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Timestamps, timezones, and interval arithmetic ~ what you need to know, and what you don’t need to know

Bryn Llewellyn

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Who am I?
~
Who do I think you are?

PostgreSQL Person of the Week — Bryn Llewellyn — 2-Aug-2021

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Interviewed by: Andreas Scherbaum

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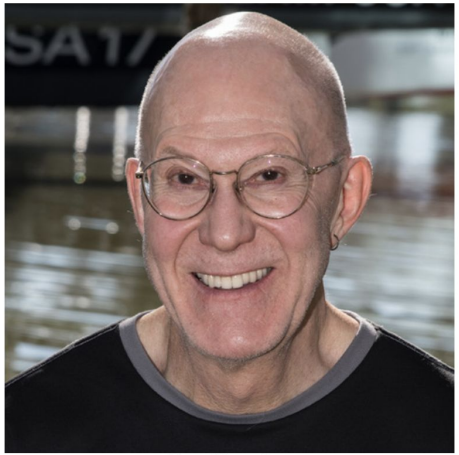
LinkedIn, Twitter, and blogs

- LinkedIn: Bryn Llewellyn
- Twitter: @BrynLite
- Blogs: blog.yugabyte.com/author/bryn/



Bryn Llewellyn

Tell us about your present job, and how it relates to PostgreSQL

I came to PostgreSQL only relatively recently, in the spring of 2019, when I left my job in the PL/SQL Team at Oracle HQ to join Yugabyte Inc. This is an exciting Silicon Valley startup, one of whose founders had been a close colleague of mine in the PL/SQL team. My first blog post in my new job, Why I Moved from Oracle to YugaByte, explains how I was easily persuaded to make this change after close to thirty years with Oracle.

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Google for:

"PostgreSQL Person of the Week" Bryn

- You know PostgreSQL very well
- Not a week goes by without you typing SQL at the *psql* prompt
- You don't need me to tell you about the reasons to use SQL
- You don't mind that Codd and Date laid the foundations as long ago as the nineteen-sixties
- Maybe you even have some exposure to YugabyteDB
- **You might find the whole business of *date-time* datatypes, and the operations that use these, mysterious and daunting**

References

Date and time data types
Download and install the date-time utilities code

“Date and time data types” in the YugabyteDB documentation:

docs.yugabyte.com/latest/api/ysql/datatypes/type_datetime/

APIs > YSQL > Data types >

Date and time data types

Synopsis

YSQL supports the following data types for values that represent a date, a time of day, a date-and-time-of-day pair, or a duration. These data types will be referred to jointly as the *date-time* data types.

DATA TYPE	PURPOSE	INTERNAL FORMAT	MIN	MAX	RESOLUTION
date	date moment (wall-clock)	4-bytes	4713 BC	5874897 AD	1 day
time [(p)]	time moment (wall-clock)	8-bytes	00:00:00	24:00:00	1 microsecond
timetz [(p)]	*avoid this*				
timestamp [(p)]	date-and-time moment (wall-clock)	12-bytes	4713 BC	294276 AD	1 microsecond
timestamptz [(p)]	date-and-time moment (absolute)	12-bytes	4713 BC	294276 AD	1 microsecond
interval [fields] [(p)]	duration between two moments	16-bytes 3-field struct			1 microsecond

Companion downloadable code:

docs.yugabyte.com/latest/api/ysql/datatypes/type_datetime/download-date-time-utilities/

Each section divider has link(s) to the relevant subsection(s) in the YugabyteDB documentation

The main point

- The date-time apparatus is vast and complex
- It's complex because of inescapable facts of astronomy and human convention
- The SQL Standard folks introduced notions in successive iterations of thinking — bringing some inconsistency
- Early PostgreSQL versions implemented questionable decisions
- You can easily go wrong
- For new work, you need only a small "tamed" subset of the whole apparatus. This depends on some user-defined utilities

Timezones

Timezones and UTC offsets

- People have always organized their lives by the the sun, so you can't get away from timezones — despite the PRC's one-timezone policy

- *pg_timezone_names* has 593 rows (in YSQL on PG 11.2)

- See the doc section "The *extended_timezone_names* view"

- Leads to the *canonical_real_country_no_dst* and *canonical_real_country_with_dst* views

  39 distinct UTC offsets across these two views

```
-- 01.sql
with
  c1 as (
    select utc_offset as "Offset"
    from canonical_real_country_no_dst
    union
    select std_offset as "Offset"
    from canonical_real_country_with_dst
    union
    select dst_offset as "Offset"
    from canonical_real_country_with_dst),
  c2 as (
    select interval_mm_dd_ss("Offset") as x
    from c1)
select to_char((c2.x).ss/3600.0, '09.99') as "Offset"
from c2
order by (c2.x);
```

```
-11.00
-10.00
-09.50
-09.00
-08.00
-07.00
-06.00
-05.00
-04.00
-03.50
 ...
 09.00
 09.50
 10.00
 10.50
 11.00
 12.00
 12.75
 13.00
 13.75
 14.00
```

- **39 distinct UTC offsets**
- **Recommendation:**
  use only timezones listed in *canonical_real_country_no_dst* and *canonical_real_country_with_dst*
- **Else:**
  Katmandu* vs *Kathmandu

Setting the timezone

Three syntax contexts that use the specification of a UTC offset
Four ways to specify the UTC offset
Recommended practice for specifying the UTC offset

Three syntax contexts that use the specification of a UTC offset

- The three contexts:
  - Using the session environment parameter TimeZone
  - Using the *at time zone* operator — or its alternative function form *timezone()*
  - Within the text of a *timestamptz* literal or for *make_timestamptz()*'s *timezone* parameter
- You can specify the UTC offset *either* indirectly by name or directly as an *interval* value

The problem – 1

```
-- 02.sql
select name, utc_offset
from pg_timezone_names
where name in ('Etc/GMT-8', 'Etc/GMT-99');
```

Result:

```
   name     | utc_offset
------------+------------
 Etc/GMT-8  | 08:00:00
```

But this causes no error!

```
set timezone = 'Etc/GMT-99';
select ('2021-06-15 12:00:00 UTC'::timestamptz)::text;
```

Result:

```
2021-06-19 15:00:00+99
```

What's going on?

```
-- 02.sql (cont.)
select name, std_offset, dst_offset
from extended_timezone_names
where name in ('Etc/GMT-8', 'America/Los_Angeles')
order by name;
```

Result:

```
       name          | std_offset | dst_offset
---------------------+------------+------------
America/Los_Angeles | -08:00:00  | -07:00:00
Etc/GMT-8           |  08:00:00  |  08:00:00
```

There are two different conventions at work: "conventional" and POSIX
Result = confusion

POSIX brings no ultimate benefit in current PostgreSQL — so avoid it

The problem – 2

```
-- 03.sql
set timezone = 'UTC';

with c as (
  select '2021-01-01 01:00:00'::timestamp as t)
select
  timezone('America/Los_Angeles',     t)::text as t1,
  timezone(make_interval(hours=>-8), t)::text as t2,
  timezone('Etc/GMT-8',               t)::text as t3,
  timezone('Foo-8',                   t)::text as t4
from c;
```

Result:

```
t1 | 2021-01-01 09:00:00+00
t2 | 2021-01-01 09:00:00+00
t3 | 2020-12-31 17:00:00+00
t4 | 2020-12-31 17:00:00+00
```

The problem – 3

```
-- 03.sql (cont.)
set timezone = 'UTC';
with c as (
  select '2021-01-01 01:00:00'::text as t)
select
  (t||' America/Los_Angeles')::timestamptz as t1,
  (t||' Foo-8'               )::timestamptz as t2
from c;
```

Result:

```
t1 | 2021-01-01 09:00:00+00
t2 | 2020-12-31 17:00:00+00
```

Recommended practice for specifying the UTC offset

- See the doc section with this title (search the ToC). Create two user-defined function overload sets, thus:
  - *set_timezone()*, with *(text)* and *(interval)* overloads
  - *at_timezone()* with *(text, timestamp)*, *(interval, timestamp)*, *(text, timestamptz)*, *(interval, timestamptz)* overloads
- Use these wrappers instead of the “raw” native functionality
- The practice ensures that only approved arguments are used

Example

```
-- 04.sql
deallocate all;
prepare stmt as
with c as (
  select '2021-01-01 01:00:00'::timestamp as t)
select
  at_timezone('America/Los_Angeles',    t)::text as t1,
  at_timezone(make_interval(hours=>-8), t)::text as t2
from c;

call set_timezone('America/New_York');
execute stmt;
```

Result:

```
t1 | 2021-01-01 04:00:00-05
t2 | 2021-01-01 04:00:00-05
```

Next:

```
call set_timezone(make_interval(hours=>-5));
execute stmt;
```

Result is the same

Counter-examples

```
-- 04.sql (cont.)
call set_timezone('Etc/GMT-99');
```

Causes error:

```
ERROR:  22023: Invalid value for parameter TimeZone "Etc/GMT-99"
HINT:  Use a name that's found exactly once in "approved_timezone_names"
```

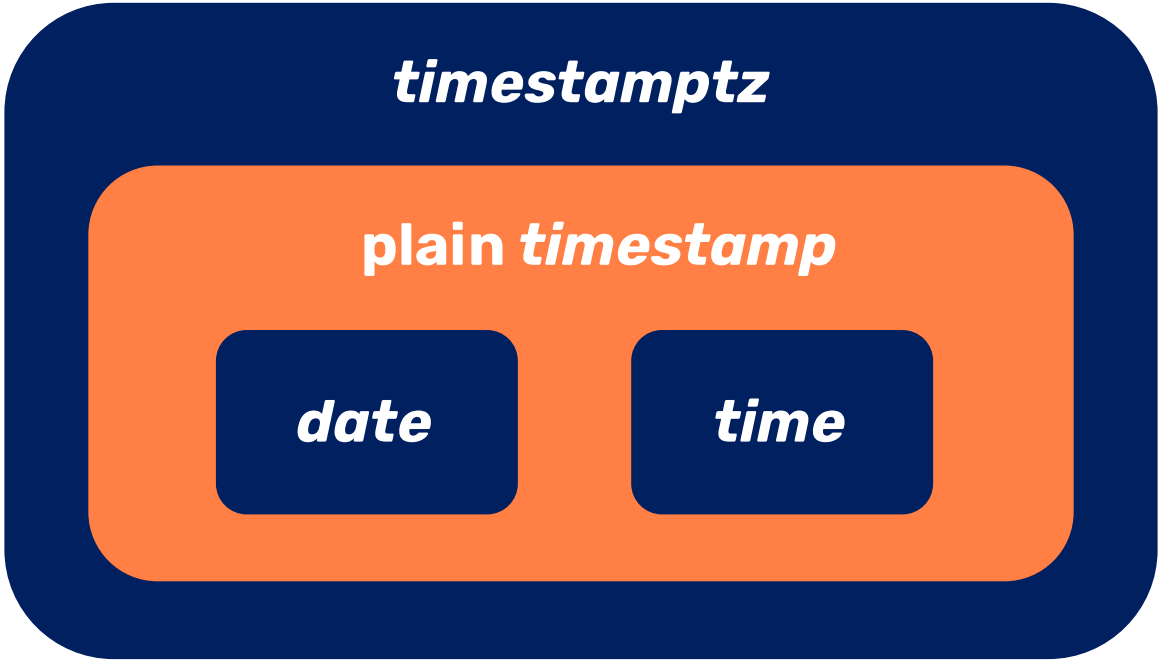
Next:

```
with c as (
  select '2021-01-01 01:00:00'::timestamp as t)
select
  at_timezone('Etc/GMT-99', t)::text as t1
from c;
```

Causes exactly the same error

Choosing the right “moment” data type from *date*, *time*, plain *timestamp*, *timestamptz*

The plain timestamp and timestamptz data types



- plain *timestamp* combines *date* and *time*
- *timestamptz* adds timezone awareness to plain *timestamp*

- **Always prefer *timestamptz* for data that you persist**

- **If appropriate, record the reigning timezone offset and name when the moment was recorded in partner columns**

- **You can always derive a plain *timestamp* value, a *date* value, or a *time* value from a *timestamptz* value**

- **Document your reasons for going against this recommended practice if you decide that you have to. This will clarify your thinking for yourself and others — and creating the write-up might make you change your mind**

Example

```
-- 05.sql
drop function if exists reigning_timezone_offset() cascade;
create function reigning_timezone_offset()
  returns interval
  language plpgsql
as $body$
declare
  t  constant timestamptz not null := transaction_timestamp();
  h  constant int         not null := date_part('timezone_hour', t)::int;
  m  constant int         not null := date_part('timezone_minute', t)::int;
  i  constant interval    not null := make_interval(hours=>h, mins=>m);
begin
  return i;
end;
$body$;

drop table if exists events cascade;
create table events(
  k               serial       primary key,
  created_ts      timestamptz  not null default transaction_timestamp(),
  created_tz      interval     not null default reigning_timezone_offset(),
  created_tzname  text         not null default current_setting('TimeZone'),
  what            text         not null);
```

Example – cont.

```
-- 05.sql (cont.)
call set_timezone('America/Los_Angeles');
insert into events(What) values('Arrived Los_Angeles');

call set_timezone('Europe/London');
insert into events(What) values('Arrived London');

call set_timezone('Asia/Kathmandu');
insert into events(What) values('Arrived Kathmandu');

call set_timezone('UTC');
select created_ts::text, created_tz::text, created_tzname, what
from events
order by k;
```

Result:

```
          created_ts            | created_tz |   created_tzname    |        what
--------------------------------+------------+---------------------+--------------------
 2021-10-27 01:34:01.597628+00 | -07:00:00  | America/Los_Angeles | Arrived Los_Angeles
 2021-10-27 01:34:01.658141+00 |  01:00:00  | Europe/London       | Arrived London
 2021-10-27 01:34:01.708605+00 |  05:45:00  | Asia/Kathmandu      | Arrived Kathmandu
```

Example – cont.

```
-- 05.sql (cont.)
with c as (
  select k, at_timezone(created_tz, created_ts) as ts, what
  from events)
select
  to_char(ts::date, 'Day dd-Mon-yyyy'        )  as "Local Date",
  to_char(ts::time,                 'hh24:mi')  as "Local Time",
  what
from c
order by k;
```

Result:

```
      Local Date        | Local Time |        what
------------------------+------------+--------------------
 Tuesday   26-Oct-2021 | 18:34      | Arrived Los_Angeles
 Wednesday 27-Oct-2021 | 02:34      | Arrived London
 Wednesday 27-Oct-2021 | 07:19      | Arrived Kathmandu
```

The timezone-sensitivity of the conversion of a *timestamptz* value to a *text* value

Sensitivity of converting between timestamptz and plain timestamp to the UTC offset

A contrived app for creating and viewing meetings

```
-- 06.sql
-- This is done when the app is installed.
drop table if exists meetings cascade;
create table meetings(k int primary key, t timestamptz);

deallocate all;

prepare cr_mtg(int, text, int, text) as
insert into meetings (k, t) values
  ($1, $2::timestamptz),
  ($3, $4::timestamptz);

prepare qry_mtg as
select
  k                                                                as "Mtg",
  to_char(t, 'Dy hh24-mi on dd-Mon-yyyy TZ ["with offset" TZH:TZM]') as "When"
from meetings
order by k;
```

Rickie lives in LA, adds two meetings, and views the result

```
-- 06.sql (cont.)

-- She has the timezone 'Europe/Amsterdam' set in her calendar preferences.
-- Notice that Daylight Savings Time starts, in LA,
-- on Sunday 14-Mar-2021
set timezone = 'America/Los_Angeles';
execute cr_mtg(
  1, '2021-03-09 08:00',
  2, '2021-03-16 08:00');

execute qry_mtg;
```

Result:

```
 Mtg |                          When
-----+-----------------------------------------------------
   1 | Tue 08-00 on 09-Mar-2021 PST [with offset -08:00]
   2 | Tue 08-00 on 16-Mar-2021 PDT [with offset -07:00]
```

Vincent lives in Amsterdam. He views his meetings

```
-- 06.sql (cont.)

-- He has the timezone 'Europe/Amsterdam' set in his calendar preferences.
-- Notice that Daylight Savings Time starts, in Amsterdam,
-- on Sunday 28-Mar-2021

set timezone = 'Europe/Amsterdam';
execute qry_mtg;
```

Result:

```
 Mtg |                          When
-----+-----------------------------------------------------
   1 | Tue 17-00 on 09-Mar-2021 CET [with offset +01:00]
   2 | Tue 16-00 on 16-Mar-2021 CET [with offset +01:00]
```

The result of *date_value('epoch', timestamptz_value)* is not affected by the session timezone

```
-- 07.sql
deallocate all;
prepare stmt as
select date_part('epoch', '2021-06-15 12:00:00 UTC'::timestamptz) as epoch;

call set_timezone('America/Los_Angeles');
execute stmt;

call set_timezone('Asia/Kathmandu');
execute stmt;
```

The result, both in 'America/Los_Angeles' and in 'Asia/Kathmandu' is the same:

```
1623758400
```

interval arithmetic

Interval arithmetic
Sensitivity of timestamptz-interval arithmetic to the current timezone

Example One

```
-- 08.sql
-- Helper function to show the internal representation of an interval value
drop function if exists i_repn(interval) cascade;

create function i_repn(i in interval)
  returns text
  language plpgsql
as $body$
declare
  repn constant interval_mm_dd_ss_t not null := interval_mm_dd_ss(i);
  mm constant text not null := (repn.mm)::text;
  dd constant text not null := (repn.dd)::text;
  ss constant text not null := (repn.ss)::text;
begin
  return '['||mm||', '||dd||', '||ss||']';
end;
$body$;
```

How does YSQL represent an interval value?

Example One — cont

```
-- 08.sql (cont.)
drop function if exists f(text) cascade;

create function f(timezone in text)
  returns table(z text)
  language plpgsql
as $body$
declare
  t constant timestamptz not null := at_timezone(timezone, '2021-03-10 12:00'::timestamp);
  i1 constant interval not null := make_interval(months=>1);
  i2 constant interval not null := make_interval(days=>30);
  i3 constant interval not null := make_interval(secs=>2592000);
begin
  z := 'i1:                    '||i1::text;                        return next;
  z := 'i2:                    '||i2::text;                        return next;
  z := 'i3:                    '||i3::text;                        return next;
  z := '';                                                         return next;

  z := 'i1_repn:               '||i_repn(i1);                      return next;
  z := 'i2_repn:               '||i_repn(i2);                      return next;
  z := 'i3_repn:               '||i_repn(i3);                      return next;
  z := '';                                                         return next;

  z := 'i2 = i1:               '||(i2 = i1)::text;                 return next;
  z := 'i3 = i1:               '||(i3 = i1)::text;                 return next;
  z := '';                                                         return next;

  z := 'i2 == i1:              '||(i2 == i1)::text;                return next;
  z := 'i3 == i1:              '||(i3 == i1)::text;                return next;
  z := '';                                                         return next;

  z := 't:                     '||t::text;                         return next;
  z := 't + i1:                '||(t + i1)::text;                  return next;
  z := 't + i2:                '||(t + i2)::text;                  return next;
  z := 't + i3:                '||(t + i3)::text;                  return next;
  z := '';                                                         return next;

  z := '(t + i1) = (t + i2):   '||((t + i1) = (t + i2))::text;     return next;
  z := '(t + i1) = (t + i3):   '||((t + i1) = (t + i3))::text;     return next;
  z := '(t + i2) = (t + i3):   '||((t + i2) = (t + i3))::text;     return next;
end;
$body$;
```

Example One — cont

```
-- 08.sql (cont.)
call set_timezone('America/Los_Angeles');
select z from f('America/Los_Angeles');

call set_timezone('Asia/Kathmandu');
select z from f('Asia/Kathmandu');
```

- The rules of *interval* arithmetic are different for the three kinds of "pure" *interval* values: pure months; pure days; and pure seconds

- In particular, the rules for pure seconds *interval* values are timezone-sensitive when the value spans the Daylight Savings Time moment

- Who knows what the rules are for hybrid *interval* values !

Example Two

```
-- 09.sql
drop function if exists f() cascade;

create function f()
  returns table(z text)
  language plpgsql
as $body$
declare
  tz    constant text        not null := 'America/Los_Angeles';
  t1    constant timestamptz not null := at_timezone(tz, '2021-03-10 12:00'::timestamp);
  t2    constant timestamptz not null := at_timezone(tz, '2021-04-09 13:30'::timestamp);
  diff  constant interval    not null := t2 - t1;
  t3    constant timestamptz not null := t1 + diff;
  b     constant boolean     not null := t3 = t2;
begin
  z := 't1:                      '||t1::text;              return next;
  z := 't2:                      '||t2::text;              return next;
  z := 't2 - t1:                 '||i_repn(diff);          return next;
  z := 't1 + (t2 - t1):          '||t3::text;              return next;
  z := '';                                                 return next;
  z := '(t1 + (t2 - t1)) = t2:   '||b::text;               return next;
end;
$body$;
```

Example Two — cont.

```
-- 09.sql (cont.)
call set_timezone('America/Los_Angeles');
select z from f();
```

Result:

```
t1:                          2021-03-10 12:00:00-08
t2:                          2021-04-09 13:30:00-07
t2 - t1:                     [0, 30, 1800]
t1 + (t2 - t1):              2021-04-09 12:30:00-07

(t1 + (t2 - t1)) = t2:   false
```

Example Three

```
-- 10.sql
drop function if exists f() cascade;

create function f()
  returns table(z text)
  language plpgsql
as $body$
declare
  tz  constant text        not null := 'America/Los_Angeles';
  t1  constant timestamptz not null := at_timezone(tz, '2021-03-10 12:00'::timestamp);
  i1  constant interval    not null := '1 month'  ::interval;
  i2  constant interval    not null := '29 days'  ::interval;
  i3  constant interval    not null := '23:59:59' ::interval;

  t2  constant timestamptz not null := ((t1 + i1) + i2) + i3;
  t3  constant timestamptz not null := ((t1 + i3) + i2) + i1;

  b   constant boolean     not null := t2 = t3;
begin
  z := 't1:                                                  '||t1::text;      return next;
  z := '((t1 + i1) + i2) + i3:                               '||t2::text;      return next;
  z := '((t1 + i3) + i2) + i1:                               '||t3::text;      return next;
  z:= '';                                                                      return next;
  z := '(((t1 + i1) + i2) + i3) = (((t1 + i3) + i2) + i1):   '||b::text;       return next;
end;
$body$;
```

Example Three — cont.

```
-- 10.sql (cont.)
call set_timezone('America/Los_Angeles');
select z from f();
```

Result:

```
t1:                                                  2021-03-10 12:00:00-08
((t1 + i1) + i2) + i3:                               2021-05-10 12:00:28-07
((t1 + i3) + i2) + i1:                               2021-05-09 12:00:28-07

(((t1 + i1) + i2) + i3) = (((t1 + i3) + i2) + i1):   false
```

Custom domain types for specializing the native interval functionality

Custom domain types for specializing the native interval functionality

Recommended practice for *interval* values and *interval* arithmetic

- See the doc section *"Custom domain types for specializing the native interval functionality"* (search the ToC).
- It ensures that you work only with pure *interval* values
- You get an error if you try, say, to add a pure seconds *interval* value to a pure days *interval* value
- It provides functions for moment subtraction and to multiply, say, a pure seconds *interval* value by a real number to return a pure seconds *interval* value result

Example One — subtracting one *timestamptz* value from another

```
-- 11.sql
-- Uses the helper function i_repn(interval) from 08.sql
drop function if exists f() cascade;

create function f()
  returns table(z text)
  language plpgsql
as $body$
declare
  t1         constant timestamptz not null := '2021-01-01 12:00:00 UTC';
  t2         constant timestamptz not null := '2021-11-30 23:55:55 UTC';
  i_hybrid   constant text        not null := i_repn(t2 - t1);
  i_mm       constant text        not null := i_repn(interval_months (t2, t1));
  i_dd       constant text        not null := i_repn(interval_days   (t2, t1));
  i_ss       constant text        not null := i_repn(interval_seconds(t2, t1));
begin
  z := 'i_hybrid: '||i_hybrid;                  return next;
  z := 'i_mm:     '||i_mm;                      return next;
  z := 'i_dd:     '||i_dd;                      return next;
  z := 'i_ss:     '||i_ss;                      return next;
end;
$body$;
```

Example One — cont

```
select z from f();
```

Result:

```
i_hybrid: [0, 333, 42955]
i_mm:     [10, 0, 0]
i_dd:     [0, 333, 0]
i_ss:     [0, 0, 28814155]
```

Example Two — multiplying a *timestamptz* value by a real number

```
select (interval_months(months=>99)*1.5432)::text;
select (interval_months(months=>99)*1.5432)::interval_months_t;
```

The second *select* causes the *23514* (*check_violation*) error:

```
value for domain interval_months_t violates check constraint "interval_months_t_check"
```

Next:

```
with c as (
  select interval_months(months=>99) as i_mm999)
select
  i_repn(i_mm999)                                    as "pure input",
  i_repn(i_mm999*1.5432)                             as "crazy hybrid result",
  i_repn(interval_months(i=>i_mm999, f=>1.5432))     as "sensible pure result"
from c;
```

Result:

```
 pure input | crazy hybrid result | sensible pure result
------------+---------------------+----------------------
 [99, 0, 0] | [152, 23, 26265.6]  | [153, 0, 0]
```

Summary

Date and time data types
Download and install the date-time utilities code

- **You've seen many ways that you can produce nonsense results. Avoid the risk as follows:**

- **Use only *timestamptz* to persist date-time values. If appropriate, record the reigning creation/modification timezone name and offset**

- **Beware *interval* arithmetic**

- **The doc sections *"Recommended practice for specifying the UTC offset"* and *"Custom domain types for specializing the native interval functionality"* come to the rescue**

- **To write brand-new application code (if you're happy simply to accept Yugabyte's various recommendations without studying the reasoning that supports these) you'll need to read only a small part of the YSQL doc's *"Date and time data types"* major section**

- **Here's what you'll need to read**

  - **Conceptual background**
  - **Real timezones that observe Daylight Savings Time**
  - **Real timezones that don't observe Daylight Savings Time**
  - **The plain *timestamp* and *timestamptz* data types**
  - **Sensitivity of converting between *timestamptz* and plain *timestamp* to the UTC offset**
  - **Sensitivity of *timestamptz-interval* arithmetic to the current timezone**
  - **Recommended practice for specifying the UTC offset**
  - **Custom domain types for specializing the native interval functionality**

- **But if you have to maintain extant *date-time* code, especially if it's poorly commented, has no external design documentation, and its authors have vanished without trace, then...**

- **You'll have to bite the bullet and study the entire *"Date and time data types"* major YSQL doc section very carefully — and especially try the code examples and make sure that you understand why they get the results that they do**

Enjoy!

Finally...

Distributed PostgreSQL on a Google Spanner Architecture": (1) Storage Layer; and (2) Query Layer

Most Advanced Open Source Distributed SQL

Query Layer

World's Most Advanced
Open Source SQL Engine

Storage Layer

World's Most Advanced
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Reuse

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