

Caution

The default or operating values used in this manual and in the program of the SyberTrol are for factory testing only and should not be construed as default or operating values for your metering system. Each metering system is unique and each program parameter must be reviewed and programmed for that specific metering system application.

Disclaimer

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Section I – Volume Calculations

Volume Calculations

Volume Calculations for Raw Volume

$$\text{Raw Volume} = \frac{\text{Input Pulses}}{\text{K Factor}}$$

Volume Calculations for Gross

$$\text{Gross Volume} = \frac{\text{Meter Factor} \times \text{Input Pulses}}{\text{K Factor}}$$

Volume Calculations for Gross @ Standard Temperature (GST)

$$\text{GST Volume} = \frac{\text{CTL} \times \text{Meter Factor} \times \text{Input Pulses}}{\text{K Factor}}$$

Volume Calculations for Gross Standard Volume (GSV)

$$\text{GSV Volume} = \frac{\text{CTL} \times \text{CPL} \times \text{Meter Factor} \times \text{Input Pulses}}{\text{K Factor}}$$

Volume Calculations for Net Standard Volume (NSV)

$$\text{NSV Volume} = \text{GSV Volume} \times \left(\left(\left(1 - \left(\frac{\% \text{BSW}}{100} \right) \right) \right) \right)$$

Section II – Mass Calculations

Mass Calculations

A.

$$\text{Mass} = \text{Gross Volume} \times \text{Observed Density}$$

or

$$\text{Mass} = \text{GSV Gross Standard Volume} \times \text{Reference Density}$$

B. Mass calculation using reference density

1. Program entry conditions

- a. A non-zero reference density entry.
- b. Valid density units select entry.
- c. Valid entries for GST compensation.
- d. Mass units

2. Hardware conditions

- a. A temperature probe installed. (*Note:* Maintenance temperature may be used instead of a temperature probe.)

3. Definition

With this method the reference density and GSV volume are used to calculate the mass. Therefore, the reference density program code must contain a non-zero entry, temperature must be installed, and GST compensation must be available.

4. Calculation method

$$\text{Mass} = \text{GSV Volume} \times \text{Reference Density}$$

C. Mass calculation using a Densitometer

1. Program entry conditions

- a. Valid density units select entry.
- b. Valid densitometer configuration entries.
- c. Mass units.

Section II – Mass Calculations

2. Hardware conditions

- a. A densitometer installed.

3. Definition

This method uses the densitometer input as the line density for calculating mass totals.

4. Calculation method

$$\text{Mass} = \text{Gross Volume} \times \text{Observed Density}$$

Section III – Meter Factor Linearization Calculations

Meter Factor Linearization Calculations

The nonlinearity of the meter calibration curve for each product can be approximated through use of a linearization method by entering meter factors at up to six different flow rates.

The meter factors used will be determined from a straight line interpolation of the meter factor and its associated flow rate.

Graphically, the linearization method used can be represented as a point slope function between points:

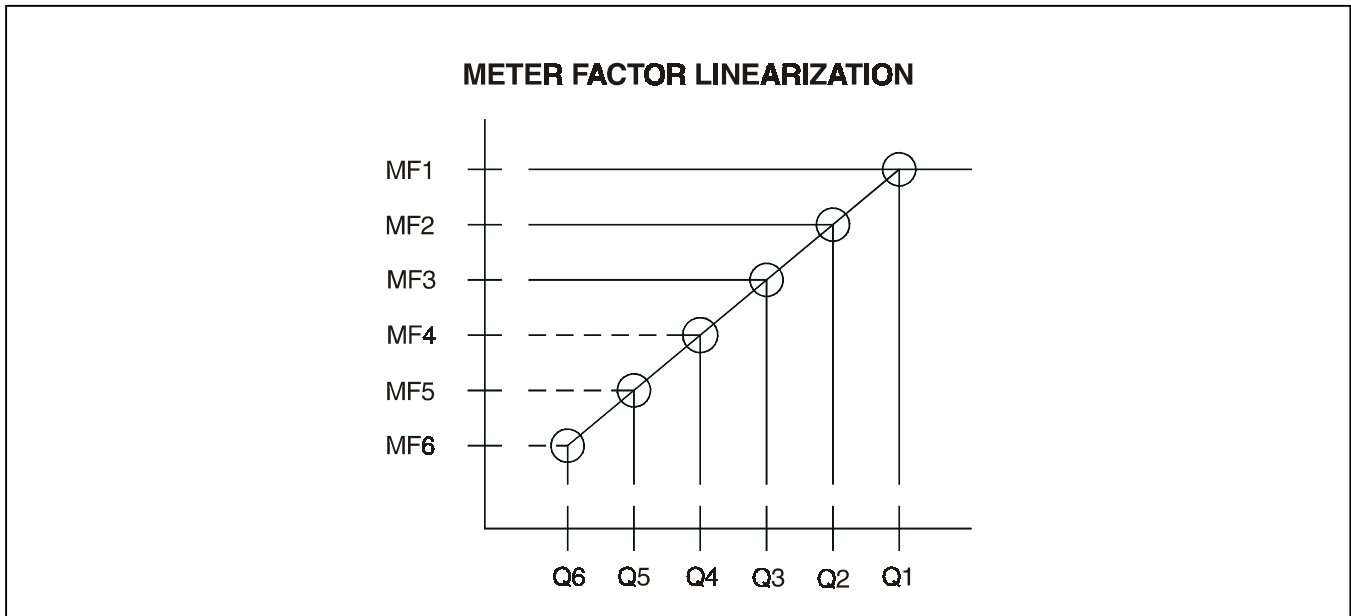


Figure 1. Meter Factor vs. Flow Rate

where: MF1, MF2, MF3, MF4, MF5, MF6 = meter factors 1, 2, 3, 4, 5, and 6
Q1, Q2, Q3, Q4, Q5, Q6 = associated flow rates 1, 2, 3, 4, 5, and 6

The number of factors used is determined by the programming. Up to six factors are available at corresponding flow rates. (See the meter factors and flow rate program codes.)

The input meter pulses may also be monitored by the unit to verify the integrity of the meters and/or transmitters. This is accomplished through pulse comparator circuitry. The pulse comparator verifies the integrity of the meter and the voltage sense verifies the integrity of the transmitter. The type and resolution of the pulse input stream to the unit is also programmable.

The input resolution, pulse and transmitter integrity, meter factors and their controls and adjustments may be defined through use of program parameters.

Section III – Meter Factor Linearization Calculations

A. Calculations for meter factors between the flow points:

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

where:

m = slope (to be calculated)

y_2 = Meter factor @ the lower flow rate

y_1 = Meter factor @ the higher flow rate

x_1 = Flow rate for the meter factor of y_1

x_2 = Flow rate for the meter factor of y_2

B. After calculating m , calculate the straight line equation:

$$y - y_1 = m(x - x_1)$$

so

$$y = m(x - x_1) + y_1$$

where:

x = the present flow rate

y = the unknown meter factor.

C. Meter Factor calculating methods

1. The six-point linearization method uses six sets of the flow rate and associated meter factor program codes.

Method:

1. From zero to factor 6 flow rate, factor 6 will be used.
2. Linearize from factor 6 flow to factor 5 flow.
3. Linearize from factor 5 flow to factor 4 flow.
4. Linearize from factor 4 flow to factor 3 flow.
5. Linearize from factor 3 flow to factor 2 flow.
6. Linearize from factor 2 flow to factor 1 flow.
7. From factor 1 flow rate up, factor 1 will be used.

Section III – Meter Factor Linearization Calculations

2. The five-point linearization method uses five sets of the flow rate and associated meter factor program codes.

Method:

1. From zero to factor 5 flow, factor 5 will be used.
2. Linearize from factor 5 flow to factor 4 flow.
3. Linearize from factor 4 flow to factor 3 flow.
4. Linearize from factor 3 flow to factor 2 flow.
5. Linearize from factor 2 flow to factor 1 flow.
6. From factor 1 flow up, factor 1 will be used.

3. The four-point linearization method uses four sets of the flow rate and associated meter factor program codes.

Method:

1. From zero to factor 4 flow, factor 4 will be used.
2. Linearize from factor 4 flow to factor 3 flow.
3. Linearize from factor 3 flow to factor 2 flow.
4. Linearize from factor 2 flow to factor 1 flow.
5. From factor 1 flow up, factor 1 will be used.

4. The three-point linearization method uses three sets of the flow rate and associated meter factor program codes.

Method:

1. From zero to factor 3 flow, factor 3 will be used.
2. Linearize from factor 3 flow to factor 2 flow.
3. Linearize from factor 2 flow to factor 1 flow.
4. From factor 1 flow up, factor 1 will be used.

5. The two-point linearization method uses two sets of the flow rate and associated meter factor program codes.

Method:

1. From zero to factor 2 flow, factor 2 will be used.
2. Linearize from factor 2 flow to factor 1 flow.
3. From factor 1 flow up, factor 1 will be used.

6. The single-point method uses one meter factor program code.

Method:

1. Factor 1 will be used at all flow rates.

Section IV – Temperature Calculations

Volume Correction for Temperature (CTL) Calculation

1. Volume correction factor terms, formulas and constants:

a) Definition of terms

Δt = Actual Temperature - Reference Temperature

k_0 & k_1 = API product range constants

A & B = API product special range constants

ρ_t = density @ actual temperature

ρ_{60} = density @ reference temperature

α = coefficient of expansion

b) Formulas used

1. Alpha calculation

a. Using k_0 & k_1 constants

$$\alpha = \frac{k_0}{\rho_{60}^2} + \frac{k_1}{\rho_{60}}$$

b. Using A & B constants

$$\alpha = A + \frac{B}{\rho_{60}^2}$$

2. CTL calculation

$$\frac{\rho_t}{\rho_{60}} = e^{(-\alpha \times \Delta t (1 + 0.8\alpha \times \Delta t))}$$

3. ρ_t calculation

$$\rho_t = \rho_{60} \times e^{(-\alpha \times \Delta t (1 + 0.8\alpha \times \Delta t))}$$

4. API to density calculation

$$\rho_{60} = \frac{141.5 \times \text{weight of water at ref. conditions}}{131.5 + \text{API}}$$

Section IV – Temperature Calculations

5. Relative density to density calculation

$$\rho_{60} = \text{Relative Density} \times \text{Weight of water at reference conditions}$$

c) Constants used

1. Weight of water at reference conditions

Weight	Temperature
999.060 Kg/M ³	15°C
62.366 Lbs/Ft ³	60°F

2. k₀ and k₁ constants for different API products

API Table	Range	k ₀	k ₁
5A, 6A, 23A, and 24A Crude Oils	API 0 to 100 RD 0.6110 to 1.0760 DEN 38.11 to 67.11 LB/F ³ DEN 610.5 to 1075.0 KG/M ³	341.0957	0.0
5B, 6B, 23B and 24B Diesel, Heating and Fuel Oils	API 0 to 37 RD 0.8400 to 1.0760 DEN 52.38 to 67.11 LB/F ³ DEN 839.0 to 1075.0 KG/M ³	103.8720	0.2701
5B, 6B, 23B and 24B Jet Fuels and Kerosene	API 37.1 to 47.9 RD 0.7890 to 0.8395 DEN 49.19 to 52.35 LB/F ³ DEN 788.0 to 838.5 KG/M ³	330.3010	0.0
5B, 6B, 23B and 24B Gasolines and Naphthanes	API 52.1 TO 85 RD 0.6535 to 0.7705 DEN 40.77 to 48.07 LB/F ³ DEN 653.0 to 770.0 KG/M ³	192.4571	0.2438
5D and 6D Lube Oils	API -10 to 45 RD 0.8008 to 1.1652 DEN 49.94 TO 72.67 LB/F ³ DEN 800.0 TO 1164.0 KG/M ³	144.0427	0.1896
53A and 54A Crude Oils	API 0 to 100 RD 0.6110 to 1.0760 DEN 38.11 to 67.11 LB/F ³ DEN 610.5 to 1075.0 KG/M ³	613.9723	0.0
53B and 54B Diesel, Heating, and Fuel Oils	API 0 to 37 RD 0.8400 to 1.0760 DEN 52.38 to 67.11 LB/F ³ DEN 839.0 to 1075.0 KG/M ³	186.9696	0.4862

Section IV – Temperature Calculations

API Table	Range	k_0	k_1
53B and 54B Jet Fuels and Kerosenes	API 37.1 to 47.9 RD 0.7890 to 0.8395 DEN 49.19 to 52.35 LB/F ³ DEN 788.0 to 838.5 KG/M ³	594.5418	0.0
53B and 54B Gasolines and Napthanes	API 52.1 TO 85 RD 0.6535 to 0.7705 DEN 40.77 to 48.07 LB/F ³ DEN 653.0 to 770.0 KG/M ³	346.4228	0.4388
53D and 54D Lube Oils	API -10 to 45 RD 0.8008 to 1.1652 DEN 49.94 TO 72.67 LB/F ³ DEN 800.0 TO 1164.0 KG/M ³	259.2769	0.3413

3. A and B constants (Special Range)

API Table	Range	A	B
Special Range (°F)	API 48 to 52 RD 0.7710 to 0.7885 DEN 48.10 to 49.16 LB/F ³ DEN 770.5 to 787.5 KG/M ³	-0.00186840	1489.0670
Special Range (°C)	API 48 to 52 RD 0.7710 to 0.7885 DEN 48.10 to 49.16 LB/F ³ DEN 770.5 to 787.5 KG/M ³	-0.0336312	2680.321

4. Old Tables 24 and 54

API Table	Range
24	API 100 to 150 RD 0.5000 to 0.6000 DEN 31.18 to 37.42 LB/F ³
54	API 100 to 150 RD 0.5000 to 0.6000 DEN 499.5 to 599.4 KG/M ³

Section IV – Temperature Calculations

Volume correction factor calculation options

- A. Coefficient of expansion used (table 6C or 54C)
1. Program entry conditions
 - a. Correct entry in API table and product (code 444)
 - b. Valid entry in reference density (code 445)
 2. Hardware conditions
 - a. A temperature probe installed.
- (Note: Maintenance temperature may be used instead of a temperature probe.)*
3. Calculation method
 - a. Input temperature units.
 - b. Calculate delta t (Δt).
 - c. Coefficient of expansion entry (program code 445) will be used as alpha.
 - d. Calculate the CTL.

$$CTL = e^{(-\alpha \times \Delta t (1 + 0.8\alpha \times \Delta t))}$$

- B. API tables with API product range A, B, or D (with reference density)
1. Program entry conditions:
 - a. A valid API table and product entry (code 444).
 - b. A valid reference density entry (code 445).
 - c. A valid density units entry (code 450).
 - d. A valid temperature units entry (code 441).
 - e. A valid reference temperature entry (code 442).

2. Hardware conditions:
 - a. A temperature probe installed.

(Note: Maintenance temperature may be used instead of a temperature probe.)

3. Definition:

In this mode of operation, the SyberTrol software will calculate the CTL using the k_0 and k_1 constants of the API product range selected. (If API product range B is selected, it will use the k_0 and k_1 constants for the product range it is measuring.) All related entries shown above must correspond. If table 53 or 54 is used, the temperature units must be in Celsius.)

4. Calculation method
 - a. Input temperature units.
 - b. Calculate delta t (Δt).
 - c. Calculate the alpha and the CTL using the reference density entered.
 1. Calculate alpha with the proper k_0 and k_1 constants for API product range selected.
 2. Calculate CTL.

Section IV – Temperature Calculations

C. API tables with API product range A, B, or D (live density)

1. Program entry conditions:

- a. A valid API table and product entry (must be an odd-numbered table) (code 444).
- b. A valid density units entry (code 450).
- c. Valid density span entries (codes 451 and 452).
- d. A valid temperature units entry (code 441).
- e. A valid reference temperature entry (code 442).
- f. Density is selected in temperature/density select (code 449).

2. Hardware conditions

- a. A temperature probe installed.

(Note: Maintenance temperature may be used instead of a temperature probe.)

- b. A densitometer installed.

3. Definition:

In this mode of operation, the SyberTrol software will calculate the CTL using the k_0 and k_1 constants of the API product range selected. (If API product range B is selected, it will use the k_0 and k_1 constants for the product range it is measuring.) All related entries shown above must correspond. If table 53 or 54 is used, the temperature units must be in Celsius. Density units selected must match the densitometer output.

4. Calculation method:

- a. Input temperature units.
- b. Calculate delta t (Δt).
- c. Input density units.
- d. Calculate the density corrected to reference temperature by an iterative solution of the following steps, which will in turn calculate the required CTL.
 1. Calculate alpha selecting proper k_0 and k_1 constants for API product range selected (code 444).
 2. Calculate the CTL.
 3. Calculate the corrected density.
 4. Check for convergence of the solution. (A converged solution is reached when a change in density is less than 0.05 kg/m^3 in two successive passes.)
 5. For API product range B only, check to see that the k_0 and k_1 constants used are in the range of the corrected density calculated. If not, repeat steps 1 through 4 with the correct constants.

D. API (old) tables 24 and 54 with API range 100 to 150

1. Program entry conditions:

- a. A valid API table and product entry (code 444).
- b. A valid reference density entry (code 445).
- c. A valid density units entry (code 450).
- d. A valid temperature units entry (code 441).
- e. A valid reference temperature entry (code 442).

2. Hardware conditions:

- a. A temperature probe is installed.

(Note: Maintenance temperature may be used instead of the temperature probe.)

Section IV – Temperature Calculations

3. Definition:

In this mode of operation, the SyberTrol software will use the reference density and the current temperature to retrieve the CTL from the selected table. (If table 24 is selected, temperature units must be Fahrenheit. If table 54 is selected, temperature units must be Celsius.)

4. Calculation method

- a. Input temperature units.
- b. Using the temperature and reference density, go to the proper table (24 or 54) and select the proper CTL.

The resistance temperature detector (RTD) supplies resistance from which temperature may be calculated. The Callendar-Van Dusen equation is used to approximate the RTD curve.

$$T = \frac{-A + \sqrt{A^2 - 4B \left(1 - \frac{R}{R(0)}\right)}}{2B}$$

Where:

- T = temperature in °Celsius
- R = resistance at temperature T
- R(0) = resistance at 0°C
- A = 3.90802 E-3
- B = -5.80195 E-7

Section V – Pressure Calculations

Volume Correction for Pressure (CPL) Calculation

1. Definition of terms

- P = Pressure
- P_e = Equilibrium pressure (Vapor pressure @ temperature)
- F = Compressibility factor (API Chapters 11.2.1 or 11.2.2)
- CPL = Correction for pressure on a liquid

2. Formula used

a.

$$CPL = \frac{1}{1 - (P - P_e) \times F}$$

b.

$$API = \frac{141.5 \times \rho_{60} H_2O}{\rho_{60} Product} - 131.5$$

c. For 0 to 90 API

$$F = e^{A + (B \times T) + \frac{C}{\rho^2} + (D \times \frac{T}{\rho^2})}$$

where:

- A, B, C and D = constants
- T = Temperature (°F or °C dependent)
- ρ = Grams/cm³ @ 60°F or grams/cm³ @ 15°C

	A	B	C	D
°F	-1.99470	0.00013427	0.79392	0.0023260
°C	-1.62080	0.00021592	0.87096	0.0042092

Note that *F* is scaled before usage in the CPL formula above. If temperature is in degrees Fahrenheit, *F* is multiplied by 0.00001. If temperature is in degrees Celsius, *F* is multiplied by 0.000001.

d. For 91 to 220 API

$$F = \frac{1}{A + (D_{\rho} \times B)}$$

where:

Section V – Pressure Calculations

A and B = Calculated variables based on temperature & density

D_p = Pressure above equilibrium in (PSI or Kpa dependent) (i.e., Pressure – Vapor Pressure)

$$A * 10^{-5} = A_1 * TR^2 + A_2 * TR^2 * G^2 + A_3 * TR^2 * G^4 + A_4 * TR^3 * G^6 + A_5 \\ + A_6 * TR^3 * G^2 + A_7 * TR^3 * G^4 + A_8 * TR * G^2 \\ + A_9 * TR * G + A_{10} * TR + A_{11} * G$$

If temperature units are degrees Celsius, then $A = A * 6.894757E0$

$$B * 10^{-5} = B_1 * TR^2 + B_2 * TR * G^2 + B_3 * G + B_4 * G^2$$

where:

TR = Temperature, in degrees Rankine

G = Relative density

$A_1 = -2.1465891E-6$

$A_2 = +1.5774390E-5$

$A_3 = -1.0502139E-5$

$A_4 = +2.8324481E-7$

$A_5 = -0.95495939E0$

$A_6 = +7.2900662E-8$

$A_7 = -2.7769343E-7$

$A_8 = +0.036458380$

$A_9 = -0.05110158E0$

$A_{10} = +0.00795529E0$

$A_{11} = +9.13114910E0$

$B_1 = -6.0357667E-10$

$B_2 = +2.2112678E-6$

$B_3 = +0.00088384E0$

$B_4 = -0.00204016E0$

Vapor Pressure Calculations

A. Linearization method: Calculate the slope of a line between two points :

1. Calculate m.

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

where:

m = Slope (to be calculated)

y_2 = Vapor pressure @ x_2 in PSI, Bars or Kg/cm².

y_1 = Vapor pressure @ x_1 in PSI, Bars or Kg/cm².

x_1 = Temperature for vapor pressure of y_1

x_2 = Temperature for vapor pressure of y_2

(Note: Temperature may be in degrees C or F.)

Section V – Pressure Calculations

2. After calculating m , calculate the straight line equation:

$$y - y_1 = m(x - x_1)$$

so

$$y = m(x - x_1) + y_1$$

where:

x = the present temperature

y = the unknown vapor pressure

B. GPA TP-15 Method: Calculate vapor pressure through the use of the following formula as outlined in the GPA TP-15.

$$\text{Vapor Pressure} = e^{A_0 + A_1 \times \text{relative density} + \frac{B_0 + B_1 \times \text{relative density}}{\text{temperature}^\circ\text{F} + 443}}$$

Where A_0 , A_1 , B_0 , and B_1 are constants dependent on the range of the density.

Note that this method requires GST compensation installed as the relative density is used in the calculation.

Section VI – Load Average Calculations

Load Average Values

The load average temperature, pressure, density, and meter factor will be accumulated in a volume-weighted method (see below). At the start of any batch, a reading of each load average parameter installed will be taken. This will be the value used for the initial average. Thereafter, another sample will be taken along with the accumulated volume to determine the load average value. Samples will be taken only when flow is in progress. The following formula will be used to calculate the load average value.

Load Average Value (LAV) Formula:

$$\text{LAV} = \frac{(\Delta \text{ volume} \times \text{Current parameter reading})}{\text{Total Volume}}$$

Load average temperature, pressure and density values will only be calculated when correct entries have been made in the temperature, pressure or density program codes. If a probe or transducer alarm occurs, the corresponding current reading will stop being used in the calculation of the load average value. The current load average value for the failed probe or transducer stands until flow goes to zero. At this point the alarm must be cleared and the problem corrected for normal load average calculations to resume.

Section VII – Pulse Interpolation

Dual Pulse Chronometry

This technique, developed by the French, is termed dual pulse chronometry. High resolution crystal controlled clock pulses (approximately 150,000 Hz) are gated into counter T1, by integral meter pulses beginning with the first meter pulse after the first detector switch and ending with the first meter pulse after the second detector switch. These clock pulses are termed T1. N is the number of whole meter pulses which occurred in the time interval represented by T1. T1/N is equal to the number of clock pulses equivalent to a whole meter pulse.

A second precision counter, T2, is capable of accumulating the same high-resolution clock pulses from the same source as Counter T1. Counter T2 starts accumulating clock pulses when the first detector switch is activated and stops after the second detector is activated. T2 then represents the number of clock pulses equivalent to the precisely calibrated prover volume.

By dividing T2 by the pulses per whole meter pulse T1/N, we can then determine the magnitude of the fractional meter pulses which occur between the first detector and the first meter pulse and the last detector and the next to the last meter pulse. This formula reduces to $N(T2/T1)$ and is equal to N' the exact number of whole and fractional meter pulses between detectors.

All of the above methods have been used for pulse interpolation with acceptable results.

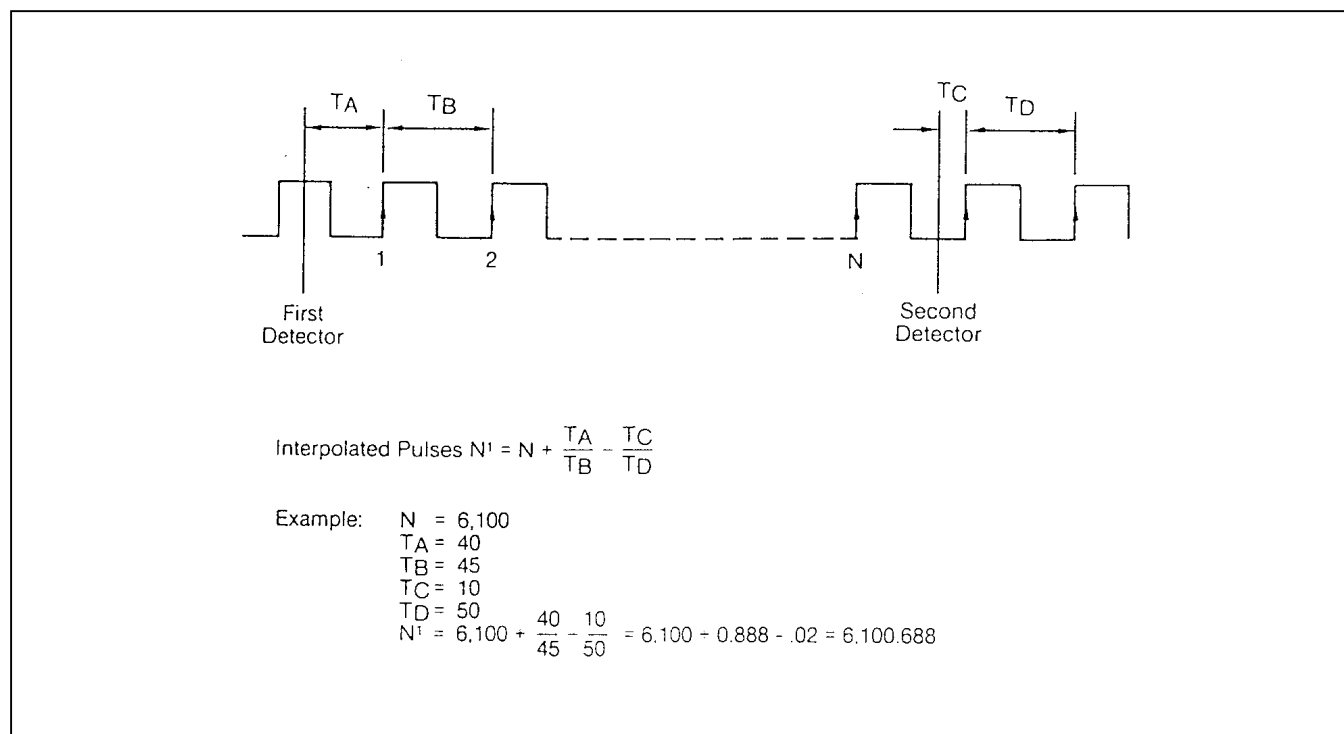


Figure 2. Four Timer or Low Frequency Pulse Technique

Section VII – Pulse Interpolation

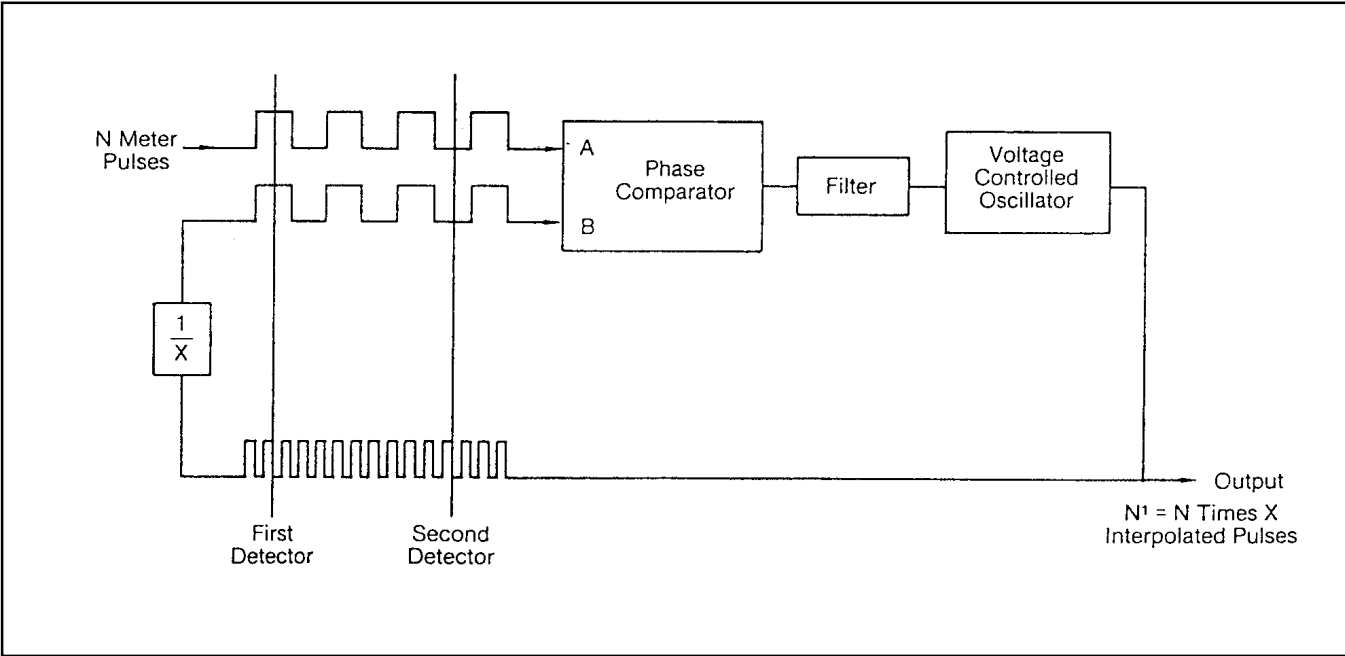


Figure 3

Section VIII – Related Publications

The following literature can be obtained from FMC Measurement Solutions Literature Fulfillment at johno@gohrs.com or online at www.fmcmeasurementsolutions.com. When requesting literature from Literature Fulfillment, please reference the appropriate bulletin number and title.

SyberTrol

Specifications	Bulletin SS09036
Programming	Bulletin MN09041
Installation.....	Bulletin MN09043
Communications.....	Bulletin MN09044
Operations	Bulletin MN09045
Modbus Communications	Bulletin MN09048

SyberMate

Specifications	Bulletin SS09037
Installation/Operations.....	Bulletin MN09047

Hand Held Controller

Specifications	Bulletin SS09039
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Revisions included in TP09002 Issue/Rev. 0.1 (11/01):
Added Caution and Disclaimer

The specifications contained herein are subject to change without notice and any user of said specifications should verify from the manufacturer that the specifications are currently in effect. Otherwise, the manufacturer assumes no responsibility for the use of specifications which may have been changed and are no longer in effect.

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