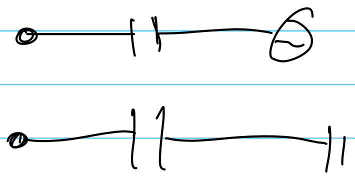
Candidate Number: SDXR8

1a i) $C = 800\,pF$ $\qquad V_s = 3V$

$$Z = \frac{1}{j\omega C} = \frac{1}{2\pi(50)(800\times10^{-12})} = 3978873.6 \quad (dp)$$



$$I = \frac{V}{Z} = \frac{3}{3978873.6} = 7.33982\ldots\times10^{-7}A \approx 754\,nA$$

$$V = IR = (7.33982\ldots\times10^{-7})(19\times10^{3})$$
$$= 0.0143\ldots$$
$$= 14.3\,mV$$

ii)

$$V_{out} = \frac{A_d V_{cm}}{CMRR} = \frac{(10)(14.3\times10^{-3})}{(19952.62315)} = 7.16697\ldots\times10^{-6}V$$
$$= 7.2\,\mu V$$

iii) $$V_{out} = A_d \times V_{cm} \times \left(\frac{1}{CMRR} + \frac{Z_2 - Z_1}{Z_{cm}}\right)$$

$$390\times10^{-6} = (10)(14.3\times10^{-3})\left[\frac{1}{19952.6\ldots} + \frac{Z_2 - 10000}{750\times10^{3}}\right]$$

$$\frac{Z_2 - 10000}{750\times10^{3}} = \frac{390\times10^{-6}}{(10)(14.3\times10^{-3})} - \frac{1}{19952.6\ldots}$$

$$Z_2 = 12007.87 \ (2sf)\ \Omega$$

1aiv) $V = 390\,\mu V$

$$V_{RMS} = \frac{390 \times 10^{-6}}{\sqrt{2}} = 2.757\ldots \times 10^{-4}$$

SNR = 14dB

$$20 \log_{10}\left(\frac{V_s^2}{V_{RMS}^2}\right) = 14$$

$$\frac{V_s^2}{V_{RMS}^2} = 10^{\frac{14}{20}} \Rightarrow V_s^2 = 10^{\frac{14}{20}} \times (2.758 \times 10^{-4})^2$$

$$V_s = \sqrt{10^{14/20}(2.758 \times 10^{-4})^2} = 617\,\mu V \quad (3sf)$$

|aV|

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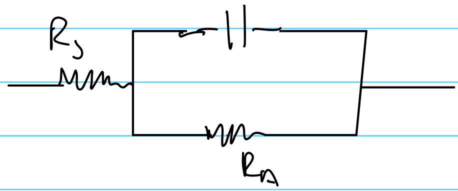
2 a) i)



Inductor $z = 2.5 k\Omega$ (R_S)

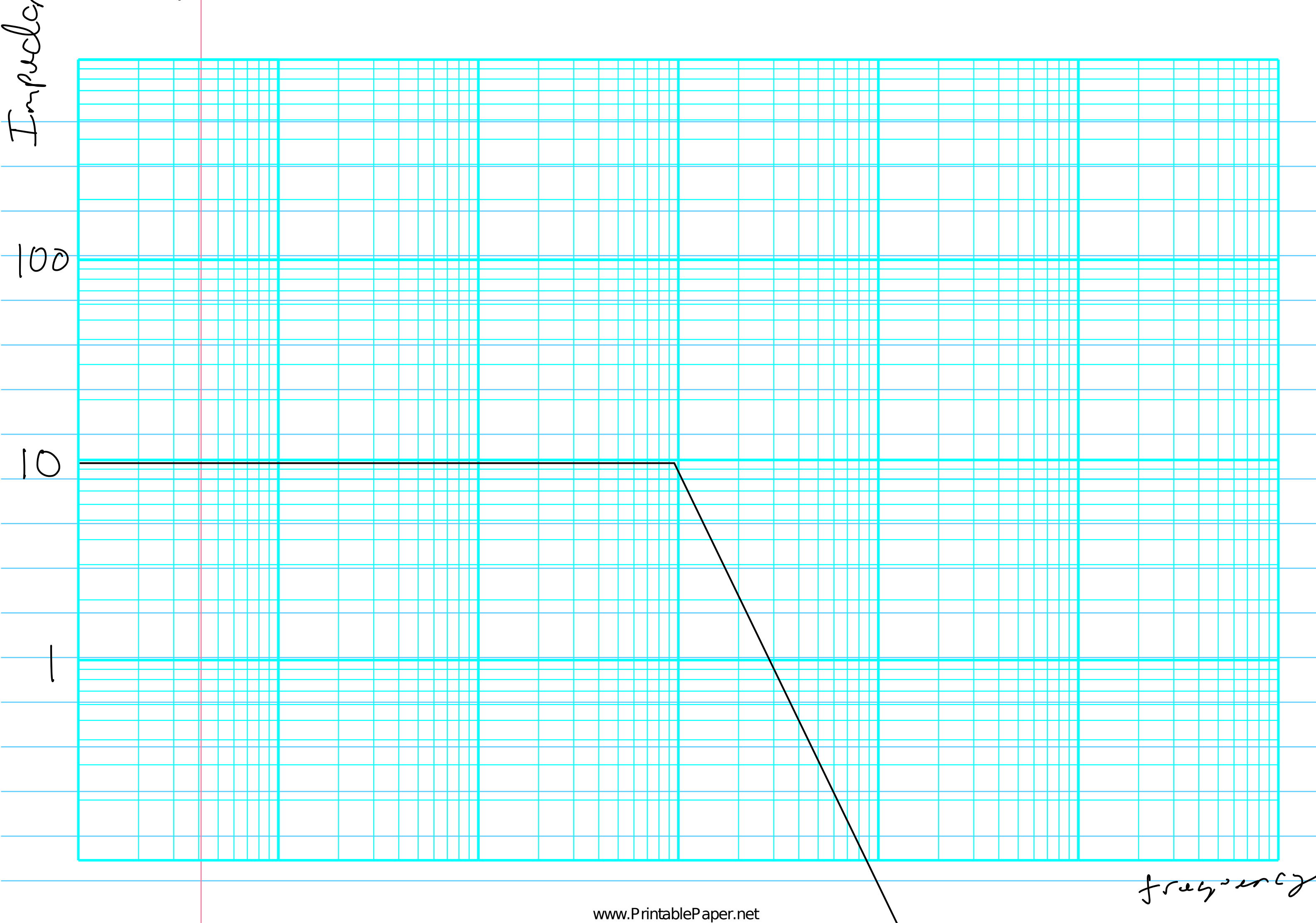
$R_T = 6.25 k\Omega$ (capacitor)

$R_T = R_A + R_S = 6.25k - 2.5k = 3.75$

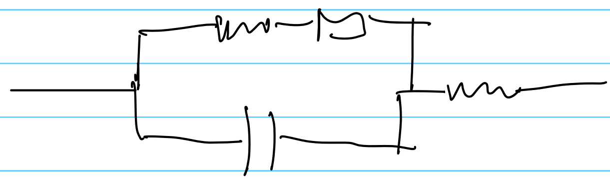
$R_T =$

$\log(R_T) = \log(3.75 \times 10^3) = 3.574...$

2a ii)



circuit:



3. a)

$$Z_C = \frac{1}{2\pi f C} = \frac{1}{2\pi\left(\frac{1}{100\times10^{-6}}\right)(10^{-6})} = 16\,\Omega \ (2sf)$$

$$\frac{1}{R_T} = \frac{1}{16\,\Omega} + \frac{1}{2.3\times10^{3}}$$

$$R_T = \frac{(16)(2.3\times10^{3})}{(16)+(2.3\times10^{3})} = 15.88\,\Omega$$

$$I = \frac{V_{Thresh}}{R_T} = \frac{20}{15.88} = 1.259\text{ A}$$

3b)

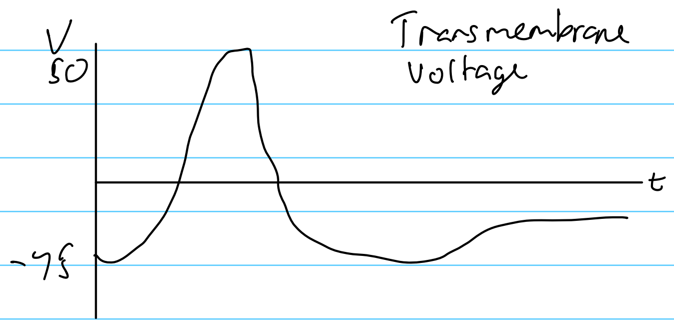
Recruitment Curve vs Strength Duration Curve

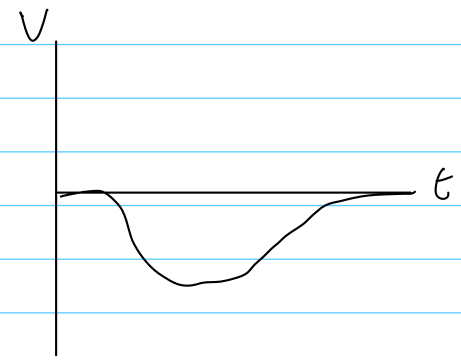
RC – This plots the stimuli response of a muscle
SDC – Indicates the characteristics that will induce a response, also the rheobase of this curve represents the minimum current for depolarisation

SDC – A Strength duration curve is characterised by the changing intensity of the time of muscle contraction.
RC – The recruitment curve has a changing pulse duration

RC – The pulse amplitude varies and
SDC – The pulse amplitude on a Strength duration curve is the amplitude required to Stimulate a response

3c) i)





3a) In signal averaging, the waves are added together

In EMG movement can't be removed

4. Drop Foot Stimulation

Background

1. Functional electrical stimulation (FES) is a technological approach providing functional correction of footdrop by delivering electrical impulses to the common peroneal nerve and anterior calf muscles

2. Functional Electrical Stimulation (FES) is a treatment where low level electrical impulses are applied to nerves or muscles to improve muscle function in patients with degenerating muscle function

3. Another study utilised FES to stimulate the femoral nerve for treatment, with the exact location specified by a physiotherapist.

4. Footdrop is caused by increased weakness of the anterior calf muscles or increased tone in the posterior calf muscles

5. Foot drop isn't just the inability to lift the foot, but it also includes dorsiflexion, which is the inability to lift the toes.

6. Some types of foot drop can utilise the Tinel's sign test, which is positive when the peroneal nerve compression is present – pins and needles sensations that occur after a particular nerve is stimulated or tapped.

Treatment

7. FES is performed in multiple sclerosis patients by using surface adherent electrodes instead of implanted systems due to the elevated implantation risks for MS patients

8. Foot drop can be clinically diagnosed through medical imaging modalities like a CT scan or x-ray to detect the drop foot.

9. FES has a better orthotic effect in generating active rather than passive movement when compared to the routine treatment of footdrop that is ankle foot orthosis (AFO)

10. FES uses randomisation of the 'size principle' in nerve fibres as whichever nerve fibres receive sufficient stimulus to reach threshold are recruited, which results in large diameter motor neurons that recruit fast twitch muscle fibres to be activated and this effect causes quick fatigue in FES patients.

11. FES electrical impulses cause depolarisation within a nerve and this causes the nerve to achieve the threshold to induce an action potential, which stimulates the surrounding affected muscle

12. An implanted electrode transmits a current of 2.5mA, which can be used in the long term, while a surface electrode corresponds to a current of 5mA-100mA since the resistance across the skin is often significant and so the voltage needs to be higher to penetrate deeper.

13. The pulse width needs to be tuned to between 150-300us since too high a pulse width like 2500us can cause overflow of the pulse into surrounding muscle groups, which can cause patients with footdrop to experience an increase in falls and loss of balance.

14. Some of the various pulses utilised in FES treatment are monopolar, bipolar, asymmetric bipolar, and a balanced asymmetric bipolar pulse.

15. The procedure costs around £5000 in private medical practices, which includes the session, the professionals experience and the device.

16. In terms of patient treatment, the decisions about whether to fund FES treatment is done by local NHS bodies, for example the local Clincal Commissioning Group (CCG).

17. Another medical treatment involves the application of botulinum toxin injections to alleviate the drop foot in patients.

Outcomes

18. In the paper 'Functional Electrical Stimulation for foot drop in people with multiple sclerosis: The relevance and importance of addressing quality of movement,' a review of 21 studies on FES for footdrop in MS shows positive orthotic benefit, which is an immediate change in gait with FES on.

19. In a long term follow up of a paper on the effects of FES on footdrop showed that FES emphasises the reduction of musculoskeletal pain and fatigue in the long term for patients.

20. FES with physiotherapy has been shown to increase plastic and adaptive processes in the central nervous system in more than 50% of patients.

21. Since FES cannot be applied as treatment for everyone, spasticity is a symptom that is used to determine whether a person can use FES to treat footdrop

22. Effective FES treatment requires the frequency of electrical impulses to be high enough (around 50-100Hz) such that the muscles don't twitch since at low frequencies twitching occurs as muscle fibres are able to return to rest between pulses.

23. In the case of a study on the risks of FES, 31 patients had implantable electrical stimulation, which led to 10 patients experiencing red skin after with a single patient having to have the electrodes removed.

24. The drop foot can be caused by a stroke, multiple sclerosis or be linked to central neurological origin, which implies that the damage is due to the disease of the brain or spinal cord instead of an injury to the nerves or leg.

25. During a study involving 71 footdrop patients, where only 36 patients were treated with surface electrical stimulation, it was found that the patients that underwent therapy experienced a 23% increase in walking speed, demonstrating the success of the therapy.

26. During a study involving 111 patients that underwent surface electrical stimulation therapy for footdrop, it was found that they were using 21% less effort while walking.

27. Electrical stimulation will cause tingling or even pins and needles in patients with drop foot.

28. A drawback of FES treatment is that patients are required to come back to the hospital to have their level of electrical stimulation re-evaluated