Design of Gear Box

Using PSG Design Data Book

GOPINATH G
ASST.PROF - MECHANICAL

Sample Problem

Design a gearbox with 12 speeds from a source of motor with a speed of 1600. The required speed range is from 160 rpm to 2000 rpm.

Given:

n = 12

N_{min} = 160 rpm

N_{max} = 2000 rpm

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Step - 1 “Calculation of Step ratio”

$$\frac{N_{max}}{N_{min}} = \varnothing^{\,n-1}$$

$$\frac{2000}{160} = \varnothing^{\,12-1}$$

$$\varnothing = 1.258$$

Referring PSG Data Book P. No : 7.20 the calculated step ratio is not a std. value

Since its not a std. value, Using multiples of std. value the required step ratio is calculated

1.6 - Cannot be used

1.25 - Cannot be used

1.12 - 1.12 x 1.12 = 1.254

1.06 - 1.06 x 1.06 x 1.06 x 1.06 = 1.238

Multiples of 1.12 gives nearest value of 1.258

As 1.06 is multiplied 1 times we skip 1 speed

Hence std. Ø = 1.12 & R 20 series is selected

Step - 2 “Selection of Speeds”

100	112	125	140	160	180	200	224	250	280	315	355	400	450	500
560	630	710	800	900	1000	1120	1254	1404	1573	1762	1973	2210		

The obtained speeds are;
160,200,250,315,400,500,630,800,
1000,1254,1573,1973

Check for deviation

The allowable deviation and actual deviation is calculated,

$$\text{Allowable deviation} = \pm 10\,(\text{Ø} - 1)\,\%$$

$$= \pm 10\,(1.258 - 1)\,\%$$

$$= \pm 2.58\,\%$$

$$\text{Actual deviation} = (N_{\text{max actual}} - N_{\text{max}}) \times \frac{N_{\text{min}}}{N_{\text{max}}}$$

$$= (1973 - 2000) \times \frac{160}{2000}$$

$$= \mathbf{-\ 2.16\ \%}$$

Since the deviation is within the allowable range we can design for standard speeds.

The selected standard speeds are;
160, 200, 250, 315, 400, 500, 630, 800, 1000, 1254, 1573, 1973

Step - 3 “ Structural formula & Ray Diagram ”

The structural formula for 12 speed gear box is

3 (1) 2 (3) 2 (6)

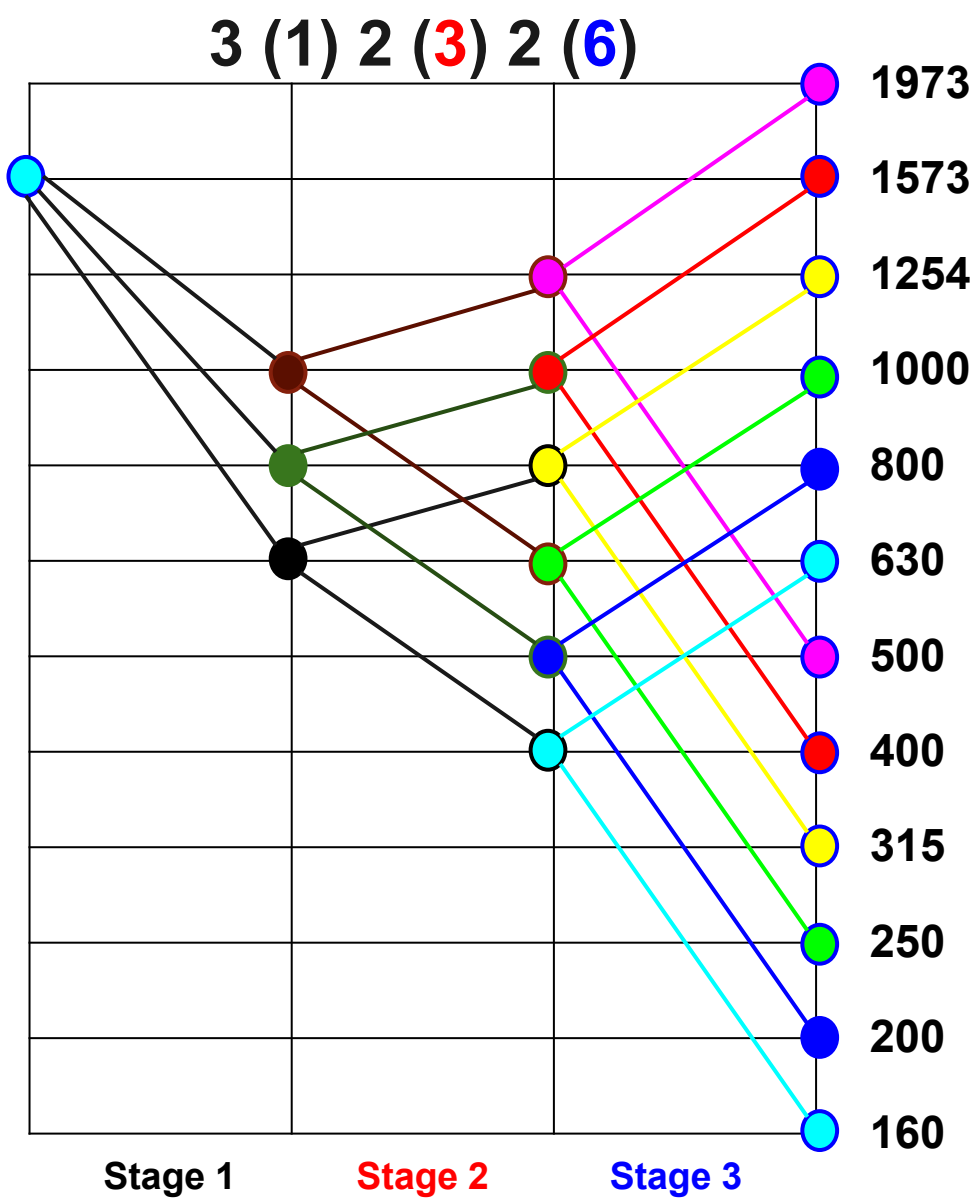
Stage 1 - Single input is splitted into 3 speeds

Stage 2 - 3 input is splitted into 6 speeds

ie., each input is splitted into 2 speed

Stage 3 - 6 input is splitted into 12 speeds

ie., each input is splitted into 2 speed



Stage - 3

$$\frac{N_{min}}{N_{i/p}} = \frac{160}{400} = 0.4 \quad \geq 0.25$$

$$\frac{N_{max}}{N_{i/p}} = \frac{630}{400} = 1.57 \quad \leq 2$$

Stage - 2

$$\frac{N_{min}}{N_{i/p}} = \frac{400}{630} = 0.63 \quad \geq 0.25$$

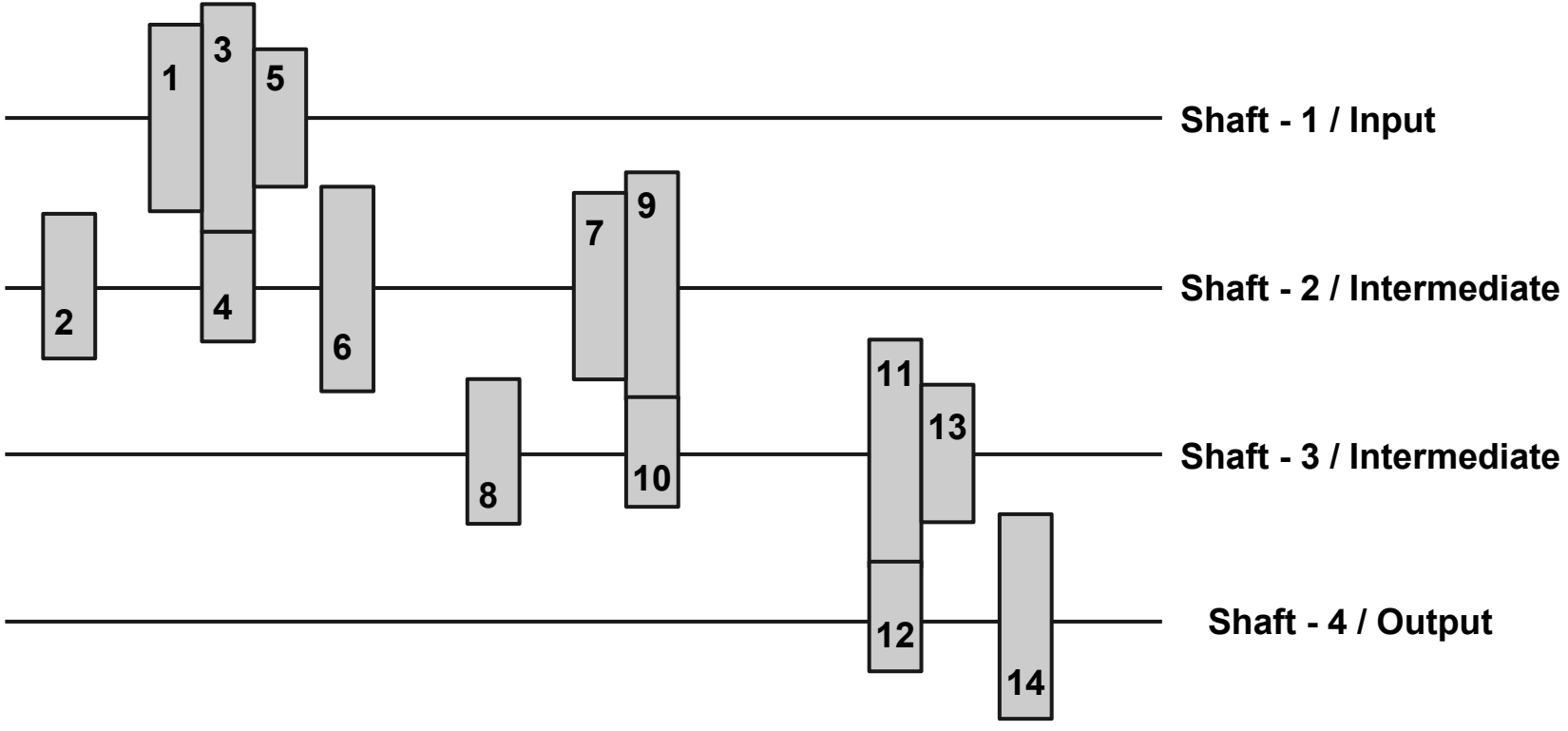
$$\frac{N_{max}}{N_{i/p}} = \frac{800}{630} = 1.27 \quad \leq 2$$

Stage - 1

$$\frac{N_{min}}{N_{i/p}} = \frac{630}{1573} = 0.40 \quad \geq 0.25$$

$$\frac{N_{max}}{N_{i/p}} = \frac{1000}{1573} = 0.63 \quad \leq 2$$

Step - 4 “ Kinematic Arrangement ”



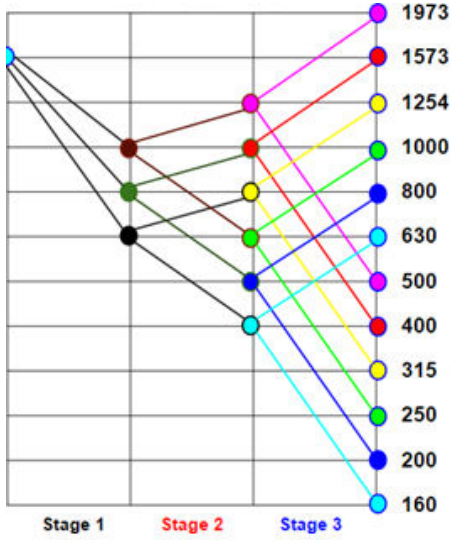
Step - 5 “ Calculation of number of number of teeth in gears ”

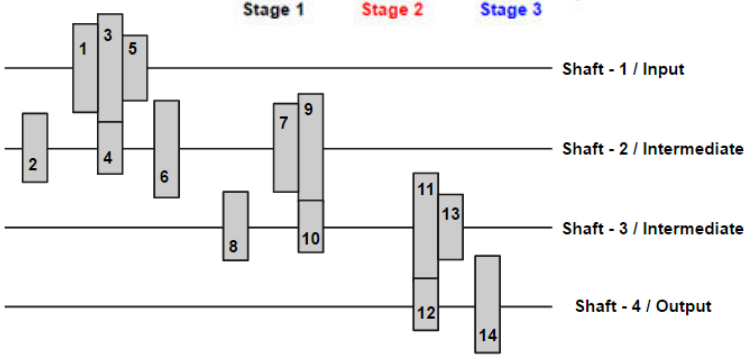
Stage - 3 “First Pair - Lowest speed o/p

Assume number of teeth in driver, $Z_{13} = 20$

$$\frac{z_{13}}{z_{14}} = \frac{N_{14}}{N_{13}} \Rightarrow \frac{20}{z_{14}} = \frac{160}{400}$$

$$z_{14} = 50$$





Stage - 3 “Second Pair

$$\frac{z_{11}}{z_{12}} = \frac{N_{12}}{N_{11}} \Rightarrow \frac{z_{11}}{z_{12}} = \frac{630}{400}$$

$$z_{11} = 1.575\, z_{12}$$

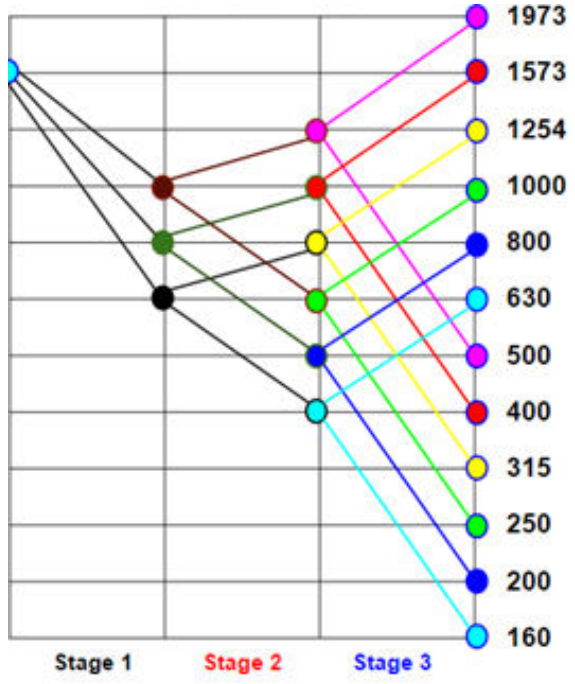
$$z_{11} + z_{12} = z_{13} + z_{14}$$

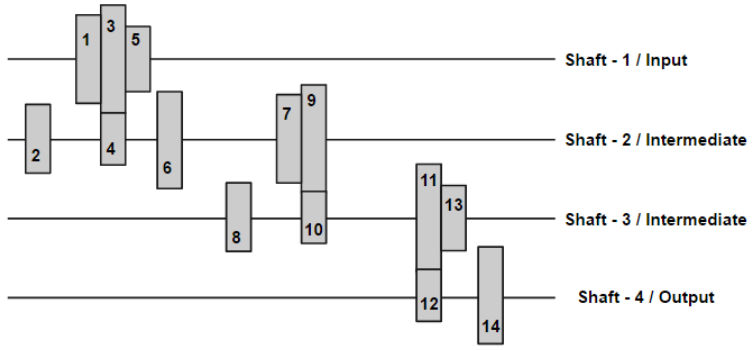
$$z_{11} + z_{12} = 20 + 50 = 70$$

$$1.575\, z_{12} + z_{12} = 70$$

$$z_{12} = 27\ .18 \cong \mathbf{27}$$

$$z_{11} = \mathbf{43}$$



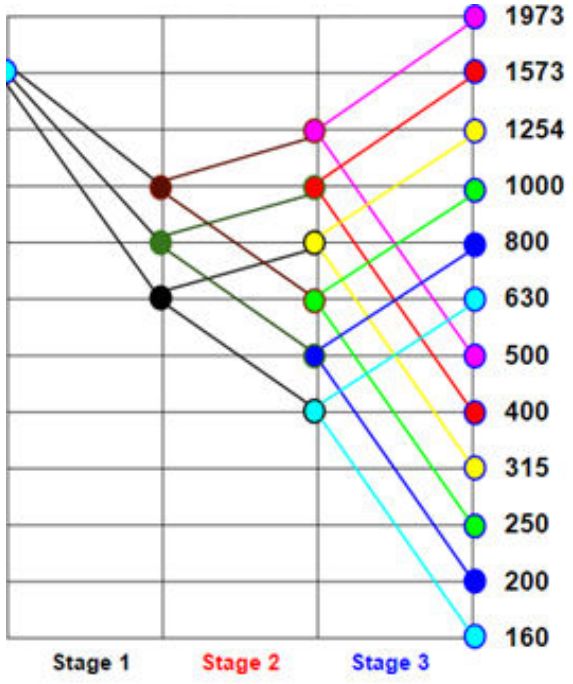


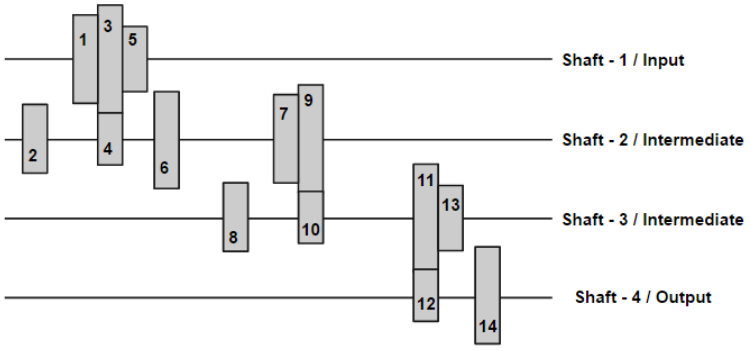
Stage - 2 “First Pair - Lowest speed o/p

Assume number of teeth in driver, $Z_7 = 20$

$$\frac{z_7}{z_8} = \frac{N_8}{N_7} \Rightarrow \frac{20}{z_8} = \frac{400}{630}$$

$$z_8 = 31.5 \cong \mathbf{32}$$





Stage - 2 “Second Pair

$$\frac{z_9}{z_{10}} = \frac{N_{10}}{N_9} \Rightarrow \frac{z_9}{z_{10}} = \frac{800}{630}$$

$$z_9 = 1.269\, z_{10}$$

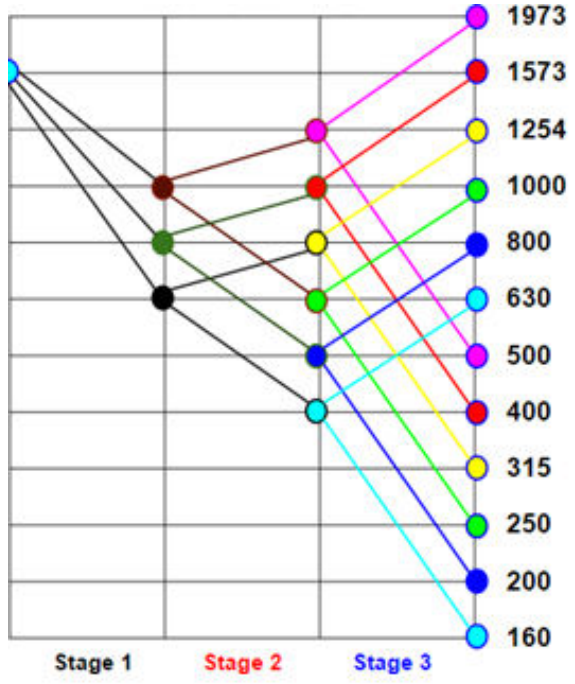
$$z_7 + z_8 = z_9 + z_{10}$$

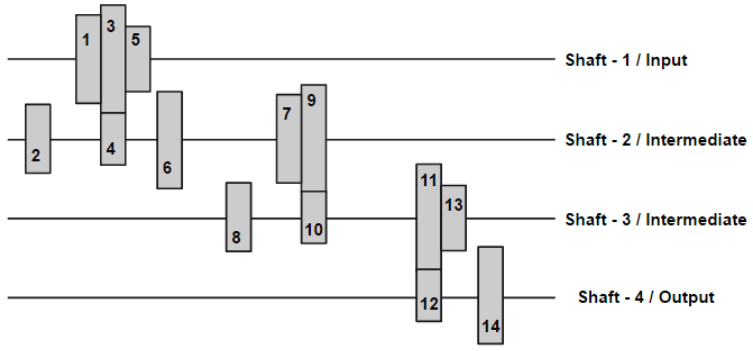
$$20 + 32 = z_9 + z_{10} = 52$$

$$1.269\, z_{10} + z_{10} = 52$$

$$z_{10} = 22.9 \cong \mathbf{23}$$

$$z_9 = \mathbf{29}$$



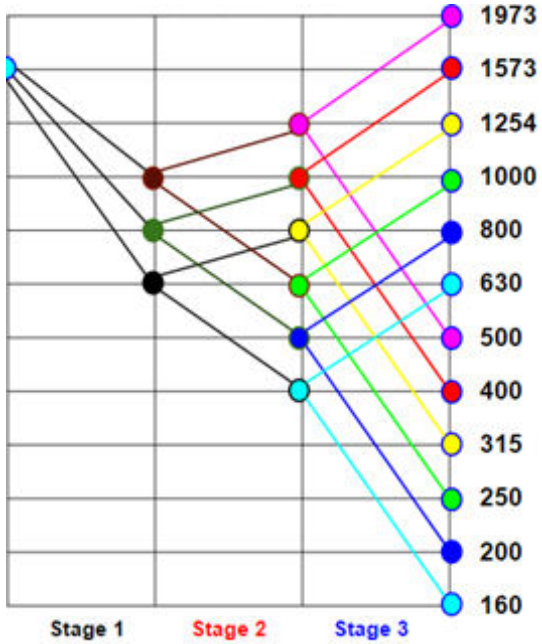


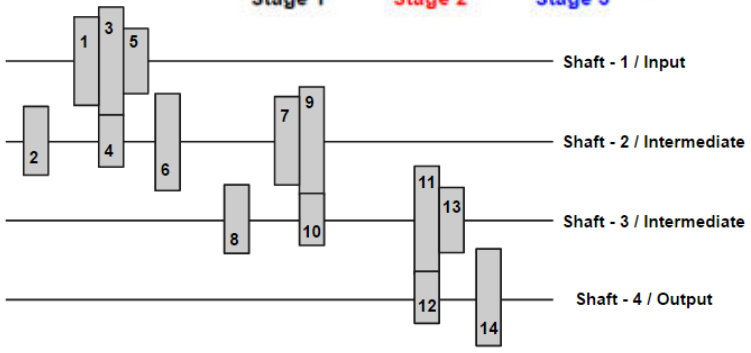
Stage - 1 “**First Pair -** Maximum Speed Reduction”

Assume number of teeth in driver, $z_5 = 20$

$$\frac{z_5}{z_6} = \frac{N_6}{N_5} \quad \Rightarrow \quad \frac{20}{z_6} = \frac{630}{1573}$$

$$z_6 = 49.9 \cong 50$$

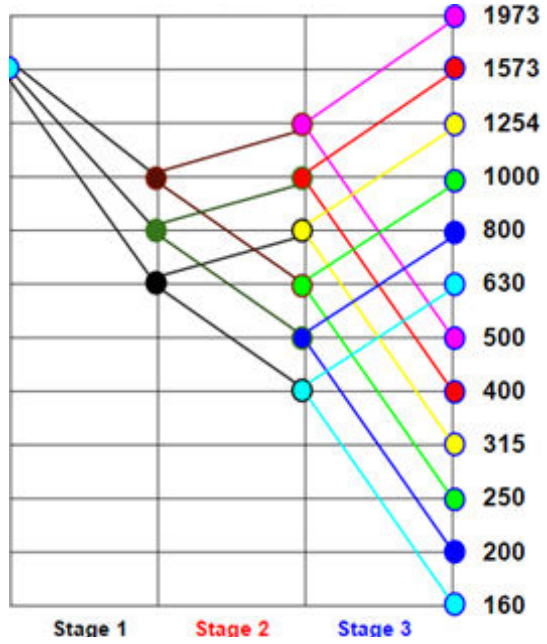


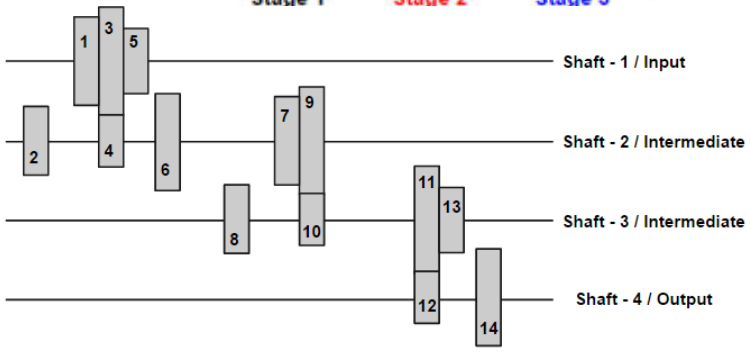


Stage - 1 “Second Pair”

$$\frac{z_1}{z_2} = \frac{N_2}{N_1} \quad \Rightarrow \quad \frac{z_1}{z_2} = \frac{800}{1573}$$

$$z_1 = 0.50\, z_2$$

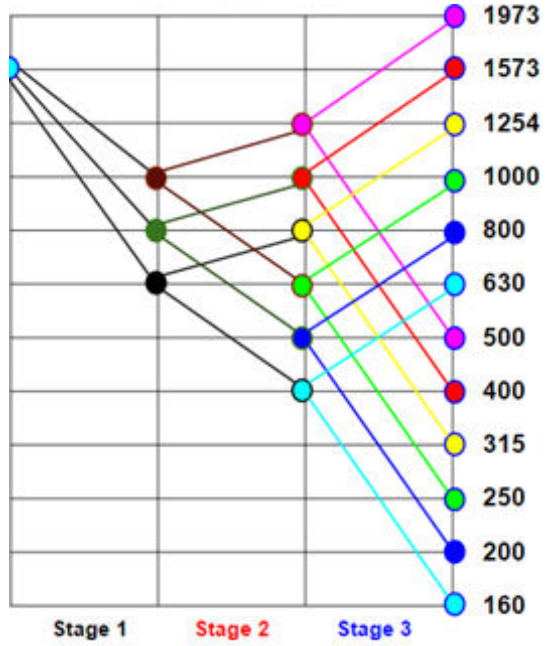


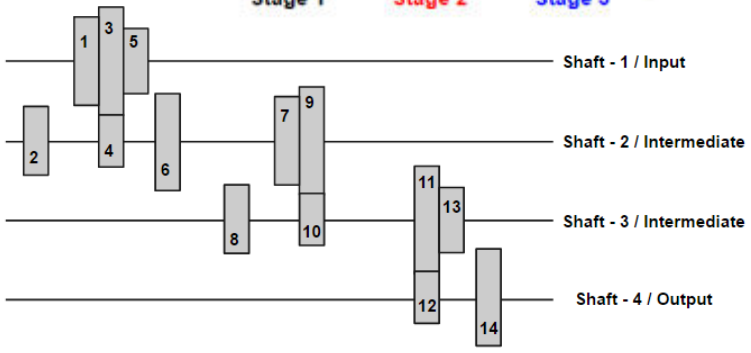


Stage - 1 “Third Pair”

$$\frac{z_3}{z_4} = \frac{N_4}{N_3} \quad \Rightarrow \quad \frac{z_3}{z_4} = \frac{1000}{1573}$$

$$z_3 = 0.63\, z_4$$





Stage - 1

$z_1 + z_2 = z_3 + z_4 = z_5 + z_6$

$z_1 + z_2 = z_3 + z_4 = 20 + 50 = 70$

$z_3 + z_4 = 70$

$0.63\ z_4 + z_4 = 70$

$z_4 = 42.94 \cong 43$ $\qquad z_3 = 27$

$z_1 + z_2 = 70$

$0.50\ z_2 + z_2 = 70$

$z_2 = 46.6 \cong 47$ $\qquad z_1 = 23$

$z_5 = 20$

$z_6 = 50$

$z_1 = 0.50\ z_2$

$z_3 = 0.63\ z_4$

Solution

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$z_1 = 23$

$z_2 = 47$

$z_3 = 27$

$z_4 = 43$

$z_5 = 20$

$z_6 = 50$

$z_7 = 20$

$z_8 = 32$

$z_9 = 29$

$z_{10} = 23$

$z_{11} = 43$

$z_{12} = 27$

$z_{13} = 20$

$z_{14} = 50$