How to Steal Cars – A Practical Attack on KeeLoq®

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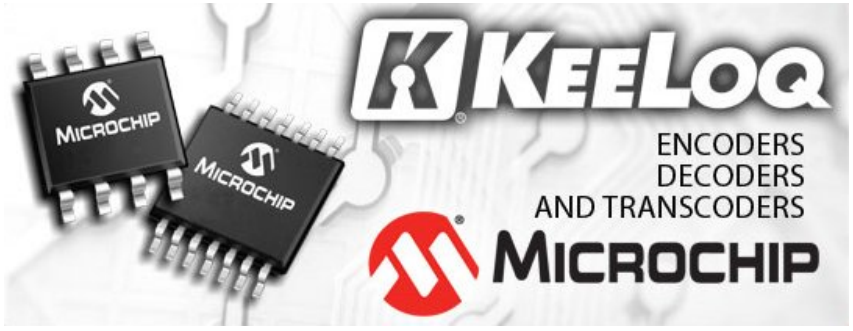
KeeLoq®

What?

- Lightweight block cipher
- 32-bit block size
- 64-bit key
- Sold by Microchip® Inc.



Where Is It Used?

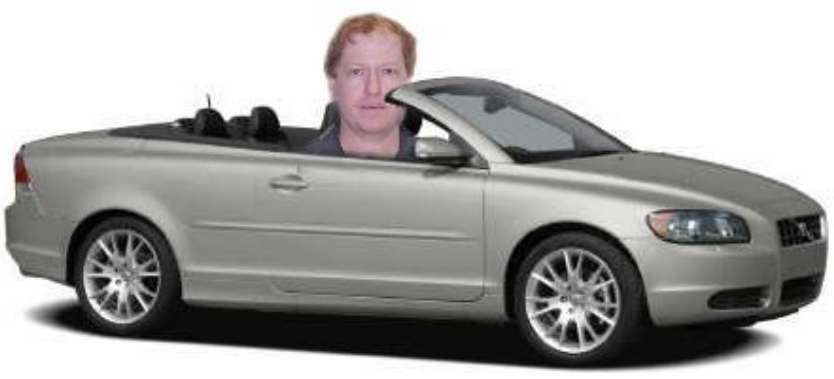
- Remote keyless entry applications
- Car locks and alarms

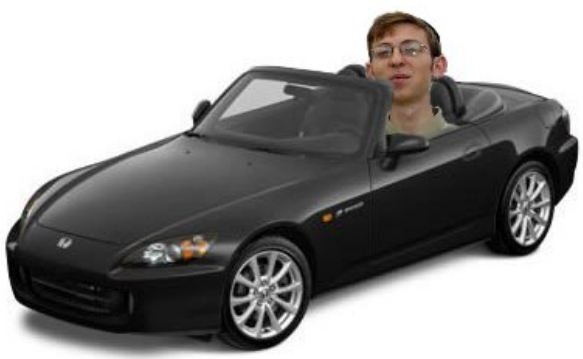
Cars?

- Supposedly all use KeeLoq®

Previous Attacks on KeeLoq®

Attack Type	Data	Time	Memory	Reference
Slide/Guess&Det.	2^{32} KP	2^{52}	16 GB	[B07]
Slide/Guess&Det.	2^{32} KP	$2^{50.6}$	16 GB	[B07b]
Slide/Algebraic	2^{16} KP	$2^{65.4}$	?	[CB07]
Slide/Algebraic	2^{16} KP	$2^{51.4}$	?	[CB07]
Slide/Fixed Points	2^{32} KP	2^{43}	$>$ 16 GB	[CB07]
Slide/Cycle	2^{32} KP	$(2^{35.4})$	16.5 GB	[CB07]
Slide/Cycle/Guess&Det.	2^{32} KP	(2^{37})	16.5 GB	[B07b]

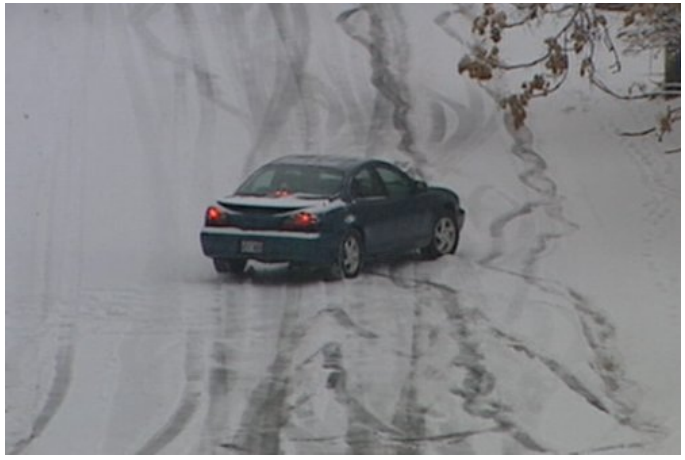




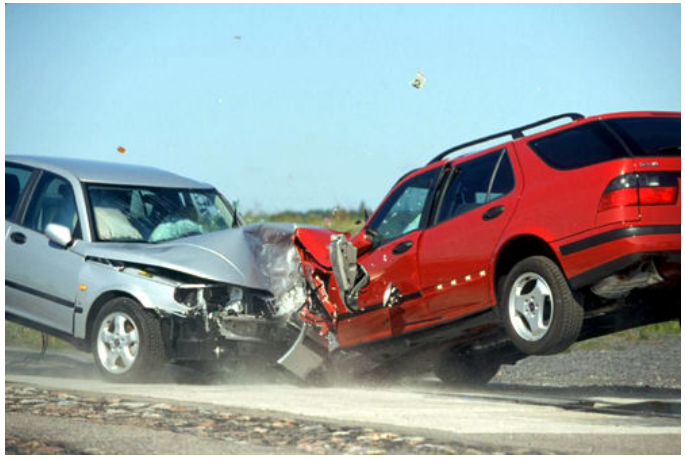
Our Attacks on KeeLoq®

Key Recovery Attack

- Based on:
  - Slide Attack
  - Meet-in-the-Middle
- 2^{16} Known (or Chosen) Plaintexts
- $2^{44.5}$ KeeLoq® Encryptions
- $<$ **3 MB** Memory



"Slide"

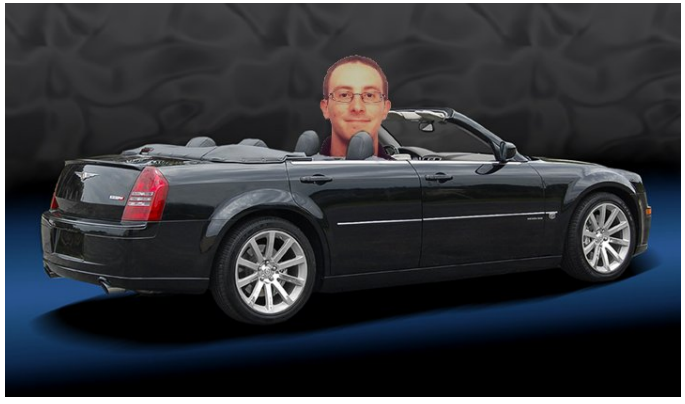


"Meet-in-the-Middle"

Our Attacks on KeeLoq® (cont.)

"Secure Learning" Key Derivation Procedure

- The manufacturer has a master secret
- For each car there is a unique identifier (known to the attacker)
- The XOR of these two gives the secret key used in this car.



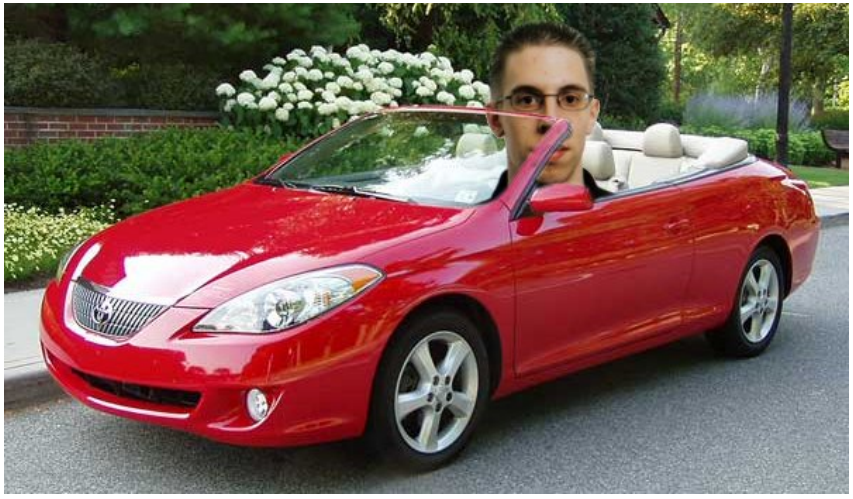
Conclusion

- Finding **one** KeeLoq key leaks the **master secret**.

Our Attacks in Practice

Gathering Data

- "Identify Friend or Foe" (IFF) protocol
- Get 2^{16} chosen plaintexts in $\approx$ **65 min.**!



Attack Implementation

- Fully implemented and tested
- $< \mathbf{2^{16} \cdot 5}$ minutes on an AMD Athlon 64 X2 4200+
- **€10 000**, 50 Dual Core machines, about **two days**
- Up to **500**$\times$ faster than previously known attacks

Conclusions

- **KeeLoq® is badly broken**
- Soon, cryptographers will all drive expensive cars*

Attack Type	Data	Time	Memory
Slide/Meet-in-the-Middle	2^{16} KP	500 CPU days	$\approx$ 3 MB
Slide/Meet-in-the-Middle	2^{16} CP	218 CPU days	$\approx$ 2 MB

http://www.cosic.esat.kuleuven.be/keeloq/

*Not all conclusions are to be taken too seriously...

References

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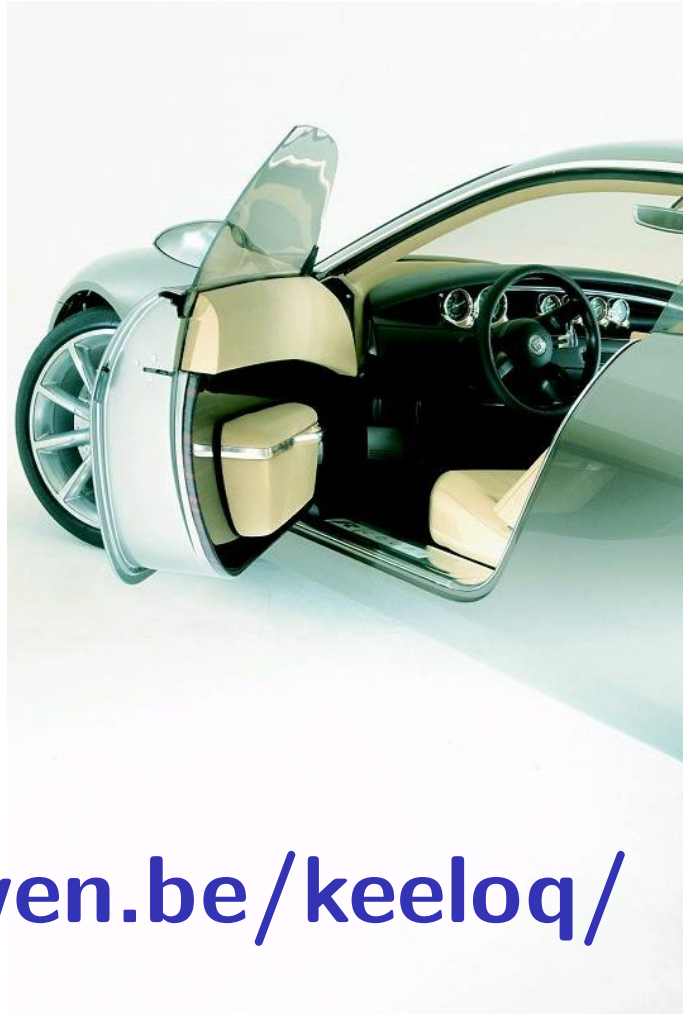

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