Understanding Numbers in Firebird

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Who am I?

- Maintainer of www.firebase.com.br and www.firebirdnews.org
- Author of 2 Firebird books published in Brazil
- Software developer for about 30 years
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Do you wanna go crazy?!
Warnings!

1. Internal storage type depends on database dialect

2. The dialect has influence in the precision of some types and in the results of calculations

3. Depending on the datatype used, the retrieved value can be different from the original value!!

4. Decimal separator is always the dot “.”
INTEGER types

• SMALLINT
  – 16 bits
  – between -32.768 and 32.767

• INTEGER
  – 32 bits
  – between -2.147.483.648 and 2.147.483.647

• BIGINT
  – 64 bits
  – between -9.223.372.036.854.775.808 and 9.223.372.036.854.775.807
  – Only available in dialect 3
FLOATING POINT types

• FLOAT
  – 32 bits: 1 for signal, 8 for exponent and 23 for the mantissa.
  – 7 digits of precision
  – Between $-3.4 \times 10^{38}$ and $3.4 \times 10^{38}$

• DOUBLE PRECISION
  – 64 bits: 1 for signal, 11 for exponent and 52 for the mantissa.
  – 15 digits of precision
  – Between $-1.7 \times 10^{308}$ and $1.7 \times 10^{308}$
Pros and cons of floating types

• Stored following the standard defined by the IEEE (Institute of Electrical and Electronics Engineers), with an approximated representation of the real number.

• Calculations uses the math co-processor (faster).

• Not recommended due to lack of precision.
Accuracy in FLOAT/DblOUBLE (1/2)

```
SQL> select cast(1234567.1234 as float) from rdb$database;
CAST
======
1234567.1

Result displayed by IBExpert:

1234567.125
```
Imprecision in FLOAT/DOUBLE (2/2)

SQL> select cast(1234567.4321 as float) from rdb$database;

    CAST

======

    1234567.4

Result displayed by IBExpert:

1234567.375
Fixed point

- NUMERIC (p,s) / DECIMAL (p,s)
- Is stored occupying either 16, 32 or 64 bits
- \( p = \text{precision (total digits)} \) \[1 \leq p \leq 18\]
  \( s = \text{scale (number of digits after the “comma”)} \)
- \( s \) must be always lower or equal to \( p \)
- If \( p \) and \( s \) is not informed, the internal type will be INTEGER
- In FB, \( p \) always determinates the minimum number of stored digits (not follow the standard)
- The retrieved value is always exactly equal to the original value!
Internal storage of NUMERIC and DECIMAL

<table>
<thead>
<tr>
<th>PRECISION</th>
<th>INTERNAL TYPE</th>
<th>DIALECT 3</th>
<th>DIALECT 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1..4</td>
<td>NUMERIC</td>
<td>SMALLINT (*)</td>
<td>SMALLINT</td>
</tr>
<tr>
<td>1..4</td>
<td>DECIMAL</td>
<td>INTEGER (*)</td>
<td>INTEGER</td>
</tr>
<tr>
<td>5..9</td>
<td>NUMERIC e DECIMAL</td>
<td>INTEGER</td>
<td>INTEGER</td>
</tr>
<tr>
<td>10..18</td>
<td>NUMERIC e DECIMAL</td>
<td>BIGINT</td>
<td>DOUBLE PRECISION(!)</td>
</tr>
</tbody>
</table>

In Firebird, DECIMAL and NUMERICs are the same thing, if p < 10.

(*) In this case, the range of supported values are different compared to NUMERIC and DECIMAL
Determining the capacity of chosen numeric/decimals

1. Check the internal type used depending on the precision (p) of the field.

2. Check the range of values supported by the internal type.

3. Divide the min and max values by $10^s$ to know the effective range of accepted values for the field.
Determining the capacity of chosen numeric/decimals

Example:

1. NUMERIC (9,2) or DECIMAL (9,2)
2. Internally stored as INTEGER
3. Integer = -2,147,483,648 to 2,147,483,647
4. As $s = 2$, divide by $10^2$
5. Accepted range for a field declared as NUMERIC/DECIMAL (9,2) = -21,474,836,48 to 21,474,836,47
Testing the limits of numeric/decimal

SQL> select cast(-21474836.48 as numeric (9,2)),
    cast(-21474836.48 as decimal (9,2)) from rdb$database;

    CAST        CAST
=============== ============
-21474836.48  -21474836.48

SQL> select cast(-21474836.49 as numeric (9,2)),
    cast(-21474836.49 as decimal (9,2)) from rdb$database;

    CAST        CAST
=============== ============
-21474836.49  -21474836.49

Statement failed, SQLSTATE = 22003
arithmetic exception, numeric overflow, or string truncation
-numeric value is out of range
Testing the limits of numeric/decimal

SQL> select cast(32768 as decimal(4,0)) from rdb$database; --integer
  CAST
==========
  32768

SQL> select cast(32768 as numeric(4,0)) from rdb$database; --smallint
  CAST
=====

Statement failed, SQLSTATE = 22003
  arithmetic exception, numeric overflow, or string truncation
  numeric value is out of range
Moving from dialect 1 to 3

• Is there any field declared as NUMERIC or DECIMAL with $p > 9$?
  – No: there will be no problem at all
  – Yes: you may have problems!

• NUMERIC and DECIMAL with $p > 9$ are stored as double precision in dialect 1 and the existing fields will stay like this if the DB is “migrated” to dialect 3 using `gfix -sql_dialect 3`.

• New fields declared as NUM/DEC with $p > 9$, created after the DB was converted to dialect 3 will use `BIGINT` internally.

• **Recommended solution:** create a new DB using a script and pump the data from old to new database.
Integer divisions

• Dialect 1, dividing \textit{int} by \textit{int} results in \textbf{double precision}

\[
\text{l.e.: } 1/3 = 0,3333333333333
\]

• Dialect 3, divide \textit{int} by \textit{int} results in \textbf{integer}

\[
\text{l.e.: } 1/3 = 0
\]
Division/Multiplication of fixed point numerics

• In dialect 1, the division will always return a double precision.
• In dialect 3, the result will be a type with $p = 18$ and $s =$ sum of the scales of the involved types.

```sql
SQL> select cast(0.33 as numeric (9,2))/
    cast (1 as numeric(9,2))
from rdb$database;
    DIVIDE
_____________________
     0.3300
```
Division/Multiplication of fixed point numerics

SQL> select (3.00/1.00*3.5)*2.00 as total from rdb$database;

  TOTAL

=-------------------

  21.0000000

SQL> select (3.00/1.00/3.5)/2.00 as total from rdb$database;

  TOTAL

=-------------------

   0.4285700
Division/Multiplication of fixed point numerics

• There can be overflows, specially with calculations involving multiple arguments!

```
select cast(1 as numeric(15,6))*
cast(1 as numeric(9,8)) *
cast(1 as numeric(15,5)) from
rdb$database

~ 1.000000 * 1.00000000 * 1.00000
```

Integer overflow. The result of an integer operation caused the most significant bit of the result to carry.
Addition/Subtraction of fixed point numbers

- Result will have $s$ equal the biggest scale of the bigger member of the operation.
- In dialect 1, result will always have $p = 9$
- In dialect 3, result will always have $p = 18$

```
SQL> select cast(1 as numeric(9,2)) +
    cast(2 as integer) from rdb$database;
    ADD
```
```
3.00
```
```
SQL> select cast(0.5 as numeric(9,2)) -
    cast(1 as numeric(9,3)) from rdb$database;
    SUBTRACT
```
```
-0.500
```
Tips summary

• Always create the database in dialect 3, and connect to it using the same dialect.
• For “monetary” fields, choose *numeric* or *decimal* to guarantee the accuracy.
• When need to store numbers with variable scale (s), choose *double precision*.
• To migrate a DB from dialect 1 to 3, prefers to PUMP the data instead of using gfix.
• Take care with overflows in calculations involving *numeric/decimal*. 
Curiosities

INDEXES

• Numbers are stored in keys as double precision (exception to the rule is BIGINT)
• Pros:
  – For numeric/decimal, allows changing p or s without needing to reindex
  – For smallint/integer, allows converting between the types or to a type having a scale (s) without need to reindex
• Obs: Due to lack of precision of the double precision, the search if done in an interval between the bigger previous value and the lower next value related to the searched value.

GENERATORS

• Dialect 1 = integer
• Dialect 3 = bigint
Curiosities (do you wanna go more crazy??)

CHECK CONSTRAINTS and CLIENT DIALECTS
The rules applied by a check constraint are based on the dialect used by the client connection in the time the constraint was created.

Ex: check (int1 / int2) > 0.5 (rule created with dialect 1 connection)
When connecting to the DB using dialect 3:
Insert ... (int1, int2) values (2, 3); -- Success! ~ 0.66666666

Ex: check (int1 / int2) > 0.5 (rule created with dialect 3 connection)
Insert ... (int1, int2) values (2, 3); -- FAILURE! ~ 0
Changing the scale of numeric/decimal fields

- Raising the scale means shortening the range of accepted values

  I.e.:

  numeric (9,2): range -21.474.836,48 to 21.474.836,47
  numeric (9,3): range -2.147.483,648 to 2.147.483,647

  This operation is not defined for system tables.

  Unsuccessful metadata update.

  New scale specified for column AFIELD must be at most 2.
Changing the scale of numeric/decimal fields

- Changing the scale of (9,2) to 3.
- Solutions:
  - Create new field declared as (9,3)
  - Copy the values to the new field
  - Drop the old field
  - Rename the new field as the old one

- Changing to (10,3)
  - Problem if there are indexes defined for that field, since the internal type changes to bigint!
Changing the scale of numeric/decimal fields

```sql
CREATE TABLE test (afield numeric (9,2));
COMMIT;

INSERT INTO test VALUES (10.12); COMMIT;
ALTER TABLE test ALTER afield TYPE NUMERIC (9,3);

This operation is not defined for system tables. Unsuccessful metadata update.
New scale specified for column AFIELD must be at most 2.

ALTER TABLE test ALTER afield TYPE NUMERIC (10,3);
COMMIT;
UPDATE test SET afield = 10.123; COMMIT;
SELECT afield FROM test; COMMIT;
Result: 10.123
```
Changing the scale of numeric/decimal fields

```
alter table test
    alter afield type numeric (10,2); commit;

select afield from test;
commit;
Result: 10.12

alter table test
    alter afield type numeric (11,3); commit;

select afield from test;
commit;
Result: 10.123
```
Changing the scale of numeric/decimal fields

```sql
alter table test alter afield type numeric (10,2); commit;
select afield from test; commit;
Result: 10.12

/* "Dumb" Update */
update test set afield = afield; commit;

alter table test
  alter afield type numeric (11,3); commit;

select afield from test; commit;
Result: 10.120
```
Changing the scale of numeric/decimal fields

“Hardcore” solution:

update RDB$FIELDS set
RDB$FIELD_SCALE = -3
where RDB$FIELD_NAME = 'RDB$nnn';

Warning!

• Be sure that the existing values “fits” in the new range, otherwise some records will be inaccessible (corruption).

• Will not work in Firebird 3!
Additional attention!

• When changing the “size” of an existing field, it can be identified with a different type by the “language/access technology” used in the client application.
Roudings

- Firebird uses “standard rounding”:
  - Chose what digit will be the limit
  - Add 1 if the next digit is >= 5
  - Don’t change the digit if the next is < 5

I.e.:

```sql
select cast(123.45 as numeric (9,1))
from rdb$database -- result: 123.5
```

```sql
select cast(123.42 as numeric (9,1))
from rdb$database -- result: 123.4
```
Questions?

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