Ch. 14 Problems

Greg Christian

14-6 (a) Long shaping times ⟺ accurate measurement of collected charge

⇒ Long shaping times give better pulse height resolution.

(b) From fig. 14-14, we can see that the best signal : noise ratios occur for monopolar shaping methods. Since random noise degrades amplitude (pulse height) information, we want the best signal : noise ratio possible. Thus choose monopolar shaping over bipolar for better pulse height resolution.

(c) Baseline restoration introduces noise to the system, thus decreasing the signal : noise ratio. Although it's benefits may overweigh its problems for high rate systems, here we are dealing with a low average rate (as stated in the problem), so if we want the best preservation of pulse height information we should not use active baseline restoration.

[14-4] $f_e = \dfrac{e^{-n\tau}}{n\tau + 1}$ $\qquad$ n: total count rate $= 25{,}000\ s^{-1}$
$\tau = 4\times10^{-6}\ s$

(non-paralyzable)

$\therefore f_e = \dfrac{\exp[0.1]}{0.1+1}$

$f_{e,np} = 82.3\%$ (fraction of events escaping pileup)

$f_e = e^{-2n\tau}$ (paralyzable)
$= e^{-2(.1)}$
$f_{e,p} = 81.9\%$

~~[illegible]~~

Since pileup can occur with any pulse, the fraction of total events lost is the same as the fraction of full energy events lost.

Also, $f_{lost} = 1 - f_e$

$\Rightarrow$ $f_{lost}^{(paralyzable)} = 18.1\%$

$f_{lost}^{(non-paralyzable)} = 17.7\%$

17-11 Chance coincidence rate = $2\tau r_1 r_2$

Since the pulses are random + uncorrelated, all coincidences will be chance coincidences.

Anti-coincidence units provide an output pulse each time there is a coincidence event (so that the unit can only supply an output when there is **not** an anti-coincidence pulse). Thus the anti-coincidence output rate is just the coincidence rate which here is given by the chance coincidence rate:

$$\boxed{r_{ch} = 2\tau r_1 r_2}$$ ✓

~~17-13~~ $t_{delay} = l / v_{cc}$

where l = cable length
v_{cc} = current carrier velocity $\simeq c = 3\times10^8\ m/s = 0.3\ m/ns$

not true in a cable
use Table in text

$\Rightarrow l = t_{delay} \cdot 0.3\ m/ns$

$l = (100\ ns)(0.3\ m/ns)$ * velocity fraction ~ 0.659

$$\boxed{l = 30\ m}$$

Corrected on next page.

$\boxed{17\text{-}13}$ $t_{delay} = l / v_{cc}$

l = cable length

v_{cc} = current carrier velocity = $(3\times10^{8}\ m/s)\underbrace{[0.659]}_{}$ = $0.1977\ m/ns$

from table 16-1, for a polyethelyne coaxial cable.

$\Rightarrow l = t_{delay}\, v_{cc}$

$= (100\ ns)(0.1977\ m/ns)$

$\therefore \boxed{l = 19.8\ m}$

17-15 $r_t = \epsilon_1 \epsilon_2 S$

$r_{ch} = 2\tau r_1 r_2$

$r_1 = \epsilon_1 S$
$r_2 = \epsilon_2 S$ $\Rightarrow r_1 r_2 = \epsilon_1 \epsilon_2 S^2$

$\downarrow$

$r_{ch} = 2\tau \epsilon_1 \epsilon_2 S^2$
$r_t = \epsilon_1 \epsilon_2 S$ $\Rightarrow \boxed{\frac{r_t}{r_{ch}} = \frac{1}{2\tau S}}$

(a) changing solid angle changes ϵ_1 and ϵ_2
$\Rightarrow$ changing solid angle has no effect on r_t/r_{ch}

→ Practical considerations: limited by geometry of the detectors

(b) Varying source material varies S
$\Rightarrow$ less source material = increased r_t/r_{ch}

→ still need enough source material to get good statistics

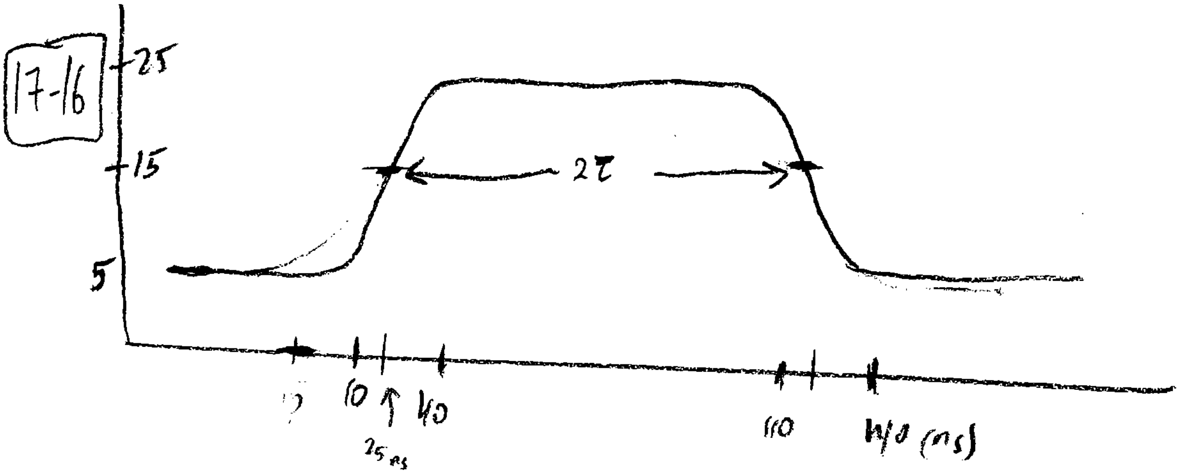
(c) $r_t/r_{ch} \propto 1/\tau$ → lowering τ increases r_t/r_{ch}.

→ need τ to be at least as large as ½ the width (at the base) of the prompt coincidence peak, otherwise we cut out true coincidences.

(d) Varying the pulse height window just varies the rates r_1 and r_2: it is the same as having the efficiencies ϵ_1 and ϵ_2 change. Since r_t/r_{ch} has no dependence on ϵ_1 and ϵ_2, varying pulse height window has no effect on r_t/r_{ch}.

→ can't make the window too restrictive or else we will cut out too many events

17-16



(a) 2τ = FWHM of curve from 10 ns $\to$ 140 ns.

curve is approx. linear from 10 ns $\to$ 40 ns and 110 ns $\to$ 140 ns

(10 $\to$ 40): slope $= \frac{20}{30} = 2/3$ $\Rightarrow$ $f(t_1) = 15 = \frac{2}{3}t - 5/3$

offset $= -5/3$

$\Rightarrow t_1 = 25$ ns

$t_2 = 125$ ns

FWHM $= t_2 - t_1 = 125 - 25 = 100$ ns

$\Rightarrow 2\tau = 100$ ns $\Rightarrow$ $\boxed{\tau = 50 \text{ ns}}$

Corrections on next page

(b) Width of prompt coincidence peak $= 2\tau = \boxed{100 \text{ ns}}$ — no it shows up in rise time

(c) $r_{ch} = 2\tau r_1 r_2 = 5$ (ns^{-1}) (from graph) — per second on graph

$r_1 = r_2 \Rightarrow r = \left(\frac{5}{2\tau}\right)^{1/2} = \left(\frac{5\text{ ns}^{-1}}{2(50\text{ ns})}\right)^{1/2} = \sqrt{0.05}\ \text{ns}^{-1} \Rightarrow \boxed{r = 0.224\ \text{ns}^{-1}}$

(14-16) (b) here τ is longer than ½ the width (at the base) of the prompt coincidence peak (because of the flat-topped plateau)

$\Rightarrow$ width of prompt coincidence peak will show up within the plateau.

· Use the marks on the graph as the width;

$\Rightarrow$ $W = 110_{ns} - 40_{ns}$

$$\boxed{W = 70_{ns}}$$

(c) $r_{ch} = 2\tau r_1 r_2 = 5\, s^{-1}$

$r_1 = r_2 \equiv r \Rightarrow r = \left[\dfrac{5\times10^{-9}\,(ns^{-1})}{2\,\tau}\right]^{1/2} = \left[\dfrac{5\, s^{-1}}{2(50\times10^{-9})s^{-1}}\right]^{1/2} = \sqrt{5\times10^{7}\, s^{-1}}$

$$\Rightarrow \boxed{r = 7071\, s^{-1}}$$

$\boxed{17\text{-}17}$ # of comparators for n bits = $2^n - 1$

=> 3 stages of 4 bits each => $(2^4-1)\cdot 3$ = 45 comparators

4 " — " 3 " — " $(2^3-1)\cdot 4$ = 28 Comparators

=> 4 Stages of 3 bits each requires less total comparators.

Latency Time $\propto$ # of ~~channels~~ stages = $2^{\{\#\text{ of Stages}\}}$

=> 3 stages of 4 bits each has lower latency time.

$\left(\underline{2^3 = 8} \text{ -vs- } \underline{2^4 = 16}\right)$