Constant-Time Foundations for the New Spectre Era

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Spectre attacks can break secure code.

The only robust way to prevent leaking secrets in cryptographic code is to use constant-time programming.

Unfortunately, Spectre attacks reveal that even securely written cryptographic code may unintentionally leak secret information as a result of misspeculation in the processor.

The example on the left is constant-time. But if the processor misspeculates into the branch, it can still leak bytes of secretKey via the cache!

Existing Spectre defenses are ad hoc and miss attacks.

Existing defenses are generally unsound (Microsoft’s /Qspectre compiler flag) or far too heavy-handed (Intel’s SSBD feature) — we need defenses rooted in formal methods. To that end, we define Speculative Constant-Time (SCT), the first formal notion of security for cryptographic code. Code that is SCT is secure even when the attacker has complete control over the branch predictor or other hardware features!

We can adapt new hardware features and model future Spectre variants.

Pitchfork reveals Spectre gadgets in real code.

Our semantics is also the basis for Pitchfork, our prototype analysis tool. Pitchfork explores every speculative execution path in a binary and detects whether secrets can be leaked.

We used Pitchfork to find Spectre gadgets in the libsodium and OpenSSL libraries, in code that was previously verified to be constant-time. In fact, we found that compilers themselves can insert Spectre gadgets: The vulnerable code in libsodium was part of Clang’s stack-smashing defense!