

# Keynotes

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## The Auto Issue

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Decoding an SFIC System

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# Decoding an SFIC System

By William M. Lynk, CRL

## Scenario

There are occasions when a locksmith may inherit an SFIC (small format interchangeable core) system to service without access to the control key. Often times bitting lists are not maintained, are missing or simply unavailable. In order to remove cores for recombining (rekeying), the control key, sometimes called a "core key," must be determined and originated. Thus, a sample core, representative of the system, needs to be acquired and decoded. If the sample core must be removed from a housing, that can be accomplished by manipulating (picking) the core, drilling the core out, drilling through the IC housing or pining off the core face and shimming at the control shear line.



In order to fully understand the process of decoding an SFIC system, a brief synopsis of SFIC basics will follow. For those not familiar with SFICs, this overview will assist the reader in appreciating the numerical signifi-

cances within the various decoding formulae that will follow. We'll conclude with a look at two SFIC decoding tools that may assist you in reverse engineering a system.

It is assumed for the purpose of this presentation that you do not have access to the control key, but may have change keys and the top master key. Incidentally, without access to the top master key, it is possible in some systems to decode for that key. But, that is a story for another time.

## SFIC Mechanics

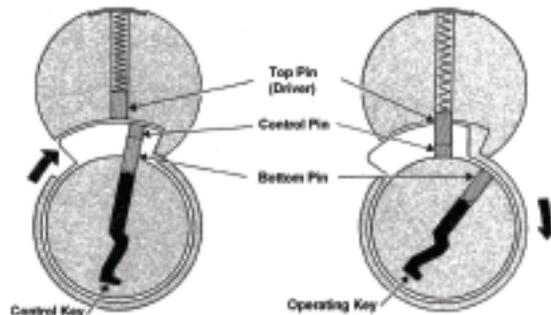
The basic small format interchangeable core consists of the plug, sleeve, shell and retainer. This constitutes the Core assembly.



## Two Shear Lines

The beauty of a small format IC is that there exist two separate shear lines that act independently of each other. The operating shear line drives the plug. When the bottom pins or master pins align at the operating shear line (also called the plug shear line), the plug is free to rotate and turn the throw member or tailpiece in order to activate the locking hardware. The direction it turns (clockwise, counterclockwise or both) is dependent on the IC hardware it supports.

The operating shear line (which allows the plug to turn) is accomplished through the operating keys. They include the change key (CK), master keys (BEST calls them submasters) and the Top Master Key (TMK). This action occurs solely at the plug level. This cutaway view exemplifies a non-master keyed SFIC.



When the pins align at the control shear line (ten increments above the operating shear line), the control key will turn approximately 15 degrees clockwise and allow core retraction from or insertion into the IC housing. That is the single purpose for the control shear line. The control shear line is activated only by the control key (CTL). Note that it is NOT an operating key and does not align pins at the plug level.

## SFIC



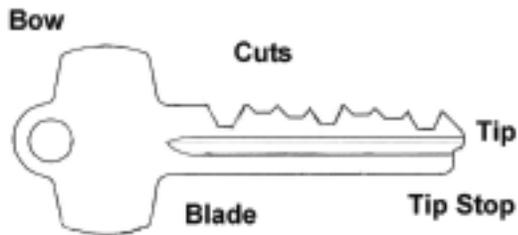
The terminology "small format interchangeable core" (SFIC) was not around in the 1920s. Today it references cores that are size and shape similar to that of the original BEST core. In order to alleviate having to use the term "BEST-style", Schlage Lock Company introduced the generic term "small format" in the late

1990s to differentiate their full size interchangeable core from their new Schlage Everest product which was offered full size or "BEST-style". The industry caught on and the nomenclature SFIC is now standard. Remember that IC, as defined by the LIST Council, stands for "interchangeable core" and not simply "interchangeable." Therefore, there is no such thing as an IC core, translated as "interchangeable core core." That is a redundancy and is incorrect nomenclature. Acceptable uses are: SFIC, small format IC, I-Core or IC.



## Tip To Bowl

Because the keys to an SFIC have no shoulder (in most situations), the key is read and gauged from TIP to BOW – the opposite from most conventional keying systems. The core chambers are also numbered from the back of the core as



chamber #1 going toward the face of the core. There exists a small undercut beneath the key's tip that stops it at the back of the core and aligns the cuts with the chambers. This is known as the Tip Stop.



### A2 System – The Pins

When Frank Best first developed his system of interchangeable cores in the mid-1920s, he designed a pin increment system known as the A2 System. Tumbler pins were a diameter of .108" and utilized an increment of only .0125". Because the drop (increment) was so small, it had to be a two-step system maintaining parity for each chamber. That is, in a single chamber, key cuts could only be even parity or odd parity. This meant every other bitting number could be used in any one chamber.

**Even Parity 0, 2, 4, 6, 8**  
**Odd Parity 1, 3, 5, 7, 9**

As you can see, the bottom pins and the corresponding key cuts ranged from zero to nine, allowing for 10 possible cut depths. Because the design of the system did not produce any adjacent cut violations, a zero cut could be placed next to a nine cut with no adverse effects. Thus, the MACS (Maximum Adjacent Cut Specification) for an A2 system are 0-9. Wafer pins ranged from two through nineteen and the pin stack height totals 23. A2 is the most common and widely used pinning system for SFIC and is the default system in this presentation unless otherwise stated.

BEST used Total Position Progression (TPP) in setting up their master key systems. Rotating Constants, popular in Europe, was not utilized. This meant that in an A2 system:

- ▶ 4, 096 bittings were available using a 6-pin core
- ▶ 16, 384 bittings were available using a 7-pin core

### A3 & A4 Systems

Eventually BEST Universal Lock Company recognized that they required more bittings for larger IC systems. Without having to resort to repeating bittings via different keyways, the

A2 SFIC System KEY BITTING and PIN SPECIFICATIONS Two-Step Progression – .0125" Increment		
Key Depth:	Bottom Pin Length:	Coded Number:
.3187"	.110"	0A
.3062"	.1225"	1A
.2937"	.135"	2A
.2812"	.1475"	3A
.2687"	.160"	4A
.2562"	.1725"	5A
.2437"	.185"	6A
.2312"	.1975"	7A
.2187"	.210"	8A
.2062"	.2225"	9A
	Wafer Pin Length:	Coded Number:
	.025"	2B
	.0375"	3B*
	.050"	4B
	.0625"	5B
	.075"	6B
	.0875"	7B
	.100"	8B
	.1125"	9B
	.125"	10B
	.1375"	11B
	.150"	12B
	.1625"	13B
	.175"	14B
	.1875"	15B*
	.200"	16B
	.2125"	17B*
	.225"	18B
	.2375"	19B*
*Not Used in a Pure 2-Step Progression		
<small>Pin Stack Total: .397" * Pin Diameter = .108" * Coded Stack Length = 23            Decoding for CTL: 13 – Code of Top Pin = CTL Key Cut OR (Build Up Pin – 10) + Plug Total = CTL Key Cut            Keys Read/Cut = TIP to BOW * Root Cut = 0.54" * Angle of Cut = 90°            .150" SPACING (Tip to Bow from center of Cut) – From Tip Stop, each cut:            #1=.088" #2=.238" #3=.388" #4=.538" #5=.688" #6=.838" #7=.988"</small>		

A3 SFIC System KEY BITTING and PIN SPECIFICATIONS Single-Step Progression – .018" Increment [Discontinued]		
Key Depth:	Bottom Pin Length:	Coded Number:
.318"	.110"	0C
.300"	.128"	1C
.282"	.146"	2C
.264"	.164"	3C
.246"	.182"	4C
.228"	.200"	5C
.210"	.218"	6C
	Wafer Pin Length:	Coded Number:
	.018"	1D
	.036"	2D
	.054"	3D
	.072"	4D
	.090"	5D
	.108"	6D
	.126"	7D
	.144"	8D
	.162"	9D
	.180"	10D
	.198"	11D
	.216"	12D
	.234"	13D
<small>Pin Stack Total: .398" * Pin Diameter = .108" * Coded Stack Length = 16            Decoding for CTL: 10 – Code of Top Pin = CTL Key Cut OR (Build Up Pin – 7) + Plug Total = CTL Key Cut            Keys Read/Cut = TIP to BOW * Root Cut = 0.54" * Angle of Cut = 90°            .150" SPACING (Tip to Bow from center of Cut) – From Tip Stop, each cut:            #1=.088" #2=.238" #3=.388" #4=.538" #5=.688" #6=.838" #7=.988"</small>		

A4 SFIC System KEY BITTING and PIN SPECIFICATIONS Single-Step Progression – .021" Increment		
Key Depth:	Bottom Pin Length:	Coded Number:
.318"	.110"	0E
.297"	.131"	1E
.276"	.152"	2E
.255"	.173"	3E
.234"	.194"	4E
.213"	.215"	5E
	Wafer Pin Length:	Coded Number:
	.021"	1F
	.042"	2F
	.063"	3F
	.084"	4F
	.105"	5F
	.126"	6F
	.147"	7F
	.168"	8F
	.189"	9F
	.210"	10F
	.231"	11F

Pin Stack Total: .404" \* Pin Diameter = .108" \* Coded Stack Length = 14  
Decoding for CTL: 8 – Code of Top Pin = CTL Key Cut OR (Build Up Pin – 6) + Plug Total = CTL Key Cut  
Keys Read/Cut = TIP to BOW \* Root Cut = 0.54" \* Angle of Cut = 90°  
.150" SPACING (Tip to Bow from center of Cut) – From Tip Stop, each cut:  
#1=.088" #2=.238" #3=.388" #4=.538" #5=.688" #6=.838" #7=.988"

A3 System was developed. Tumbler pins were a still a diameter of .108" but now utilized an increment of .018". Because the drop was a single-step system, maintaining parity for each chamber was no longer necessary. Bottom pins/cuts ranged zero through six and could all be used within any chamber. The wafer pins ranged one through thirteen and the pin stack height was 16.

Through the implementation of the A3 system:

- ▶ 46, 656 bittings were available using a 6-pin core
- ▶ 279, 936 bittings were available using a 7-pin core

This excitement and joy of over a quarter of a million bittings was cut short when it was discovered that the thinness of the .018" master wafer was causing it to tip sideways and effecting core failure. In addition, unexpected key interchange was occurring. Subsequently, the A3 system was discontinued in favor of the A4 System – another single-step master keying system.

The A4 System utilized a thicker increment of .021" and is effectively used today to create more available bittings than the A2 system. The A3 system produces:

- ▶ 15, 625 bittings were available using a 6-pin core
- ▶ 78, 125 bittings were available using a 7-pin core

Bottom pins/cuts range from zero through five, providing six possible cuts, all can be used within any core chamber since

parity is not an issue. Wafers range from one through eleven and the pin stack totals 14.

SFIC Key Biting Progressions/Change Keys			
System: (Using TPP)	Configuration: 6-Pin Core	Configuration: 7-Pin Core	Progression Type:
A2 System	4,096	16,384	2-Step
A3 System	46,656	279,936	1-Step
A4 System:	15,625	78,125	1-Step

\* Total Position Progression (TPP) – Master Pin is in every chamber; Change Keys & TMK different in every position; Used by BES T; Easy to implement & understand; Limited keying possibilities; More capable of reverse engineering  
\* Retaining Constant (RC) – Master Pin only in certain chambers; Change Keys & TMK the same in certain positions; Used mainly in Europe; More expensive keying possibilities; Cost is more physically secure & difficult to reverse engineer; Suited for lower level MK systems; Not suited for higher level MK systems



### Uniform Pin Stack

As you may have noticed, SFICs utilize Uniform Pin Stack Height. That is, all pins in every chamber in an A2 system, for example, must total a coded 23. Notice that I used the word "coded." That's because Frank Best

opted for using simple whole numbers for pin designations instead of using .1725" for a #5 bottom pin or .200" for a #16 driver pin. This simplified the mathematics considerably.

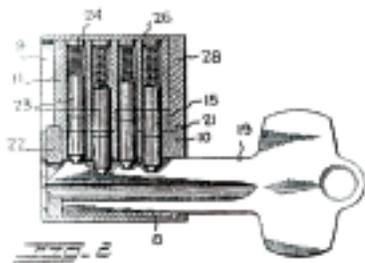
Pin stacks will usually be composed of a bottom pin, master pin, control pin and top pin (4 pins per chamber). If the chamber (or core) is not master keyed, it will not contain a master pin (3 pins per chamber). The control pin may also be called the build-up pin. The top pin may also be referred to as the driver.

### Key Relationships

One question that comes up in most IC classes is: "Can you decode for the control key in a small format system if you have the top master key?" The answer is a resounding NO! If your SFIC system follows TPP method, then there will be NO relationship between the TMK bitting and the control key bitting. That is because be chosen and then excluded from use as a change key. Computer software will eliminate the bitting so that it cannot be accidentally used; however, if you hand-write a SFIC master key system, be careful to manually exclude it from the key bitting array.

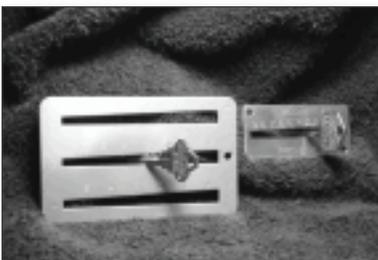
Take good care of the control key when it is in your possession. It is as valuable in a system as the TMK. Actually, it can be more so if the system is split into two top masters (no one TMK) under one control.

If you DO have the TMK and at least one change key (CK), you can easily eliminate a measurement step when decoding the pins within the core. In each position (key cut), gauge each cut on both keys and compare for the largest number



(deepest operating cut) in each corresponding position. That number will become the plug total (bottom pin + master pin = plug total) for each of the core's chambers. This numeral will be used in an upcoming formula and will eliminate you having to measure two pins in each chamber:

**TMK = 8472956**  
**Change = 2850374**  
**Deepest Operating Cut = 8872976 (Plug Total)**



Remember to gauge all SFIC keys from the tip cut to the bow cut.

### Decoding the Core

Now armed with the basics, it will be easier to comprehend how we

may proceed in decoding a single I-core from a system to determine the control key bitting for that system. As stated earlier, most SFICs are master keyed so they will contain four pins per chamber, if using TPP and following conventional masker keying rules.



As I say to students in each of the interchangeable core classes I teach for ALOA, there are many paths to the same place. More specifically, there are other formulae, though more involved and perhaps convoluted, that will allow us to arrive at the same calculation.

That being said, we will examine two decoding formulae and determine how and when to use each.

### Relying on the Top Pin!

Decoding an SFIC could be quick and easy...if. The "if" is dependent on two major factors:

- If the IC is pinned according to standard combining procedures
- If there were no errors introduced, especially with regard to the top pin

Assuming that we are utilizing an A2 system, one formula that is reliable only if the above proves true, is as follows:

Formula #1

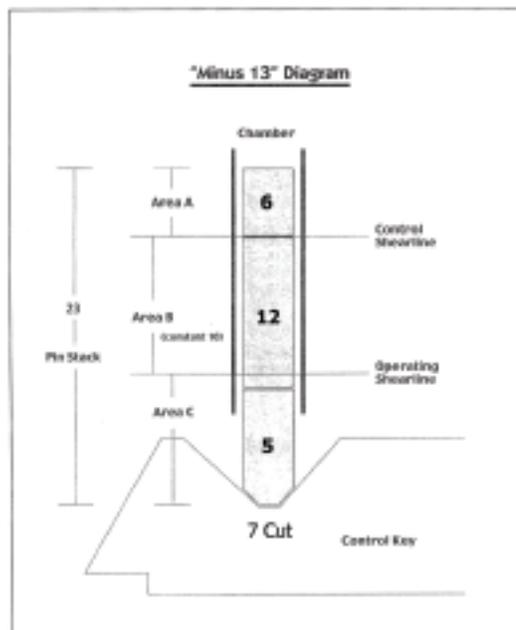
**13 – Code of Top Pin = Control Key Cut**

The relationship between 13, 10 and 23 should begin to become evident. As a matter of fact, there is a simple chart that shows the inverse relationship of the Top Pin Code to the Control Key Cut:

Top Pin Code:	Control Key Cut:
13	0
12	1
11	2
10	3
9	4
8	5
7	6
6	7
5	8
4	9

### The Magic 13

So, where exactly does the number 13 come from in Formula #1? Answer: It is the Pin Stack Height (23) minus the coded distance between the two shear lines (10). Here is a diagram that I call "The Minus 13 Diagram" which may help visually explain the numbers. It shows the correlation of the pin stack to the actual control key cut.



In this diagram we can clearly see that a seven (7) cut at the tip of the control key aligns the pin stack to the control shear line in that chamber. Notice that subtracting the value of the top pin of six (6) from 13 will yield the control cut:

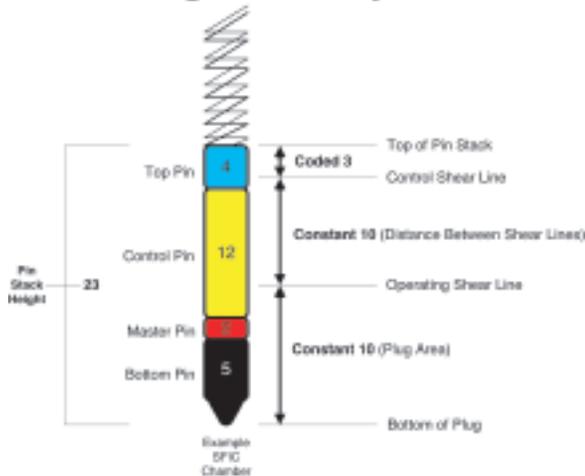
## 13 - 6 = 7

This pin stack alignment blocks the operating shear line so the plug will not turn.

### Fixed Distances

One of the most salient pieces of information with regard to understanding the decoding of the SFIC is the fixed vertical distances between the bottom of the plug to the top of the core. Notice that two distances are always constant in an SFIC. This will be discussed again later in more detail.

## SFIC Distance Relationships Using an A2 System



### Top Pin Neglect

With regard to SFIC decoding, here's a news flash: The top pin is basically useless in detecting key operation errors, even though it does drive the pin stack downward courtesy of the spring, make up the pin stack height difference between the plug total and the control pin increment, and it does guard the spring from ever getting caught up at the control shear line. So, I guess it does have a purpose in life.

Nonetheless, there exists no relationship between the functioning of the operating keys and control key and the functioning of the top pin. If a top pin was inserted one increment longer or shorter than necessary (pin stack = 24 or 22), all keys would work the core as usual and the incorrect top pin would continue to do its job completely unnoticed. That is, until someone comes along and tries to decode the core. Formula #1 is fine if the top pins are correct.

Additionally, the top pin measurements will be the same in all cores within that system. That is, if the control key is not master keyed and the cores are part of the TMK system. If the top pins in a sample core are:

**6 4 12 9 5 4 11**

Then, all cores in that system will have the top pins configured the same as shown.

## An Example

First, let's try an example of a properly combined I-core in an A2 system. Here is the pinning chart:

PINS	#1	#2	#3	#4	#5	#6	#7
TP:	6	4	12	9	5	4	11
CP:	8	12	4	12	12	12	4
MP:	6	2	4	2	4	6	8
BP:	3	5	3	0	2	1	0

Using Formula #1 requires simple subtraction to determine the control key:

Formula #1

**13 - Code of Top Pin = Control Key Cut**

$$\begin{array}{r} 13 \quad 13 \quad 13 \quad 13 \quad 13 \quad 13 \quad 13 \\ -6 \quad -4 \quad -12 \quad -9 \quad -5 \quad -4 \quad -11 \\ \hline 7 \quad 9 \quad 1 \quad 4 \quad 8 \quad 9 \quad 2 \end{array}$$

CUTS	#1	#2	#3	#4	#5	#6	#7
CTL:	7	9	1	4	8	9	2

From the previous example, and using Formula #1, our control key biting is 7914892.

Again, this formula works well IF the top pin finishes off the stack height in an A2 system at 23 (NOTE: in an A4 system, the pin stack height would be 14 and the number 8 would replace the 10 in the formula).

### Wrong Top Pin?

There exist two reasons that a top pin could be incorrect:

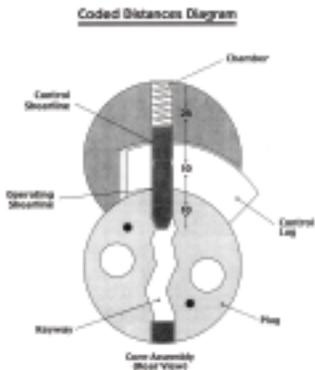
- 1) inadvertently placed there
- 2) intentionally placed there

If the person combining the core drops in a driver that was incorrect in the pin kit (dropped previously into the wrong compartment) or picks up the wrong pin, no one would be the wiser.

If a locksmith intentionally desires to thwart reverse engineering, a longer top pin in one or more chambers might occur. Keep in mind that if one measures all pins in the core, the error(s) will be discovered and the adjustment can be made accordingly. However, there are sound reasons to avoid such efforts.

<p><b>Adjusted Formula #1A</b></p> <p><b>Top Pin is one increment longer</b></p> <p><b>Pin Stack = 24</b></p> <p><b>14 - Code of Top Pin = Control Key Cut</b></p>	<p><b>Adjusted Formula #1B</b></p> <p><b>Top Pin is one increment shorter</b></p> <p><b>Pin Stack = 22</b></p> <p><b>12 - Code of Top Pin = Control Key Cut</b></p>
--	---

Here are two adjusted formulae when the top pin is one increment longer or shorter than required in an A2 system:



The Coded Distances Diagram will help to further explain the importance of the set distance between the shear lines:

Maintaining even spring pressure is desired in an SFIC. The grand incremental total, with spring, is 46 in an A2 system. This accounts for the distance from the bottom of the plug to the top of the shell. From the top of the control shear line to

the top of the shell is a distance of 26. The stack height should be 23. That only leaves three increments leeway. Pressed in caps need to remain sealed. Also, lowering the pin stack to 22 or 21 would have more adverse effects. If all chambers were at a stack height of 21, key wear would eventually cause the top pin to fall below the control shear line and lead to core failure. In addition, operating keys may turn into control keys. Not a pretty sight.

This is why when decoding NEVER discard the remainder of the pin stack until you are certain that the top pins will yield the Top Control Key.

### Master Keying the Control Key

Notice the last three words of the previous sentence: "top control key." Yes, the control key can be mastered to allow sub groups of cores to be operated by separate control keys, whereas a Top Control Key will operate all of the cores in the system. This can be accomplished by splitting the top pin into two pins. Thus, in a master keyed SFIC that also master keyed the control key, there would be five (5) pins. The procedure for this type of master keying is beyond the scope of this presentation; however, it should be noted that when using a split top pin, the formula previously shown would not yield the Top Control Key. So, what is the answer?

### Another Control Cut Formula

Obviously we are in need of a formula that will work to decode a small format core with no regard to the top pin. Here it is:

Formula #2

$$\text{CTL Pin} - (10 - \text{Plug Total}) = \text{Control Key Cut}$$

Remember that the Plug Total is the sum of the bottom pin and master pin (if there is one). When working with a multi-operational formula, always work from the inside out.

The reason the value of "10" appears in Formula #2 is that it represents the coded distance between the two shear lines

(operating & control). This formula requires measurement of the bottom pin, master pin and control pin, but disregards the top pin. Let's work an example to see the formula in action:

PINS	#1	#2	#3	#4	#5	#6	#7
TP:	8	12	7	8	5	8	5
CP:	8	2	8	6	12	6	14
MP:	4	2	8	4	4	2	2
BP:	4	7	0	5	3	6	2

Above is a seven-pin core with which we have removed the pins in order to carefully measure them with a caliper. To double-check our accuracy, total each chamber to assure that it equals 23. In this case it does NOT! Some chambers equal 23, some 24 and some 22. What a mess.

From this information we may assume that either some of our measurements were inaccurate OR the top pins are not correct. Let's implement Formula #2 for a try:

Formula #2

$$\text{CTL Pin} - (10 - \text{Plug Total}) = \text{Control Key Cut}$$

- ◆ Step #1: Add the BP + MP to determine the Plug Total in Chamber #1: (BP=4 + MP=4) equals Plug Total of 8  
*NOTE: If you have the TMK and one CK, simply decode the keys for each position, compare and use the deepest operating cut as the plug total for that chamber. It's just two pins less to measure per chamber.*
- ◆ Step #2: Subtract the Plug Total from the numeral 10:  
 $10 - 8 = 2$
- ◆ Step #3: Subtract the result above from the Control Pin:  
 $8 - 2 = 6$
- ◆ Answer: Final result is the Control Cut for Chamber #1: 6

CUTS	#1	#2	#3	#4	#5	#6	#7
CTL:	6	1	6	5	9	4	8

The control key for this core (and presumably the entire system) is: 6165948. Obviously, this formula will work regardless of the top pin lengths as long as the core is part of the system and keyed according to conventional master keying principles.

### SFIC Decoding Tools

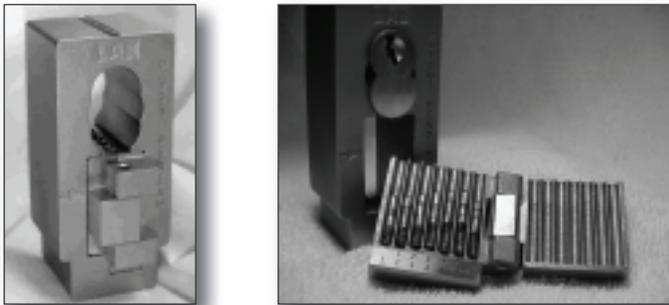
In order to efficiently decode an SFIC, there are a number of quality tools on the market to make your decoding experience more pleasant as well as cost-effective. Remember: Time = \$ and each and every mistake requires valuable time and wasted efforts.

The A-1 Block has been an industry favorite for decades. The color-coded Xperinetix version is shown here. The core is

placed in the Block upside down so the evictor tool can be placed into the ejector holes located on the bottom of the core. A small mallet will gently push out each chamber into the Block so that it can be opened and pins measured for decoding.



LAB has also created a tool that not only allows the pin stacks to be saved for decoding, but can act as a capping tool as well. The magazine is held into place with a small detent and has two sets of numbers for either a 6-pin core or a 7-pin core. Both are excellent tools for decoding the SFIC.



## Conclusion

Determining the control key for a conventional small format interchangeable core system is not an extremely difficult task, nor does it have to be a time consuming process. When re-

verse engineering becomes necessary because of lost records or unavailable biting lists, there are some caveats that the locksmith must recognize before dumping any pins.

Accurately measuring all pins within a representative core that is part of the TMK system is a sure bet to successful decoding. Pin measurement time can be saved if one can first gauge the TMK and a sample change key to determine plug total.

If the core is pinned according to accepted SFIC rules, then this formula will work well:

However, if the top pin is inaccurate in any position, operating keys will work properly, but decoding using this formula will not produce a workable control key.

► **13 - Code of Top Pin = Control Key Cut**

The following formula will result in a correct control key biting, regardless of top pin size:

► **CTL Pin - (10 - Plug Total) = Control Key Cut**

There are a number of SFIC tools available for decoding. The most popular are made by A1 Manufacturing and LAB. They retain the pins in order for decoding.

When analyzing the pin stacks, remember to check for split top pins (master keying the control) and for cores pinned outside of the system (i.e., not part of the control key system). Following these rules and formulae may help to make all of your decoding attempts successful! 2



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