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2. Apply principles to crypto.

Let’s try some examples . . .

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Suppose we know (some) const-time machine instructions.

Suppose programming language has “secret” types.

Easy for compiler to guarantee that secret types are used only by const-time instructions.

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Eliminating branches
Let's try sorting 2 integers.
Assume int32 is secret.
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Syntax is different but “?:” is a branch by definition:

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  x[c] = x0;
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Safe compiler won’t allow this: won’t allow secret data to be used as an array index.
Cache timing is not constant: see earlier attack examples.
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void sort2(int32 *x)
{
    int32 x0 = x[0];
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    int32 c = -(x1 < x0);
    c &= x1 ^ x0;
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void sort2(int32 *x)
{ int32 x0 = x[0];
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int32 isnegative(int32 x)
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Why this works: the bits \((b_{31}, b_{30}, \ldots, b_2, b_1, b_0)\) represent the integer \(b_0 + 2b_1 + 4b_2 + \cdots + 2^{30}b_{30} - 2^{31}b_{31}\).

“1-bit signed right shift”: \((b_{31}, b_{31}, \ldots, b_3, b_2, b_1)\).

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int32 ispositive(int32 x)
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This code is incorrect!
Fails for input \(-2^{31}\),
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int64 x; int32 c;
for (x = INT32_MIN; x <= INT32_MAX; ++x) {
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### Side note illustrating -fwrapv

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int32 isnonzero(int32 x)
{ return isnegative(x) || isnegative(-x); }
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int32 ispositive(int32 x)
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Not constant-time.

Even worse: without \texttt{-fwrapv}, current gcc can remove the
\texttt{x == -x} test, breaking this code.

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Incompetent language standard.

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Safe compiler will allow this.

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for (j = 0; j < 10000000; ++j) {
    x += random(); y += random();
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Some verification strategies: 
• Think this through. 
• Write a proof. 
• Formally verify proof. 
• Automate proof construction. 
• Test many random inputs. 
• A bit painful: test all inputs. 
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void sort2(int32 *x)
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}

void sort(int32 *x, long long n)
{ long long i, j;
    for (j = 0; j < n; ++j)
        for (i = j - 1; i >= 0; --i)
            minmax(x + i, x + i + 1);
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Safe compiler will allow this if array length n is not secret.
int32 issmaller(int32 x,int32 y) {
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