Tutorial: Time and Time Error

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Presentation overview

- What is time?
- What is time error?
- Characterising time error

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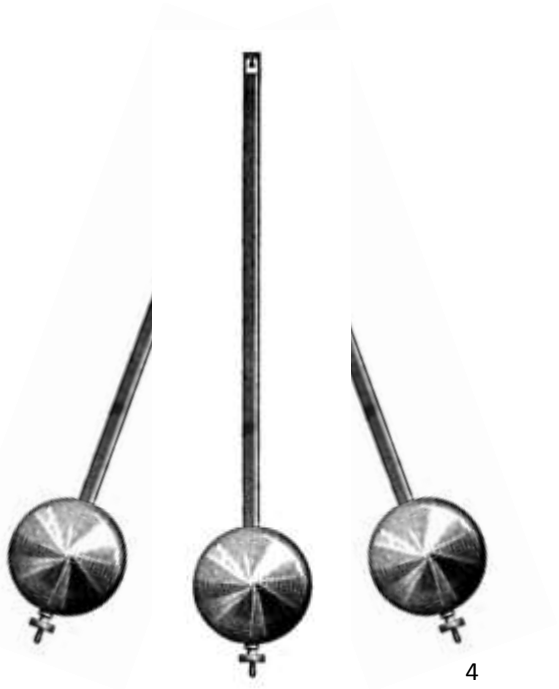
What is Time?

What is Time?

- Time is a fundamental physical dimension
  - Allows ordering and scheduling of events
  - Enables sharing of resources (e.g. time division multiplexing)
- Passage of time measured by counting a regularly repeating event
  - Astronomical events, e.g. day/night, month, year

  - Physical events, e.g. pendulum, quartz resonance or atomic transitions



Common Time

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- Common time requires a reference point
  - Time at an instant has no meaning without a reference
  - Need to start counting from a common point, or ***epoch***
  - Example: the Gregorian calendar counts years from the birth of Christ

- Legal and civil time based on UTC (Universal Time Co-ordinated)
  - Uses the Gregorian calendar epoch
  - Counts in step with TAI (atomic time)
  - Adjusted by leap seconds when required to match rotation of earth
  - Fixed offset added in each time zone to match daylight hours

- A ***time reference clock*** is a measurement device, counting at a constant frequency from a known epoch

Distributing Time

- Send a time message...
  - Need to know how long the message takes to get to the destination
    - A letter – might be usable for setting the date, e.g. next day delivery
    - A phone call – could use to set hour/minute/seconds, e.g. speaking clock
    - A packet – millisecond level accuracy
- GPS uses one-way messages
  - Uses knowledge of position and speed of light to estimate delay
- Send a return message
  - “Please check my time estimate”
    - Use round-trip delay to estimate one-way delay
    - Accuracy dependent on symmetrical delays
- Two way messaging used by both NTP and PTP

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What is Time Error?

Time Error

- The ***time error*** of a clock is the difference between the time indicated by that clock and a reference clock
- Always relative: has no meaning without a reference
- Defined by ITU-T Recommendation G.810:

$$x(t) = \mathrm{T}(t) - \mathrm{T}_{\mathrm{ref}}(t)$$

Time error

Time at measured clock

Time at reference clock

Direction of Time Error – clocks

Reference Clock:

Measured Clock:

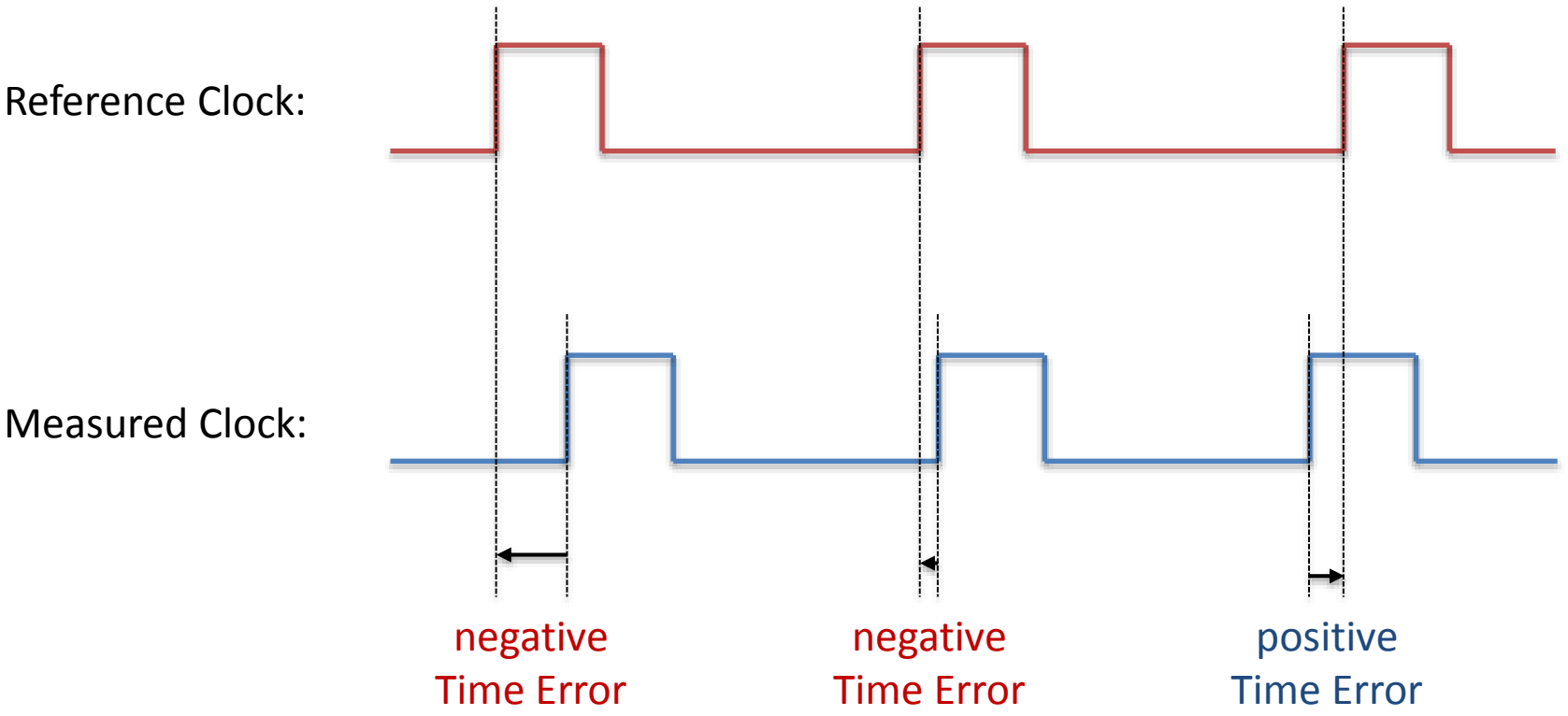
Time Error
= 11.55 – 12.00
= – 5 minutes

Time Error
= 12.05 – 11.00
= + 5 minutes

Clock lags reference *(slow, delayed)*: **negative time error**

Clock leads reference *(fast, advanced)*: **positive time error**

Direction of Time Error – signals



Signal lags reference *(slow, delayed)*: **negative time error**

Signal leads reference *(fast, advanced)*: **positive time error**

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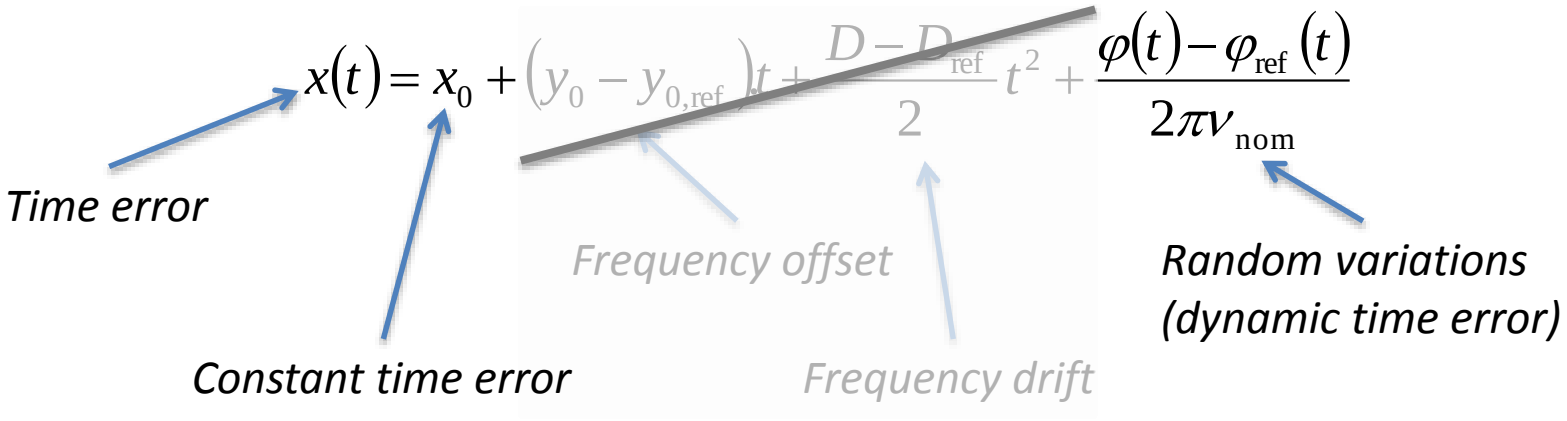
Characterising Time Error

Time Error Function

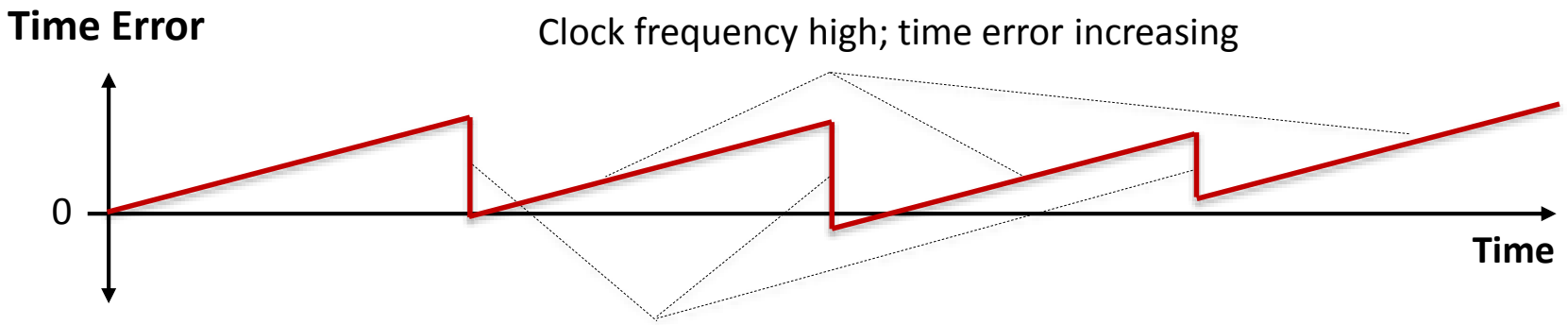
- Time error varies with time and can be expressed as a function:



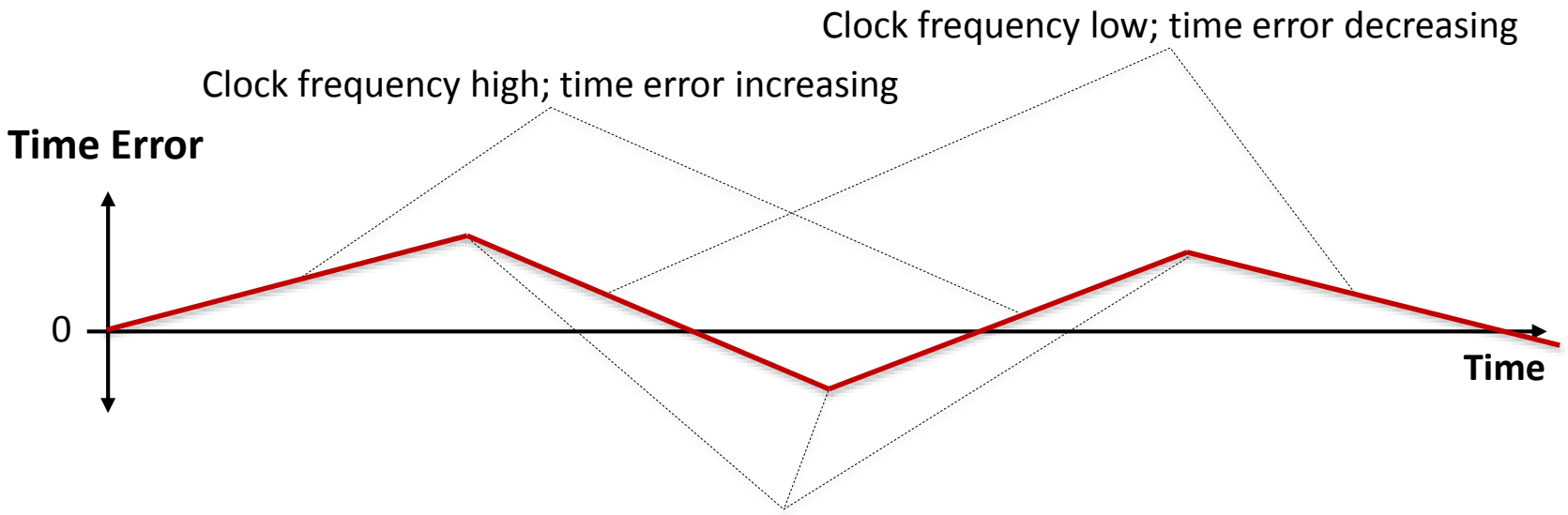
- If clocks are locked in phase, frequency offset and drift are eliminated, and time error reduces to two components:
  - ***Constant time error*** or offset
  - ***Dynamic time error*** or random variations

(Equation defined in ITU-T Recommendation G.810)

Examples of Time Error Functions



Periodic time corrections (not always accurate)



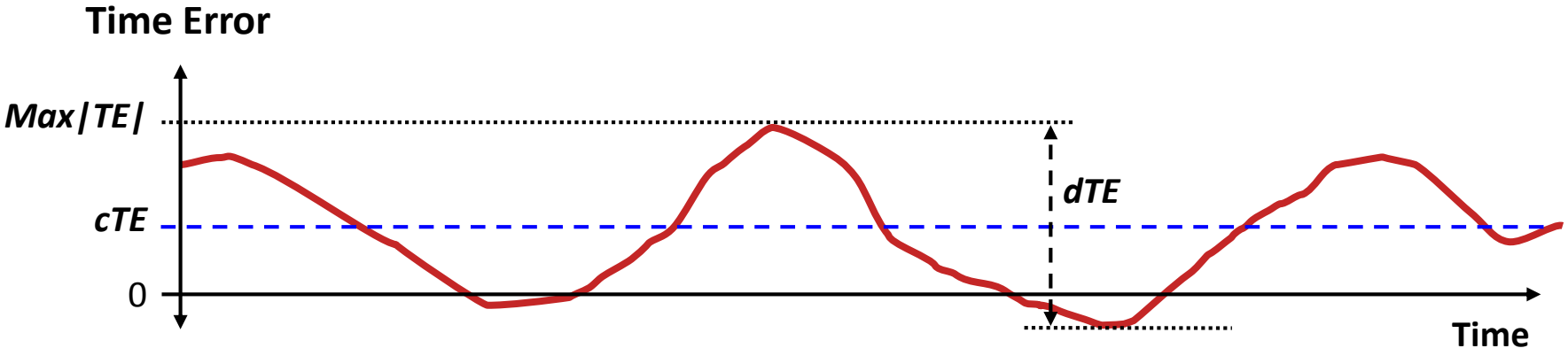
Periodic frequency corrections

Measuring Time Error

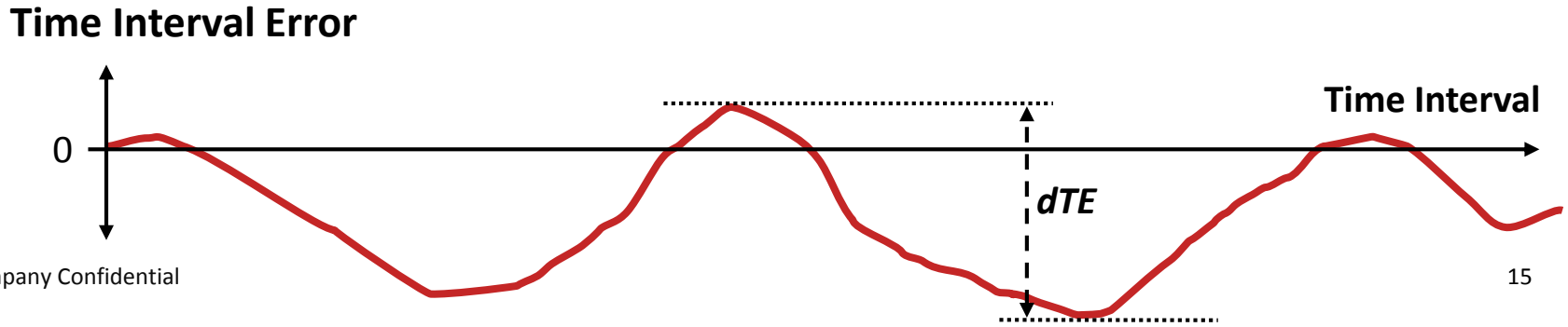
- **Need an accurate time reference!**
  - Time has no meaning without a reference
- ***Maximum Absolute Time Error (Max\|TE\|)*** is the maximum distance from zero of the time error function
  - Sign doesn't matter: excursions may be positive or negative
- ***Constant Time Error (cTE)*** is the mean of the time error function
  - Period over which mean is measured is not specified; depends on signal
- ***Dynamic Time Error (dTE)*** is the change of the time error function
  - Effectively this is the phase or time wander
  - Analysed using MTIE and TDEV

Time Error and Time Interval Error (TIE)

- Time Error measures the time difference between two clocks



- Time Interval Error measures change of time error
  - Starts at zero, then tracks the change of time error *(dTE)*



Time Error Specifications

Time error limits may be specified for:

- Equipment clock wander or noise generation
  - e.g. PRTC, T-GM, T-BC, T-TSC
- Network limits at reference points
  - e.g. output of T-GM, output of network, output of end equipment

Time error specified using a combination of three parameters:

- Max Absolute Time Error (**max|TE|**) - specified in nanoseconds
- Constant Time Error (**cTE**) - specified in nanoseconds
- Dynamic Time Error (**dTE**) - specified with MTIE & TDEV masks

Not all parameters may be specified

- Network limit at output of network only specifies max|TE| and dTE
- Noise generation of a T-BC specifies max|TE|, cTE and dTE

INTEGRITY

TIME ERROR MEASUREMENTS REQUIRE TRUE PRECISION

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