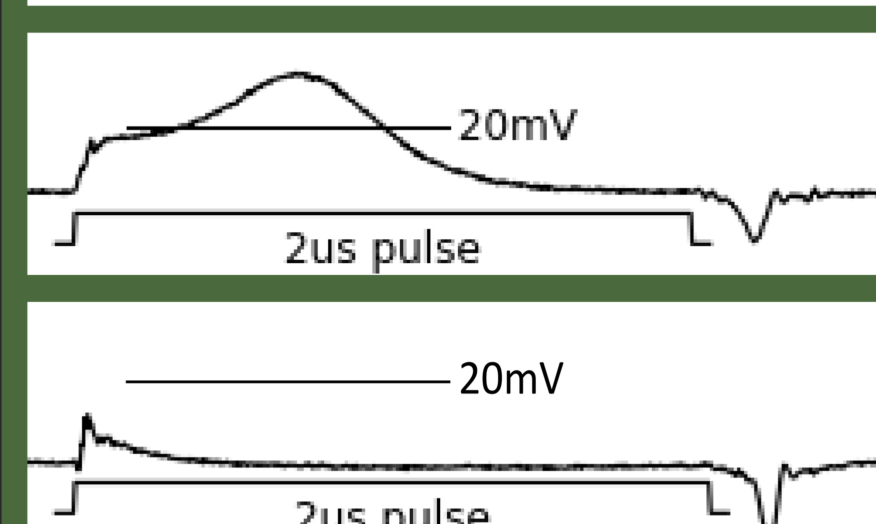
A ferrite core's magnetic field can **flip** directions when a **sufficient opposing** magnetic field is applied. The core will **keep** this orientation after the magnetic field has been **removed**. If a **matching** field is applied, **nothing** happens. When an **insufficient** force is applied, the core's magnetic field **does not** flip.



A **wire** can be used to induce the magnetic field. This wire is called a **drive wire**. Depending on the **direction** of the current, a core can be **written** to the desired direction of the magnetic field. The **direction** of rotation can be viewed as either a 1 or a 0, aka **one binary digit** (1 bit).



Resulting induced voltage from applying a magnetic field in the opposite direction (top) vs same direction (bottom)



The **switching** of the core's magnetic field can induce a small number of volts into a **second** wire, called a **sense wire**. This **only** occurs when the core **changes** states. Using this property, we can set a core to a **known** value, normally 0, then test for a response. If we detect a **change**, we know that the core went from a non-0 state to 0, so the core **was a 1**. **One** sense wire can be used for **all** cores.

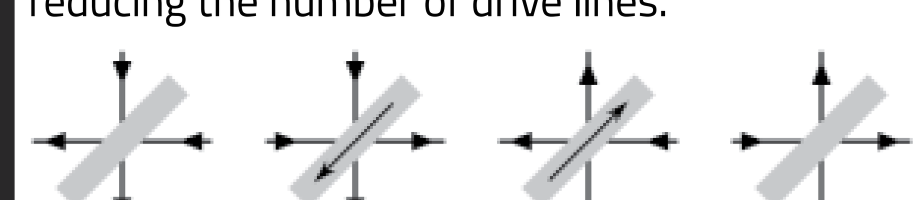
Read a Bit

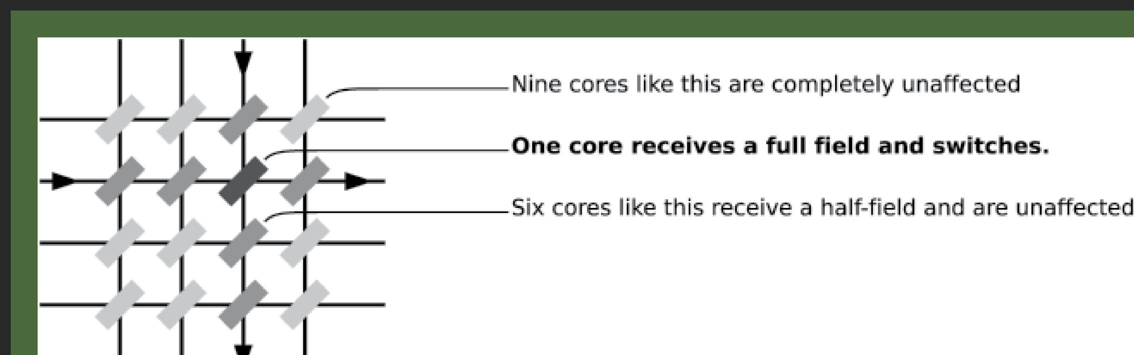
If we do **not** detect a **change**, we know that the core was originally a **0**. This is called **destructive read**, as reading a core causes that core's data to be lost. To compensate for this, the core must be **returned** to its previous state.

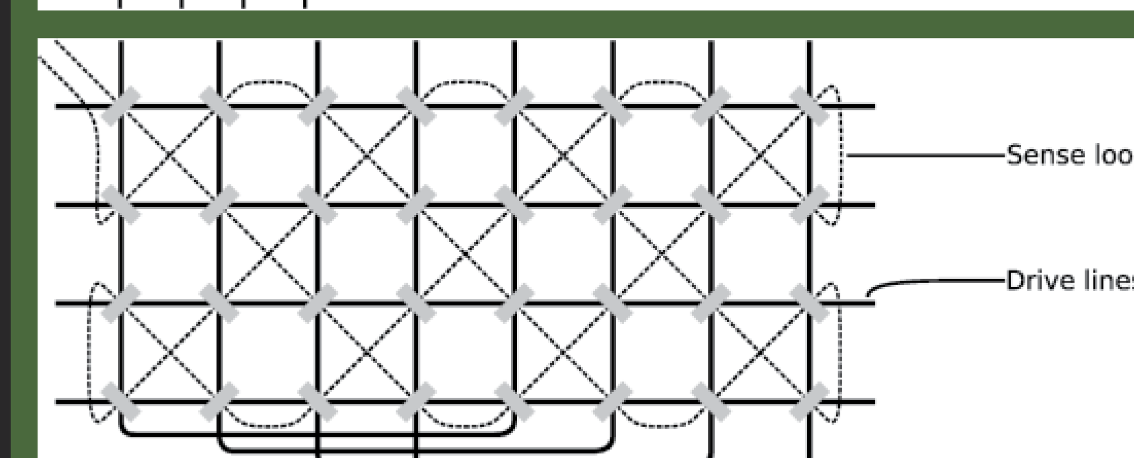
Optimization

A simplistic design uses **one** drive wire **per core** to create the nessisary field. This means that for 32 bits, you would need to power 32 drive wires, each independently controlled. Two wires, with magnetic fields going in the **same** direction, **add** together. When cores are placed in a **grid**, two powered wires **add** their fields and create the required magnetic field strength **only** at the core where the wires **intersect**.

Because **opposing** magnetic fields **cancel** each other out, additional optimization can be achieved by running the same two wires in **different** directions through **two** cores, further reducing the number of drive lines.







Process of Creation

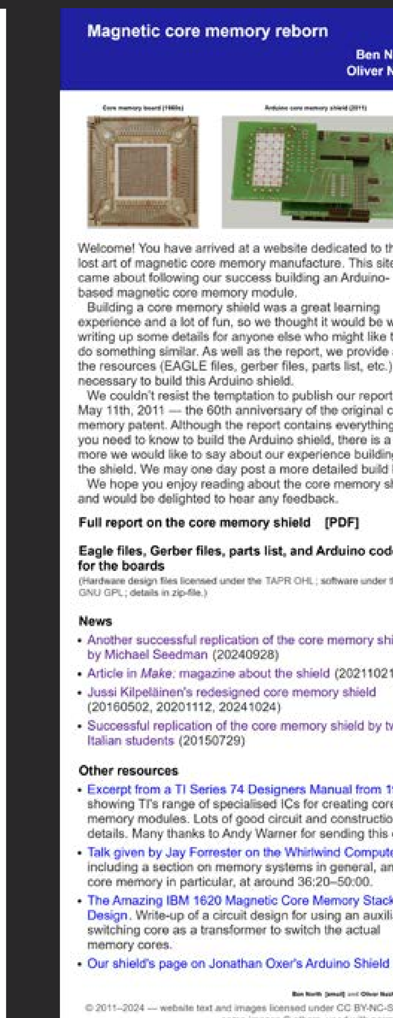
Researching core memory on the internet led me to the **excellent** *corememoryshield.com* website, created by Ben North and Oliver Nash. The site contains clear descriptions of how core memory works, and technical information for a core memory **circuit board** for an **Arduino** that authors had designed and built. I exchanged emails with the authors, who were **invaluable** in helping me understand core memory and build a board.

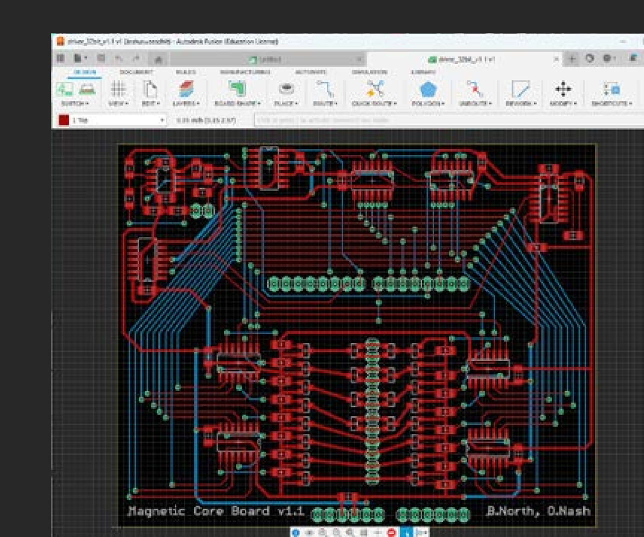
The core memory **toroids** were bought from an online retailer.

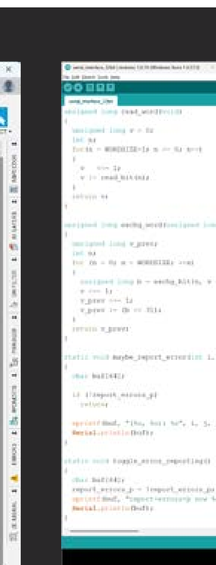
The core memory board must be "**tuned**" to the characteristics of the toroids. Working from the data sheets provided by the core memory retailer and with guidance from North and Nash, I modified the design.

I used a circuit board fabricator to manufacture the board. This process was not without **complications**, as **several** of the components specified in the design were **discontinued** or **out** of stock. This led to an **extended** back-and-forth with the fabricator identifying and ordering alternate components.

Once the fabricated boards were delivered, I **hand-soldered** the remaining components, **wove** the toroids onto the wire mesh and connected them to an Arduino Uno.







Acknowledgements

Huge thanks to Dr. Ben North and Dr. Oliver Nash for their advice and for continually maintaining *corememorysheild.com* for future hobbyists, and to Michael Seedman for sharing his experience.

Sources

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7. Allan, Roy A. A History of the Personal Computer: The People and the Technology. Allan Publishing, 2001.
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2. Courtesy of the MIT Museum
3. Sancho, Daniel. 8 bytes vs. 8Gbytes. 22 Sept. 2013. https://commons.wikimedia.org/wiki/File:8_bytes_vs._8Gbytes.jpg. Accessed 14 May 2025.
4. Pixel art bee on baby blue background. How to Make a Pixel Art Bee, MegaVoxles, https://www.megavoxels.com/learn/how-to-make-a-pixel-art-bee/. Accessed 14 May 2025.

Images, central panel and right panel, top:
1. North, Ben, and Oliver Nash. "Magnetic Core Memory Reborn." Magnetic Core Memory Reborn, 2011, corememoryshield.com/

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