“THE SOCIAL LIFE OF THE SHIFT REGISTER”

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1.INTRODUCTION

This essay is about a single electrical component, the Shift Register. It was first used in 1943 at Bletchley Park in the Colossus computer, a programmable (via switches and wires rather than software) computer used by British code-breakers to help read encrypted German messages. The Shift Register was used as an early form of computer memory and as a structure for parallel processing, where in the Colossus it allowed five simultaneous computations to be carried out[1].

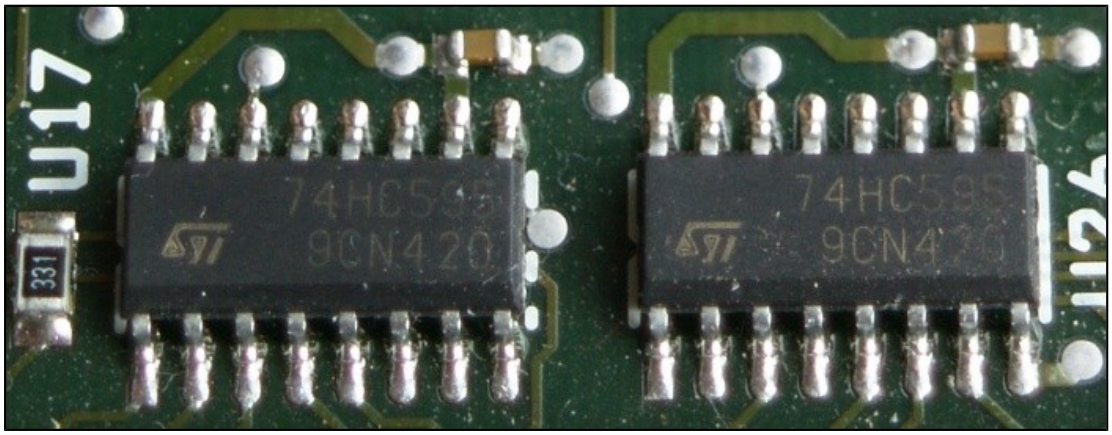

Fig1: Surface mount 74HC595 Shift Register

Both a mathematical and electronic construct, Shift Registers remain deeply embedded within cryptography and error-correction technologies[2], where they are used to generate pseudorandom binary sequences for encrypted military and civil communications. They are also fundamental in digital signal processing, used in anything from deep space, satellite, video or mobile phone communications systems to shape-shift the spaces they inhabit[3] and assemble new structures of human, material, and technological relations.

I attempt to locate the social through a reading of engineering descriptions and data sheets describing the material, operational and descriptive characteristics of Shift Registers, with specific reference to the 74HC595 Shift Register and more generally the Texas Instruments family (the 7400 series) of logic chips. These integrated circuits (ICs) were developed in the 1960s and served to popularise the use of ICs in the electronics industry. I pay attention to the characteristics of a technical object and the meaning of those

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1 [Accessed 7-5-2012]
http://en.wikipedia.org/wiki/Colossus_computer
2 [2009] A.A. Bruen and R.A. Mollin “Cryptography and Shift Registers” The Open Mathematics Journal.
3 [2005] Adrian Mackenzie “Protocols and the irreducible traces of embodiment: the Viterbi algorithm and the mosaic of machine time” P3.

characteristics[4] and use this as a means to understand the social systems that emerge through its use and production. Through this approach I aim to illustrate the social agency of the Shift Register and ICs, the arrangements of power and authority in human relations that arise through their development and use.

I question a non-social technological determinism, where technological change is simply viewed as a linear narrative of progress, driven by sequential efficiency improvements or the genius of an individual engineer. I attempt to illustrate that the Shift Register forms and is formed by messy narratives of material and human social relations. The material properties of minerals, market forces, processes of standardisation and past technological histories all intersect to shape the physical form of the shift register, its adoption use and effect[5]. I shall use the language of mechanical, material and electrical engineering, where domains of both specialised and lay knowledge serve to construct new worlds of parallel and sequential operations, electronic memory and programmable machines.

2.THE DNA OF SHIFT REGISTER

Shift Registers are simultaneously a mathematical concept, algorithm and hardware microchip, entangled within the abstract heart of software and digital technologies, a key component of digital logic with a multitude of applications. They control dizzying arrays of LEDs (light emitting diodes), act as glue between parallel and serial signals, multiplex and delay output, reduce wire count in circuits, take load off central processing units (CPU), store data bits, distribute data to peripheral devices or individual units of a CPU.

Set by timed sequences of electrical pulses, Shift Registers are used to represent numbers, perform calculations, or encode and decode wireless signals. They are a mechanism for generating and reading convolutional codes, a code that generates pseudorandom data, able to fold the history of an entire data stream into each data bit. Deciphered by the Viterbi algorithm, convolutional codes play a key role in enabling satellite, cellular phone and wireless networks to communicate, shaping a contemporary experience of space and time, generating intensive movements of data[6].

A fundamental element of the Shift Register is the *Flip-Flop*, an electronic structure that is able to store a binary state. The Flip-Flop alternates its state with a given input; meaning once it has changed it will remain that way and will not change spontaneously. A

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4 Langdon Winner “Do Artifacts have politics” from “The Social Shaping of technology” Open University Press.

5 [1998] Donald MacKenzie “Knowing Machines: Essays on Technical Change” p5. MIT Press.

6 [2005] Adrian Mackenzie “Protocols and the irreducible traces of embodiment: the Viterbi algorithm and the mosaic of machine time”

clickable retractable pen is a mechanical example of a Flip-Flop where a single force causes the mechanism to flip between an open or closed state. The diagram below shows a version of a mechanical Flip-Flop triggered by a falling marble, where the marble will cause the pivot to tip left or right, where it will remain until further input.

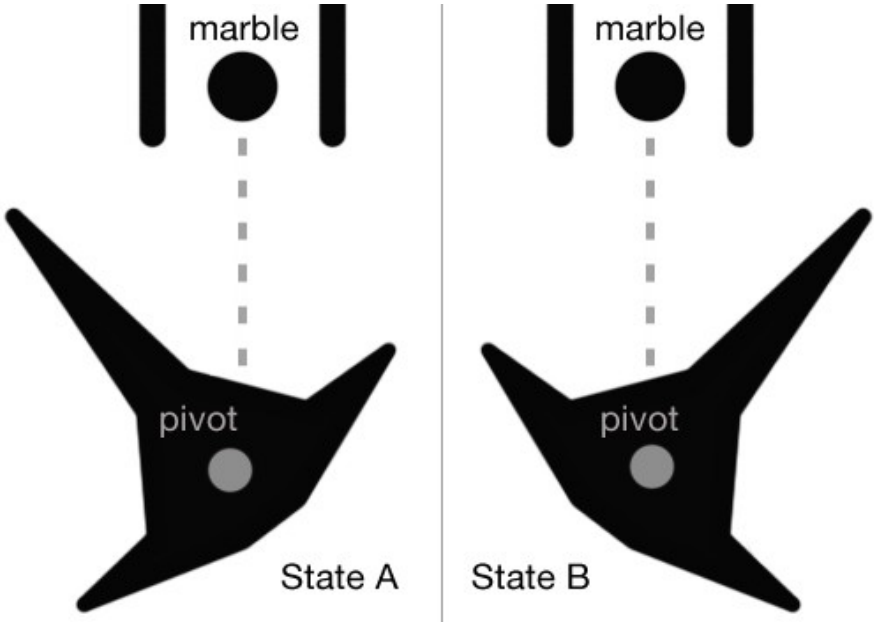

Fig2: Diagram of a mechanical Flip Flop triggered by falling marbles

A series of Flip-Flops form a Register. An 8bit Register will contain eight Flip-Flops whose collective sequence of zeros or ones constitute the current overall state of the register. A Shift Register is so called because the Flip-Flops are linked so that as a new command is received, their states are shifted one position to the left or right.

One analogy is to imagine a bag of green red and marbles (zeros and ones) and a horizontal plastic tube (the Shift Register), which is only able to hold eight marbles (8bits). If a new marble (serial data), is inserted at the left hand end then the other marbles in the tube will shift one position to the right. The marble furthest to the right will be pushed out the end, and can either enter another Shift Register, be discarded, or used as a delayed output. The tube of marbles then constitutes the current state of the Shift Register, a memory of a received sequence marbles (serial data).

Shift registers can be used to control large arrays of LEDs via a single serial input, where in contemporary use a microcontroller is used to generate a timed sequence of electronic pulses (serial data) that sets the outputs of a shift register to “on” or “off”. The on/off state of the Shift Register is characterised by a voltage differential, typically 5 volts (on) or 0 volts (off), enabling them to selectively provide power to individually attached LEDs or other logical areas of

a circuit. The modular logic of the Shift Register radically expands the number of outputs a micro-controller can turn on or off with little additional complexity, providing an additional density of computation for minimal cost.

3. PART NUMBER 74HC595

The 74HC595 Shift Register is a derivative of the Texas Instruments 7400 family of integrated circuits, collectively known as logic chips, a consumer grade[7] line of products that rapidly gained market dominance in the 1960s[8]. These circuits popularised Transistor–Transistor Logic (TTL)[9], an approach to IC design, where the controlling AND OR logic of electrical circuits is performed entirely by physical arrangements of transistors and resistors. These ICs direct the flow of electrical current following simple logical rule sets maintained by the material properties of semi-conducting materials.

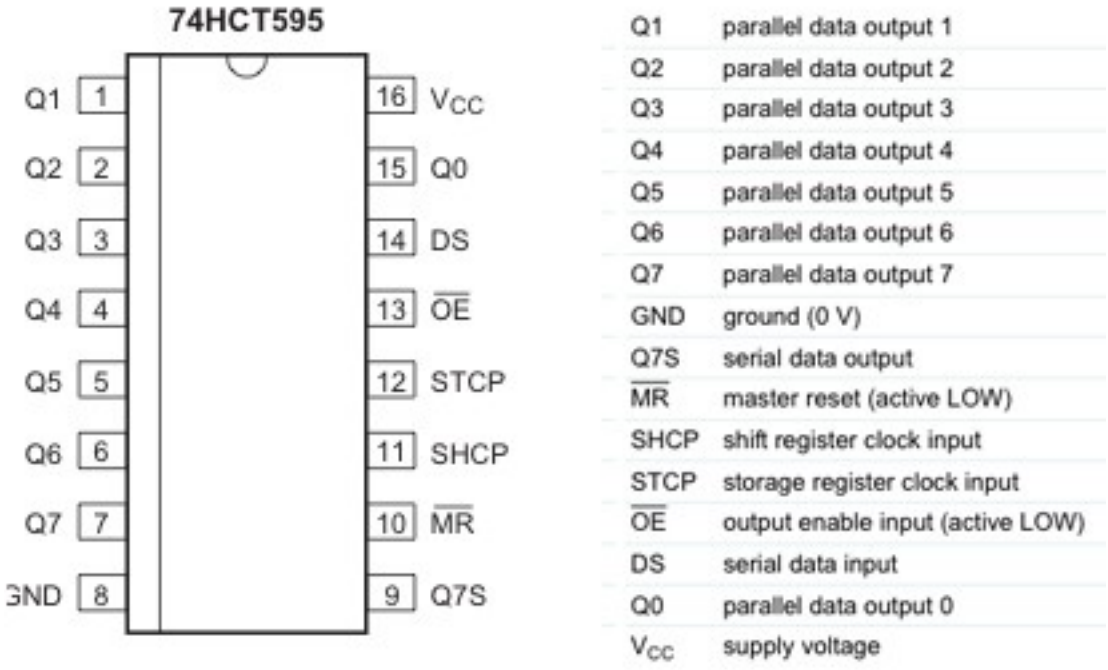

Fig3: Pin layout. Image: From Product Data Sheet

The part number provides a historical lineage, where ‘74’ relates to the 7400 TTL series of products and ‘HC’ is a compound acronym of ‘High speed’ and ‘CMOS’. High speed is a reference to how quickly the embedded transistors switch and CMOS ‘Complementary Metal–Oxide–Semiconductor’, an efficient design production technique patented by Frank Wanlass in 1967[10], characteristic of low power consumption, speed of operation and high noise immunity in dense electrical environments, such as those inside a computer. Following an ever deeper trail to the origins of this part number, CMOS is a further compound acronym consisting of ‘Complementary’ and ‘MOSFET’ (Metal Oxide Semiconductor Field Effect Transistor)[11]. ‘Complementary’ specifies a balanced layout of n-type (negative)

7 The 5400 series developed in the same period were military grade components and operated at a higher temperature.
8 History of semi-conductors. P154
9 1962
10 US patent 3,356,858

and p-type (positive) transistors and MOSFET specifies both mineral construction and the field effect of electrons physically shaping conductive channels at an atomic level.

Finally, the '595' section of the part number specifies the functionality of the chip including its internal logic structure and arrangement of pins (Fig2). This predictable component structure not only defines sets of material relations but is also defines sets of social histories and relations.

The part number allows us to unfold dense technical description, but also points to a wider social history of industrial, consumer, economic and conceptual narratives that weave through the structure of an IC. The part number summarises and becomes shorthand for structures of digital logic, defining conceptual groupings of logical thought expressed as hardware chip, structuring social systems in its realisation.

As part of the 7400 series, the 74HC595 plays its part in constructing a culture of engineering that spreads far beyond the western companies of Texas Instruments and Fairchild Semiconductors. Companies in Poland, Czechoslovakia, Hungary, Russia and China each manufacture these chips using the same identification system, one that unifies and focuses an industry around a specific, modular system of thought, one that shapes electronic devices and the software structures with which they interface and form.

4. NEAT PACKAGE

Shift Registers, and the 7400 series of TTL chips marked a dramatic shift from manufacture of individual electrical components to the printing of networked structures via photolithography techniques[12], multi-dimensional layers of semi-conducting material with precisely controlled conductive behaviours packaged in predicable forms.

Design features establish patterns of power and authority[13]. The plastic DIP (Dual Inline Package) developed by Texas Instruments was a key reason why 5400 (military grade) and 7400 (consumer grade) logic series became the most popular family of logic chips[14].

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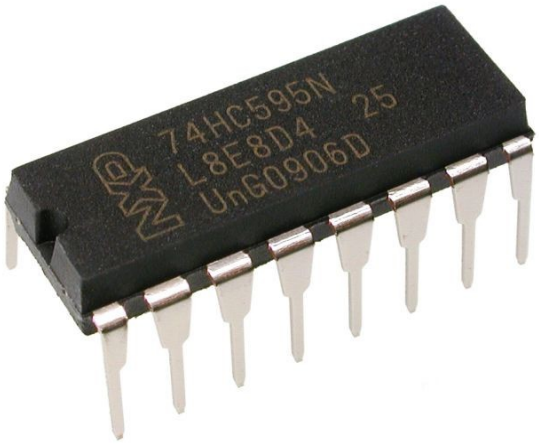
11 [Accessed 3-5-2012] http://en.wikipedia.org/wiki//Metal_oxide_semiconductor_field_effect_transistor

12 [Accessed 4-5-2012] www.computerhistory.org/semiconductor/timeline/1963-TTL.html

13 [1999] Langdon Winner "Do Artefacts have politics" from "The Social Shaping of technology" P38 Open University Press.

14 [2007] Bo Lojek "History of semiconductor Engineering" p212. Springer.

Characterised by a black rectangle with aluminium pins running along each side, the design was suited to automatic assembly techniques and allowed a far greater density of components and functionality than had previously been known. This standardised form factor aligned a willing electronics industry and helped engineer the social conditions from which a contemporary consumer electronics industry emerged.



The DIP form factor originates from an understanding of systems design and the requirements of networks. The fulfill the need for interconnecting logical structures where pin spacing of 2.54mm, length of leg, voltage and operating temperatures define the physical systems within which ICs can be used - the ordered networks of component parts. A technological system is never merely technical; its real world functioning has technical, economic, organisational and cultural aspects[15]. Standardisation embeds a method of production and disciplines sets of social relations, a simultaneous opening and closing of social options[16] as workforces, consumer patterns and inter personal relations are shaped by the technology. Engineers have perhaps always understood that engineering is the engineering of social relations as much as it is the engineering of physical things, where technology is both socially shaped and socially shaping[17].

> “it would be desirable to make multiple devices on a single piece of silicon in order to be able to make interconnections between devices as part of the manufacturing process, and thus reduce size, weight, etc., as well as cost per active element.”[18]

While standardisation in this context obviously carries economic advantage, it contains potential for problematic social and technical power relations[19], where monopolies can be upheld, and

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15 [1999] Donald MacKenzie & Judy Wajcman eds “The Social Shaping of technology” P11. Open University Press.
16 [1999] Donald MacKenzie & Judy Wajcman eds “The Social Shaping of technology” P4. Open University Press.
17 [1999] Donald MacKenzie “The Social Shaping of technology” P1. Open University Press.
18 [2007] Bo Lojek “History of semiconductor Engineering” p147. Springer.
19 [2003] “Gabriel Pickard ”Beyond The Computer” From “Shaping Technologies” P267. Thomson Press.

idiosyncrasies maintained for the sake of compatibility rather than technological suitability. Yet the power evident in this form factor is not one of an economic monopoly, but a power exerted through modularity and connectivity, a common interface and that forms industrial process, creates economic conditions and specific cultures of engineering.

5.A SOCIAL CHIP

Fig5: Practical Electronics Magazine From 1968 with an "Integrated Circuit project"

The widespread adoption of any technology is based on the creation of a set of social conditions as the operating environment of that system[20]. The development of mass automated production techniques brought prices of these ICs down from $50.00 in 1962 to $2.33 in 1968[21]. These conditions took microchips from the domain of the US military and large-scale mainframe computers, into a consumer market.

For a machine or device to be useful we need to know how to use it and it is a combination of shared institutional beliefs and tactic (informal) knowledge that informs how machines are used[22]. There has been a long history of amateur electronics and is these social interactions that work in tandem with expert cultures to socially condition a consumer market, popularising TTL logic chips (including the shift register) workingto socially engineer a personal computer industry.

Books such as the 1968 "How to build a working digital computer"[23] and the 1974 "The TTL Cookbook"[24] were designed for people without training in electronics so they could take the building blocks of logic chips, and construct their own electronic computers based around ICs. As examples, the 1974 Scelbi-8H kit computer and eventually the 1980 Sinclair ZX80 were designed with the readily available 7400 series TTL chips[25]. Logic chips can even be utilized to construct an entire Central Processing Unit, where the website www.magic-1.org is served by a computer built from these chips[26].

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20 [1999] Langdon Winner "Do Artefacts have politics" from "The Social Shaping of technology" P33 Open University Press.
21 [Accessed 9-5-2012] http://en.wikipedia.org/wiki/Integrated_circuit
22 [1998] Donald MacKenzie "Knowing Machines: Essays on Technical Change" p9. MIT Press.
23 [1968] Edward Alcosser, James P. Phillips, Allen M Wolk "How to build a working digital computer" Hayden Book Company.
24 [1974] Donald E. Lancaster "The TTL Cookbook" SAMS.
25 [Accessed 3-5-2012] http://en.wikipedia.org/wiki/ZX80
26 [Accessed 3-5-2012] www.homebrewcpu.com describes the construction of a complete CPU using 7400 series logic chips.

In contemporary professional and amateur engineering circles, the 74HC595 chip and more generally the 7400 series are famed and celebrated with ‘build’ competitions aimed to “illustrate the sheer versatility and enjoyment”[27] that engineers experience when using these IC’s. These forums aim to share knowledge and creatively challenge assumptions about how a particular component should be used and exist as a reflection of successful social, material and electronic engineering. The competitions seem to be a response to an ongoing tension within professional and amateur engineering communities: a belief that people are being excluded from a basic understanding of electrical engineering techniques. This is a complaint that is frequently levied at the Arduino electronics platform[28], which provides both technologies and a social system (forum, workshops, hack days) to introduce hobbyists, designers and artists to electronic prototyping with computers. Yet just like the Arduino, the 7400 series of logic chips were designed to hide complexity and it was this design intent that paved the way for both professional and hobbyist experimentation. The 7400 series and the garage industry cultures it developed, helped to construct the conditions for the rise of the personal computer. So in turn, we may be able to see future cultures of computing within contemporary amateur electronics cultures.

6. CONCLUSION

The interface between humans and computers does not start with the peripheral technologies of keyboards, mice and screen, but with the guts of the machine, in the component parts, chips and registers that comprise these complex systems. Processes of manufacture, sale, operation and the cultures of professional and amateur electronics construct a social environment for the Shift Register and its collective family of logic circuits to operate in. Formed by and forming complex eddies of social relation, the Shift Register is an electrical component that constitutes one of the building blocks of contemporary digital machines, as much an engineered system of thought as hardware component. They draw and transmit power, not only measured in watts, but also in a multiplicity of economic, cultural and social relation.

I have attempted to open up the literal black box of an integrated circuit, illustrating a link from minerals sourced from the earth to the algorithmic flow of computational machines. The Shift Register is a

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27 [Accessed 3-5-2012] “2011 Open 7400 Logic Competition” http://dangerousprototypes.com/2011/10/27/7400-competition-an-open-source-open-source-competition/ The ‘555 Timer’ chip is another chip with a fanatical following, which had a competition that inspired the 7400 series event.

28[Accessed 4-5-2012] “How the Arduino won? This is how we can kill it” http://hackaday.com/2011/02/11/how-the-arduino-won-this-is-how-we-can

physical algorithm based on recognisable mechanical operations. It exists as a container for the atomic level of zeros and ones, where Flip-Flops function as an electrical operation of silicon and other minerals. Shift Registers and logic chips can be compared to a reusable snippet of software code, where part numbers refer to a shared library of electronic bricks with predicable input and output structure. Packaged as a modular reusable component to be used in a multitude of context, they are designed for assembly into complex systems or the logical operator for simple electronics.

The technically ‘best’ product is not necessarily the one that wins; it is the one with the most refined social engineering, where meaning is formed through social relations rather than any particular product being the most technically suitable. The history of microchips is like that of any other technological advance, where as material property and commonly known concepts float solutions to the top of the pile, multiple people start to simultaneously form the same ideas. The rise of logic chips and the Shift Register is a story of popularisation and permutation through social systems, where people voluntarily and willingly submit to the agency of component parts, disciplined by a physical unit of logical thought.