INT33-C. Ensure that division and remainder operations do not result in divide-by-zero errors

The C Standard identifies the following condition under which division and remainder operations result in undefined behavior (UB):

<table>
<thead>
<tr>
<th>UB</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>The value of the second operand of the / or % operator is zero (6.5.5).</td>
</tr>
</tbody>
</table>

Ensure that division and remainder operations do not result in divide-by-zero errors.

Division

The result of the / operator is the quotient from the division of the first arithmetic operand by the second arithmetic operand. Division operations are susceptible to divide-by-zero errors. Overflow can also occur during two's complement signed integer division when the dividend is equal to the minimum (most negative) value for the signed integer type and the divisor is equal to 1. (See INT32-C. Ensure that operations on signed integers do not result in overflow.)

Noncompliant Code Example

This noncompliant code example prevents signed integer overflow in compliance with INT32-C. Ensure that operations on signed integers do not result in overflow but fails to prevent a divide-by-zero error during the division of the signed operands s_a and s_b:

```c
#include <limits.h>

void func(signed long s_a, signed long s_b) {
    signed long result;
    if ((s_a == LONG_MIN) && (s_b == -1)) {  /* Handle error */
    } else {
        result = s_a / s_b;
    }
    /* ... */
}
```

Compliant Solution

This compliant solution tests the division operation to guarantee there is no possibility of divide-by-zero errors or signed overflow:

```c
#include <limits.h>

void func(signed long s_a, signed long s_b) {
    signed long result;
    if (s_b == 0) || ((s_a == LONG_MIN) && (s_b == -1)) { /* Handle error */
    } else {
        result = s_a / s_b;
    }
    /* ... */
}
```

Remainder

The remainder operator provides the remainder when two operands of integer type are divided.

Noncompliant Code Example

This noncompliant code example prevents signed integer overflow in compliance with INT32-C. Ensure that operations on signed integers do not result in overflow but fails to prevent a divide-by-zero error during the remainder operation on the signed operands s_a and s_b:

```c
#include <limits.h>

void func(signed long s_a, signed long s_b) {
    signed long result;
    if (s_b == 0) || ((s_a == LONG_MIN) && (s_b == -1)) { /* Handle error */
    } else {
        result = s_a / s_b;
    }
    /* ... */
}
```
```c
#include <limits.h>

void func(signed long s_a, signed long s_b) {
    signed long result;
    if ((s_a == LONG_MIN) && (s_b == -1)) {
        /* Handle error */
    } else {
        result = s_a % s_b;
    }
    /* ... */
}

Compliant Solution

This compliant solution tests the remainder operand to guarantee there is no possibility of a divide-by-zero error or an overflow error:

```c
#include <limits.h>

void func(signed long s_a, signed long s_b) {
    signed long result;
    if ((s_b == 0) || ((s_a == LONG_MIN) && (s_b == -1))) {
        /* Handle error */
    } else {
        result = s_a % s_b;
    }
    /* ... */
}

Risk Assessment

A divide-by-zero error can result in abnormal program termination and denial of service.

<table>
<thead>
<tr>
<th>Rule</th>
<th>Severity</th>
<th>Likelihood</th>
<th>Remediation Cost</th>
<th>Priority</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>INT33-C</td>
<td>Low</td>
<td>Likely</td>
<td>Medium</td>
<td>P6</td>
<td>L2</td>
</tr>
</tbody>
</table>

Automated Detection

<table>
<thead>
<tr>
<th>Tool</th>
<th>Version</th>
<th>Checker</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrée</td>
<td>19.04</td>
<td>int-division-by-zero</td>
<td>Fully checked</td>
</tr>
<tr>
<td></td>
<td></td>
<td>int-modulo-by-zero</td>
<td></td>
</tr>
<tr>
<td>CodeSonar</td>
<td>5.2p0</td>
<td>LANG.ARITH.DIVZERO</td>
<td>Division by zero</td>
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<tr>
<td></td>
<td></td>
<td>LANG.ARITH.FDIVZERO</td>
<td></td>
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<tr>
<td>Compass</td>
<td>2017.07</td>
<td>DIVIDE_BY_ZERO</td>
<td>Fully implemented</td>
</tr>
<tr>
<td>/ROSE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coverity</td>
<td>2017.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cppcheck</td>
<td>1.66</td>
<td>zerodiv</td>
<td>Context sensitive analysis of division by zero</td>
</tr>
<tr>
<td></td>
<td></td>
<td>zerodivcond</td>
<td>Not detected for division by struct member / array element / pointer data that is 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Detected when there is unsafe division by variable before/after test if variable is zero</td>
</tr>
<tr>
<td>Klocwork</td>
<td>2018</td>
<td>DBZ.CONST</td>
<td></td>
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<td>DBZ.CONST.CALL</td>
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<td>DBZ.GENERAL</td>
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<td>DBZ.ITERATOR</td>
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</tr>
<tr>
<td>LDRA tool suite</td>
<td>9.7.1</td>
<td>43 D, 127 D, 248 S, 629 S, 80 X</td>
<td>Partially implemented</td>
</tr>
<tr>
<td>Parasoft C/C++test</td>
<td>10.4.2</td>
<td>CERT_C-INT33-a</td>
<td>Avoid division by zero</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Parasoft
Insure++
Runtime analysis

Polyspace Bug Finder
R2019b
CERT C: Rule INT33-C
Checks for:
- Integer division by zero
- Tainted division operand
- Tainted modulo operand
Rule fully covered.

PRQA QA-C
9.7
2830 [C], 2831 [D], 2832 [A]
2833 [S]
Fully implemented

PRQA QA-C++
4.4
2831, 2832, 2833

SonarQube C
3.11
S3518

PVS-Studio
6.23
V609

TrustInSoft Analyzer
1.38
division_by_zero
Exhaustively verified (see one compliant and one non-compliant example).

Related Vulnerabilities
Search for vulnerabilities resulting from the violation of this rule on the CERT website.

Related Guidelines
Key here (explains table format and definitions)

<table>
<thead>
<tr>
<th>Taxonomy</th>
<th>Taxonomy item</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>CERT C</td>
<td>INT32-C. Ensure that operations on signed integers do not result in overflow</td>
<td>Prior to 2018-01-12: CERT: Unspecified Relationship</td>
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<tr>
<td>CERT Oracle Secure Coding Standard for Java</td>
<td>NUM02-J. Ensure that division and remainder operations do not result in divide-by-zero errors</td>
<td>Prior to 2018-01-12: CERT: Unspecified Relationship</td>
</tr>
<tr>
<td>CWE 2.11</td>
<td>CWE-369, Divide By Zero</td>
<td>2017-07-07: CERT: Exact</td>
</tr>
</tbody>
</table>

CERT-CWE Mapping Notes
Key here for mapping notes

CWE-682 and INT33-C
CWE-682 = Union( INT33-C, list) where list =
- Incorrect calculations that do not involve division by zero

Bibliography
[Seacord 2013b] Chapter 5, "Integer Security"